CHAPTER I INTRODUCTION

1.1 Background of the Study

The Study Area covers the Ubate - Chiquinquira valley located 100 km northeast of Bogota City, the capital of Colombia, at an altitude of approximately 2,500 m above sea level. The Lake Fuquene with a surface area of 3,000 ha is situated in the center of the valley. The valley is highly developed by livestock and milk production. Most of the land is used for pasture and agricultural cultivation.

The water resources in the valley is not always used effectively due to insufficient water intake and distribution system. Deforestation and excessive land cultivation cause soil erosion in the watersheds. A large quantity of pollution load is generated from livestock. In addition, domestic and industrial wastewater are discharged into rivers without treatment or with insufficient treatment. They result in pollution of the surface water. Further, Lake Fuquene is suffering from excessive aquatic plants, resulting in reduction of water surface area and storage capacity, deterioration of water quality, and damage to aquatic life. Propagation of the aquatic plants has accelerated in the recent 10 years due to the invasion of exotic species and the people are worried that the water surface area might become extinct in the future. Alleviation of these environmental problems is essentially necessary to sustain the economical development of the valley.

In response to the request of the Government of Colombia (GOC), the Government of Japan (GOJ) decided to conduct the “Study on Regional Environmental Improvement Plan for the Basin of Lake Fuquene (the Study). The scope of work for the Study was agreed upon between the Regional Autonomous Corporation of Cundinamarca (CAR) of the GOC and the Japan International Cooperation Agency (JICA) in September 1998. In accordance with the scope of work, JICA dispatched the Study Team in March 1999.

1.2 Objectives and Area of the Study

1.2.1 Study Objectives

The objectives of the Study which were set up in the scope of work are:

(1) To formulate a master plan for regional environmental improvement for the Basin of the Lake (the Basin); and,

(2) To pursue technology transfer to the counterpart personnel in the course of the Study.

1.2.2 Study Area

The Study Area covers 1,752 km^2 including the entire drainage basin of the Lake and upper part of the Suarez River basin under the administration of the CAR (see, Location Map).

1.2.3 Target Year

The master plan is to be prepared with 2010 as the target year.

1.3 Implementation of the Study

1.3.1 Study Organization

The Study was carried out by a Study Team commissioned by JICA, composed of experts from a Japanese consulting firm, CTI Engineering International Co., Ltd. In the Colombian side, CAR organized a Counterpart Team to work together with the JICA Study Team. To review the findings of the Study, JICA and CAR established an Advisory Committee, respectively.

The members of the JICA Advisory Committee, JICA Study Team, CAR Advisory Committee and CAR Counterpart Team are as tabulated hereinafter.

1.3.2 Study Schedule

The Study was started in late February 1999 with completion in late May 2000 inclusive of the Final Report. Field and home office studies, as well as reporting were scheduled as mentioned below.

(1) Stage I (Field Work – early March 1999 to early June 1999)

The Inception Report was submitted by the JICA Study Team to CAR at the start of the Study in Colombia and discussed with the concerned officials of the Colombian side. The Report contained the study methodology and work schedule.

At the end of Stage I, the Progress (I) Report was presented to CAR and discussed with the concerned officials of the Colombian side. The Report covered analyses on the existing situation of socio-economy, hydrology, water use, land use, watershed management, river/lake water quality, water pollutant sources, ecology, environmental public awareness and related law/regulations.

(2) Stage II (Home Office Work – mid July 1999 to late August 1999)

The Study was continued in the home office in Japan to analyze and estimate future socio-economy, water balance, pollution load generation/runoff and propagation of aquatic plants.

(3) Stage III (Field Work – mid August 1999 to mid November 1999)

At the beginning of Stage III, the Interim Report was presented to CAR and discussed with the concerned officials of the Colombian side. The Report presented all the results of the studies in Stage I and Stage II.

During this stage, studies on water balance, optimum reservoir/lake operation, river/lake water quality, pollution load generation/runoff, wastewater treatment, application of GIS system, environmental education and institutional aspects were done. Further, experiments on the reproduction of aquatic plants, the composting of aquatic plants and grass carp feeding were conducted.

At the end of Stage III, the Progress (II) Report was presented to CAR and discussed with the concerned officials of the Colombian side. The Report covered all the results of the studies in Stage I to Stage III.

(4) Stage IV (Home Office Work – early December 1999 to late February 2000)

The Study was continued in the home office in Japan to prepare project proposals, to estimate project costs and to evaluate economic/financial viability and finally, to formulate the master plan of environmental improvement for the Basin.

(5) Stage V (Field Work – early March 2000 to late March 2000)

The Draft Final Report was submitted to CAR and discussed with the concerned officials of the Colombian side. The Report included all the results of the Study.

(6) Stage VI (Home Office Work – mid May 2000 to late May 2000)

The Final Report was prepared and submitted to CAR

1.3.3 Technology Transfer

Transfer of technical knowledge on water related environmental management to CAR's counterpart personnel was carried out through the series of studies and meetings, as follows:

(1) Through the collaborative works on data collection of previous studies/statistics and interviews with people/government officials, the objective and importance of data collection were recognized.

(2) Through the joint observation or experiment on water quality, aquatic plant reproduction and composting, and grass carp feeding, the necessity and measurement methods were understood.

(3) Through the report discussion meetings with the government officials concerned, details of the Project were confirmed.

(4) Through the seminars in Bogota and Chiquinquira, technical knowledge was imparted to the personnel concerned in both the government and private sectors.

1.4 Composition of Report

This Report consists of three (3) volumes of English and Spanish versions, as follows:

Volume I: Executive Summary

Volume II: Main Report

Volume III: Supporting Report

The Main Report presents the summarized results of all the studies. On the other hand, the Supporting Report gives a further explanation of the studies, as follows.

Appendix A: Socioeconomic Conditions

Appendix B: Hydrology

Appendix C: Water Resources and Use Management

Members of JICA Advisory Committee

	Name	Designation/Task
1.	Dr. Hiroshi Kidono	Chairman/Environmental Management Planning
2.	Mr. Tokio Mochizuki	Water Quality Control

Members of JICA Study Team

	Name	Designation/Task
1.	Mr. Naohito Murata	Team Leader/Environmental Management Planning
2.	Mr. Kunio Ishikawa	Water Quality/Eutrophication Analysis
3.	Mr. Kazuo Mibayashi	Ecological Analysis
4.	Ms. Hiroko Kamata	Wastewater Treatment
5.	Mr. Susumu Heishi	Non-point Pollution Control/Watershed Management
6.	Mr. Toshihiro Goto	Hydrological Analysis
7.	Mr. Kenichiro Kondo	Water Resources/Use Management
8.	Mr. Awadh Kishor Sah	Land Use/GIS Analysis
9.	Mr. Sebastian Guillermo Jara	Socio-economy/Finance/Environmental Education
10.	Mr. Masahiro Ibayashi	Coordination/Structural Design/Cost Estimate

Members of CAR Advisory Committee

	Name	Designation
1.	Dr. Diego F. Bravo Borda	Director General, CAR
2.	Dr. Pablo E. Huertas Porras	Assistant Director General, CAR

Members of CAR Counterpart Team

	Name	Designation/Task
1.	Ing. Hugo A. Gomez Garavito	Counterpart Leader/Environmental Management Planning
2.	Bio. Clara Ines Ortiz R.	Water Quality/Eutrophication Analysis
3.	Bio. Lydia Beatriz Chaparro R.	Ecological Analysis
4.	Dr. Fernan Castellanos	Aquatic Plant Use
5.	Ing. Gustavo Pedraza	Wastewater Treatment
6.	Ing. Alvaro Pabon	Non-point Pollution Control/Watershed Management
7.	Ing. Fernando Useche	Hydrological Analysis
8.	Ing. Jairo Gomez	Water Resources/Use Management
9.	Arq. Alfonso Herran Quintero	Land Use Planning
10.	Ing. Javier Moncada Velandia	Land Use/GIS Analysis
11.	Ing. Hernan Jimenez	Socio-economy/Finance/Environmental Education
12.	Ms. Valerie Jordan	Coordinator

CHAPTER II STUDY AREA

2.1 River Basin and Climate

2.1.1 River Basin

The Study Area covers the entire drainage basin of Ubate-Fuquene-Suarez river system upstream of Garavito (northern boundary of CAR administration) with an area of 1,752 km^2. The main river runs from south to north in the Ubate-Chiquinquira valley.

The Ubate River originates on the Pena Vidriado mountain with an altitude of 3,600 m above sea level located in the Carmen de Carupa municipality. It enters Lake Fuquene located in the center of the Study Area after being joined by the major tributaries of the Suta, Cucunuba and Lenguazaque.

Lake Fuquene, having a surface area of approximately 30 km^2, collects the water of a number of small rivers/*quebradas* in addition to the Ubate River. The total drainage area of the Lake is 992 km^2. The Lake is drained by only one (1) river, Suarez River.

The Suarez River flows down northward in a gentle slope to Garavito. Such tributaries as Susa, Simijaca and Chiquinquira join the Suarez River on the left bank before reaching Garavito.

The salient features of the river system are summarized below. The river system is shown in Fig.2.1.

River	C.A. (km^2)*	Length (km)	Origin EL.(m)	End EL.(m)	Remarks
Ubate (upper)	225	19	3,550	2,800	
Suta	112	21	3,100	2,550	
Cucunuba	92	16	2,950	2,550	
Lenguazaque	293	23	3,400	2,600	
Ubate (total)	790	29	3,550	2,540	At Ubate River Mouth
Lake Fuquene	270	-	2,800	2,540	Including Honda River
Susa	64	18	3,200	2,540	
Simijaca	153	31	3,300	2,540	
Chiquiquira	130	19	2,800	2,540	
Suarez	413	36	2,540	2,525	Lake Fuquene-Garavito
Total	1,752				

* C.A.: Drainage area

2.1.2 Climate

The temperature in the Study Area is moderate and stable, showing little seasonal change. The monthly mean temperature varies within a range of 12.0-13.2 °C at Ubate (St. Novilleros) and 12.4-13.5 °C at Chiquinquira (St. Esclusa Tolon). However, the temperature shows a large hourly variation. The extreme maximum and minimum temperatures recorded during 1966-1998 at Ubate and Chiquinquira are shown below.

Location	Annual Average (°C)	Extreme Max. (°C)	Extreme Min. (°C)
Ubate	12.5	28.9	- 5.2
Chiquinquira	13.0	30	- 3.9

The monthly average humidity presents a slight variation between 70% and 80%.

The Study Area is characterized by two (2) dry and two (2) rainy seasons which alternately occur as shown below. The driest months of the year are January and August. The rainiest months are April and October.

Dec.-Feb.	Mar.-May	June-Aug.	Sep.-Nov.
Dry	Rainy	Dry	Rainy

The average annual rainfall depth increases from south to north, ranging from 700 mm in Ubate and Cucunuba areas to 1,500 mm in the northern end of the valley. Among them, approximately two-thirds occur during rainy season. For the isohyetal map of average annual rainfall for the Study Area, see Appendix B Fig. B.1.6.

Evaporation little varies throughout the year. The average monthly evaporation is in the range of 66.7-98.6 mm at Ubate and 80.0-98.1 mm at Chiquinquira.

2.2 Socioeconomic Conditions

2.2.1 Existing Socio-economy

(1) Administrative Units in the Study Area

The Study Area covers part of two (2) prefectures consisting of 17 municipalities as listed below.

Prefecture	Municipality
Cundinamarca	Carmen de Carupa, Ubate, Tausa, Susatausa, Cucunuba, Suesca, Villapinzon, Lenguazaque, Guacheta, Fuquene, Susa, Simijaca,
Boyaca	San Miguel de Sema, Raquira, Caldas, Chiquinquira, Saboya

Among the 17 municipalities, Carmen de Carupa, Tausa, Suesca, Villapinzon, Raquira, Chiquinquira and Saboya partly fall in the Study Area, while the other municipalities entirely belong to the Study Area. The urban areas of Carmen de Carupa, Tausa, Chiquinquira and Saboya are included in the Study Area, while those of Suesca, Villapinzon and Raquira are excluded. Location of the municipalities are shown in Fig.2.2.

The territory of each municipality is mostly rural and the urban area is very small. The total urban area in the Study Area occupies approximately 9 km^2 or 0.5% of the total Study Area (1,752 km^2).

(2) Population

The municipalities in the Study Area have no real data on the existing population. However, the National Administrative Department of Statistics (DANE) has projected the population of each municipality in the country from 1993 up to 2005, based on the Census of 1993.

According to the estimation of DANE, the total population of the related 17 municipalities in 1998 is 229,011 of which 180,941 live in the Study Area. Ubate and

Chiquinquira are the two (2) largest municipalities in population size. They have 39,475 and 47,630 populations in the Study Area, respectively.

The total urban and rural populations in the Study Area are shown below compared to those in the related municipalities. The total population in the upstream basin of Lake Fuquene is also shown below.

	Municipality	Study Area	Lake Fuquene Basin *
Urban Population	86,245	75,844	27,986
Rural Population	142,766	105,097	70,435
Total Population	229,011	180,941	98,421

*: Including Carmen de Carupa, Ubate, Tausa, Susatausa, Cucunuba, Suesca, Villapinzon, Lenguazaque, Guacheta, San Migeru de Sema, Raquira, Fuquene

For the breakdown by each municipality, see Appendix A, Chapter I, Subsection 1.2.2.

(3) Major Economic Activities

(a) Livestock

The livestock breeding in the Study Area in 1998 is shown below. Among them, raising of cattle for meat and milk production is the main economic activity of the Study Area.

Animal	Study Area		Lake Fuquene Basin *
	Heads	Production (million Col$)	Heads
Cattle	171,402	165,831	109,592
Pig	29,562	7,464	19,080
Sheep	64,400	9,660	55,200
Total	265,364	182,955 (=128.3 million US$) **	183,872

*: Including Carmen de Carupa, Ubate, Tausa, Susatausa, Cucunuba, Suesca, Villapinzon, Lenguazaque, Guacheta, San Migeru de Sema, Raquira, Fuquene
**: Exchange rate in 1998: 1.0 US$ = 1,426.35 Col$

For the breakdown by municipality, see Appendix A, Table A.1.1.

(b) Agriculture

The major crops in the Study Areas are potato, wheat, pea and maize. The total cultivation area and production in 1998 are shown below.

Crop	Cultivation Area (ha)	Annual Production (ton)	Annual Production (million Col$)
Potato	16,933	280,250	80,637
Wheat	880	1,985	554
Pea	1,860	4,045	3,114
Maize	1,440	11,040	2,760
Total	21,113	297,320	87,065 (= 61.0 million US$) *

*: Exchange rate in 1998: 1.0 US$ = 1,426.35 Col$

For the breakdown by municipality, see Appendix A, Table A 1.3.

(c) Industry

The major industries in the Study Area are milk processing and mineral carbon mining.

There are 50 milk processing factories in the Study Area of which 29 are in Ubate and 10 are in Chiquinquira. They produce milk, yogurt and cheese. The total production amount in monetary term in 1998 is 168,214 million Col$ (= 117.9 million US$, exchange rate: 1.0 US$ = 1,426.35 Col$).

There are 280 mineral carbon mining in the Study Area of which 266 are small size and 14 are medium size. They are mainly distributed in Cucunuba (105), Lenguazaque (68), Guacheta (51) and Sutatausa (39). The total production amount in monetary term in 1998 is 13,747 million Col$ (= 9.6 million US$).

(4) Macro-economy of Cundinamarca Prefecture

The population and GDP of Cundinamarca prefecture were 1,975,564 persons and 5,533,949 million Col$ (= 4,849.6 million US$, exchange rate: 1.0 US$ = 1,141.12 Col$) at current price in 1997. Then, per capita GDP in 1997 is estimated at 2,801,200 Col$ (= 2,455 US$). The GDP of the prefecture shared 5.18% of the national GDP of 106,887 billion Col$ (= 93.7 billion US$) in 1997.

Agriculture-livestock is the largest industry followed by manufacturing and commerce. The structure of GDP in 1997 is shown below.

Sector	(%)
Agriculture-livestock	44.0
Manufacturing	21.5
Other Production Industries	5.8
Commerce	17.2
Other Service Industries	11.5
Total	100.0

2.2.2 Projection of Future Socio-economy

(1) Population

DANE has projected the population of each municipality in the country up to 2005. The Study Team extended this projection up to 2010 for each municipality of the Study Area. The total population of the 17 related municipalities in 2010 is estimated at 262,218. It is compared with the existing one as shown below on total municipality population basis.

Population	1998 (1)	2010 (2)	(2)/(1)
Urban	86,245	110,520	1.28
Rural	142,766	151,699	1.06
Total	229,011	262,218	1.15

The future population of the Study Area is estimated as below by assuming the same growth rate as the population of the municipalities.

Population	1998 (1)	2010 (2)	(2)/(1)
Urban	75,844	97,080	1.28
Rural	105,097	111,403	1.06
Total	180,941	208,483	1.15

(2) Livestock

Historical data of the livestock in the Study Area are available for only the recent three (3) years. The number of cattle has decreased during the three (3) years, while the number of pigs has increased as shown below.

Cattle	1996	1997	1998
Bovine	195,324	189,618	171,402
Pig	18,324	23,886	29,562
Sheep	49,430	69,360	64,400
Total	263,078	282,864	265,364

Number of the respective livestock in 2010 are assumed to be the maximum ones during the three (3) years, considering the importance of livestock economy in the Study Area, namely, cattle: 195,324, Pig: 29,562 and Sheep: 69,360.

(3) Agriculture

The agricultural cultivation area in the Study Area has yearly fluctuated since 1990, marking the maximum area of 24,365 ha in 1995. The yearly variations of cultivation area in the past are shown below.

(unit: ha)

Crop	90	91	92	93	94	95	96	97	98
Total	9,785	16,365	13,811	10,996	12,517	24,365	23,958	20,862	17,651
Growth Rate (%)		67.2	- 15.6	- 20.4	13.8	94.7	- 1.7	- 12.9	- 15.4

The cultivation area has gradually decreased since 1995. However, it is assumed to recover up to the cultivation area in 1995 by 2010, considering the agricultural development potential of the Study Area.

(4) Industry

Production of the milk industry will proportionally develop according to the increase of number of cows. The number of cows in 2010 is estimated to be 1.04 times of that in 1998 (see Appendix A, Chapter II, Section 2.5). Then, the milk industry is estimated to increase from 1998 to 2010 by 4%.

Mining industry in 2010 is assumed to maintain its maximum production value in the recent years. For details, see Appendix A, Chapter II, Section 2.5.

(5) GDP

GDP at national level has increased at the annual growth rate of 1.76 – 5.64%, averaging 4.9% during 1987 to 1997. However, the national economy has depressed in the recent years.

No data are available for projection of the future GDP at present. Then, the Study Team assumes that the growth rate of national GDP is 0.0% per annum during 1998 – 2000 and 4.0% per annum during 2001 - 2010. These growth rates are also applied for the Study Area.

CHAPTER III WATER RESOURCES AND USE MANAGEMENT

3.1 Hydrological Monitoring System and Records

3.1.1 Rainfall

The rainfall observation has been done by CAR for a comparatively long time at 33 stations among which the oldest observation dates back to 1959. However, the data after 1966 are employed for this Study in principle, considering the quantity and reliability of available data. For location of the rainfall stations, see Appendix B, Fig. B.1.3.

As mentioned before, the Study Area is characterized by two (2) dry seasons and two (2) rainy seasons which alternately occur. Monthly mean rainfall at the representative stations are shown below.

(unit: mm)

Station	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Novilleros	25	42	67	97	81	53	37	36	53	101	80	41	712
Isla [1)]	48	57	109	147	103	60	35	42	69	154	137	68	1,030
Tolon [2)]	40	54	88	128	113	67	47	51	74	143	128	63	996

Note: 1): Isla del Santauario, 2): Esclusa Tolon

The rainfall depth during dry and rainy seasons are as shown below.

(unit: mm)

Station	Dry (Dec.-Feb.)	Rainy (Mar.-May)	Dry (Apr.-June)	Rainy (Jun.-Aug.)	Annual
Novilleros	108 (15.2%)	245 (34.4%)	125 (17.5%)	234 (32.9%)	712
Isla del Santuario	173 (16.8%)	360 (35.0%)	137 (13.3%)	361(35.0%)	1,030
EsclusaTolon	156 (15.7%)	329 (33.0%)	166 (16.7%)	345 (34.6%)	996

Historical change of the annual rainfall at the above three (3) representative stations were examined for the period of 54 years during 1945-1998. No significant increasing or decreasing trend is recognized at any of the stations, although rainfalls yearly fluctuate to a considerable extent. See, Appendix B, Fig. B.1.7. (Note: The above three (3) representative stations provide reliable data for a longer period than the other rainfall stations).

3.1.2 River Discharge and Lake Water Level

(1) River Discharge

CAR has observed discharge at 51 stations in the rivers of the Study Area among which 31 stations are selected for the hydrological analysis. The discharge data after 1966 are used for this Study in principle, conforming to the period of rainfall analysis. For location of the gauging stations, see Appendix B, Fig. B.2.1.

(2) Lake Water Level

The surface water level of Lake Fuquene has been observed at Isla del Santuario since 1966. The average water level of the Lake during 33 years of 1966-1998 was 2,538.97 m. The annual average water levels varied within a range of only 71 cm during the same period.

On the other hand, the water level has seasonally fluctuated to a considerable extent and recorded the maximum level of 2,540.5 m and minimum level of 2,537.99 m during the 33 years.

Historical change of the yearly maximum and minimum water levels are shown in Fig. 3.1 along with that of the annual average water level. As shown in the figure, the maximum water level has lowered, while the minimum water level has risen gradually, decreasing the fluctuation range during 33 years.

(3) Flooding around Lake Fuquene

The water rising of the Lake floods the surrounding areas. Small dikes are provided along the perimeter of the Lake to protect the low-lying areas from over-bank floods. However, a wide depressed area is inundated by the piping effects of the lake water (the lake water springs from the underground).

CAR estimated the water level - flood prone area curve, based on the topographic map and flood records in the past as shown below.

Water Level (m)	2,539.75	2,540.00	2,540.50	2,540.57	2,541.00
Flood Area (ha)	0	500	6,000	7,700	8,600

3.1.3 Groundwater Level

Data on the groundwater level during 30 years were analyzed for the following four (4) principal stations: La Maria (Lake Fuquene sub-basin), Tichauribe (Lake Fuquene sub-basin), Esmelarda III (Suarez River sub-basin) and Sugamuxi (Suarez River sub-basin). The groundwater levels show only a small seasonal variation. The average yearly variation range at the four (4) stations are as follows: 33 cm at La Maria, 33 cm at Tichauribe, 15 cm at Esmelarda III and 50 cm at Sugamuxi.

3.2 Existing Water Use

3.2.1 Irrigation Water Use

(1) Irrigated Area and Cropping Pattern

The farmland covers a wide area of the flat planes as well as the mountains/hills in the Study Area. The farmlands on the mountain/hill areas are not irrigated. The irrigated areas extend on the flat plane of the Ubate-Chiquinquira valley along the river system of Cucunuba Lake-Ubate River-Fuquene Lake-Suarez River.

The irrigated area covering 20,337 ha is divided into 14 irrigation blocks as tabulated below.

Block No.	Irrigation Block Name	Gross Irrigated Area (ha)
1	Suta	832
2	Cap-1	634
3	Cucunuba	1,892
4	Lenguazaque	1,751
5	Cap-2	316
6	Marino	700
7	Marino-Ubate	387
8	Fuquene	2,537
9	Honda	509
10	Susa	563
11	Suarez	8,309
13	Old-Suarez	228
14	Madron	1,359
15	Merchan	320
Total		20,337

Note: Block 12 does not exist at present

Location of the above irrigated areas are shown in Fig. 3.2.

The cultivated crops in the irrigated area are pastures (Mejorados, Kikuyo and Gramineous), wheat, barley, maize, potato, tomato, etc. among which pasture and maize are predominant. The crops other than pastures and maize are negligible. Then, only pasture and maize are considered in this irrigation study. However, the existing maize cultivation is limited to the irrigated area of 3,141 ha in Block No. 11, and all the other irrigated areas are planted with pastures.

Pastures are cultivated throughout the year, while maize is cultivated twice in a year (Mar.-July and Sep.-Jan.).

(2) Irrigation System

The existing irrigation system consists of the three (3) major systems: (i) Hato Dam-Ubate River system, (ii) Cucunuba Lake-Ubate River-Fuquene Lake-Suarez River system, and (iii) Lenguazaque River system. They are divided into 14 irrigation blocks as shown in Fig. 3.2.

Pasture is irrigated by sub-terranean irrigation method. Namely, the irrigation water is first taken from a river into the irrigation canal networks in the pastureland. The water in the canals is infiltrated into the underground of the pastureland and the pasture absorbs this groundwater by capillary action.

(3) Water Requirement on Farm

The monthly irrigation water requirement on farm level has been established for each crop in the related sub-basins by CAR as the bases to manage the irrigation water use on farm level. The average monthly water requirement of pasture and maize in the Study Area is shown below.

(unit: m^3/ha)

Crop	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Pastures	690	510	150	0	20	160	470	460	200	0	0	410	3,070
Maiz	600	0	0	0	20	160	390	0	0	0	0	410	1,580

For the monthly water requirement by crop and by sub-basin, see Appendix C, Table C.1.1 to Table C.1.5.

The water requirement on farm by irrigation block is summarized below.

Irrigation Block	Irrigation Area (ha)	Crop	On-farm Water Requirement (10^3xm^3/year)	Project Efficiency	Surface Water Requirement (10^3xm^3/year)	Main Water Source
1. Suta	832	Pastures	3,243	0.64	5,067	R. Suta
2. Cap-1	634	Pastures	2,471	0.576	4,290	Hato Dam/R. Ubate
3. Cucunuba	1,892	Pastures	7,374	0.80	9,218	L. Cucunuba
4. Lenguazaque	1,751	Pastures	6,825	0.64	10,664	R. Lenguazaque
5. Cap-2	316	Pastures	1,232	0.576	2,138	Hato Dam
6. Marino	700	Pastures	2,728	0.64	4,263	Marino Canal
7. Marino-Ubate	387	Pastures	1,508	0.64	2,357	Marino C/R. Ubate
8. Fuquene	2,537	Pastures	9,889	0.64	15,451	L. Fuquene
9. Honda	509	Pastures	1,984	0.64	3,100	R. Honda/ L. Fuquene
10. Susa	563	Pastures	1,714	0.64	2,678	R. Susa
11. Suarez	8,309	Pastures/ Maize	19,404	0.64	30,319	R. Suarez/ L. Fuqune
13. Old-Suarez	228	Pastures	629	0.64	982	R. Old Suarez
14. Madron	1,359	Pastures	3,747	0.64	5,854	R. Madron
15. Merchan	320	Pastures	882	0.64	1,378	Small river
Total	20,337		63,630 (2.02 m^3/s)		97,759 (3.10 m^3/s)	

Note: Block No. 12 does not exist at present.

(4) Surface Water Use

The above water requirement on farm is supplied from surface water as mentioned before. The surface water use is estimated from the above on-farm water requirement, taking into consideration the project efficiency consisting of conveyance efficiency, field canal efficiency and field application efficiency.

The total surface irrigation water use in the Study Area is estimated to be 97.8 million m^3/year (= 3.10 m^3/s). The surface water use of each irrigation block is also shown in the above table along with the respective main surface water sources.

3.2.2 Livestock Water Use

The major livestock in the Study Area are cattle, pig and sheep. Their water uses are estimated by multiplying the number of livestock by the unit water use. In this estimation, the standard unit water consumption proposed by CAR is employed. The water consumption of each kind of animal in the Study Area is calculated as shown below. The water is mostly extracted from irrigation and drainage channels in the pasturelands.

Animal	Nos. of Animal (head)	Unit Use. (l/head/day)	Water Use (m^3/day)
Bovine	171,402	25	4,285
Pig	29,562	10	296
Sheep	64,400	15	966
Total	265,364		5,547 (0.06 m^3/s)

3.2.3 Municipal Water Use

(1) Inventory of Municipal Water Supply System

Inventory of the existing municipal water supply systems in the Study Area was prepared through questionnaire and interview surveys. The municipal water includes domestic, institutional and industrial uses. Most of the industrial water in the Study Area is taken from the municipal water supply system. A small industrial water is individually taken from groundwater wells.

Municipal water supply system serves almost all the urban and some rural population with mostly conventional treatment. Inventory of the municipal water supply systems are shown below.

Municipality	Water Source	Treatment Process	Service Ratio (%)		Monthly Average Intake Water (m^3/month)
			Urban	Rural	
C. de Carupa	R. Playa	Sedimentation only	100	0	15,000
Ubate	R. Ubate	Conventional	100	31	196,992
Tausa	Q. Chapeton	Conventional	100	n.d.	7,350
Sutatausa	Surface	Conventional	98	1	18,144
Cucunuba	Q. Lachorrera	Conventional	100	7	5,068
Lenguazaque	R. Lenguazaque	Conventional	100	1	31,104
Guacheta	Q. Honda	Conventional	100	71	31,120
S. M. de Sema	Q. La Cortadera	Conventional	100	72	49,065
Fuquene	Q. El Paramo	None	100	0	9,338
Susa	Q. Nutrias	None	100	20	12,798
Simijaca	R. Simijaca	Conventional	35	0.5	7,988
Caldas	Q. Ojo de Agua	Sedimentation only	100	23	6,187
Chiquinquira	R. Suarez	Conventional	94	n.d.	518,400
Saboya	Q. Cantoco	Sedimentation only	100	10	6,150
Total					914,704 (0.35 m^3/s)

n.d.: No data are available

The remaining rural population who are not served by the above municipal water supply systems are all served by individual small scale piped water supply system (called vereda water supply system).

(2) Water Demand

(a) Domestic Water Demand

The unit domestic water consumption is assumed as follows based on the CAR design standards.

(l/person/day)

Item	Urban Area				Rural Area
Population	< 5,000	5,001–10,000	10,001–20,000	> 20,001	
Unit Consump.	150	165	180	195	125

The existing domestic water demand in the Study Area is estimated as follows.

			(m^3/day)
Municipality	Urban Area	Rural Area	Total
Ubate	3,039	2,824	5,863
Chiquinquira	7,999	826	8,825
Others	2,691	9,490	12,181
Total	13,729	13,140	26,869 (0.31 m^3/s)

For the water demand of each municipality, see Appendix C, Table C.1.7.

(b) Institutional Water Demand

The institutional water demand is assumed at 10% of domestic water demand. The existing institutional water demand in the Study Area is estimated as follows.

			(m^3/day)
Municipality	Urban Area	Rural Area	Total
Ubate	304	282	586
Chiquinquira	800	83	883
Others	269	949	1,218
Total	1,373	1,314	2,687 (0.03 m^3/s)

(c) Industrial Water Demand

The major industrial water uses in the Study Area are those of slaughterhouse and dairy factory. The unit industrial water consumption is assumed as follows, based on the CAR design standards.

Industry	Unit Water Consumption
Slaughterhouse	Bovine: 500 l/head, Pig: 250 l/head, Sheep: 200 l/head
Dairy Factory	Milk Processing: 3,500 l/milk-ton, Cheese Production: 15,000 l/cheese-ton

The existing industrial water demand in the Study Area is estimated as follows.

			(m^3/day)
Municipality	Urban Area	Rural Area	Total
Ubate	819	131	950
Chiquinquira	17	1	18
Others	1,397	226	1,623
Total	2,233	358	2,591 (0.03 m^3/s)

For the water demand of each municipality, see Appendix C, Table C.2.2 and Table C.2.3.

(d) Total Municipal Water Demand

The existing total water demand of domestic, institutional and industrial purposes are summarized below.

(m^3/day)

Municipality	Urban Area	Rural Area	Total
Ubate	4,162	3,237	7,399
Chiquinquira	8,816	910	9,726
Others	4,357	10,665	15,022
Total	17,335	14,812	32,147 (0.37 m^3/s)

(e) Water Supply Loss

The municipal water supply systems of the Study Area serve almost all the urban population and some rural population, institutional use (10% of domestic use) and most of industrial use. The total water demand for the municipal water supply systems is estimated at 6.844 million m^3/year. On the other hand, the total water intake volume of the municipal water supply systems is estimated at 10.976 million m^3/year. Hence, the average unaccounted-for water ratio of the existing water supply systems is estimated at 60%. For details, see Appendix C, Chapter I, Section 1.4.

3.3 Future Water Use

The future water use is estimated for the target year of 2010.

3.3.1 Irrigation Water Use

According to the information of CAR, the flat lands neighboring to the existing irrigation systems are further irrigable. In this Study, these areas are assumed to be all irrigated by the year 2010. The total irrigation area of the Study Area will be extended from 20,337 ha at present to 24,849 ha in 2010. In this estimation, it is assumed that three (3) new irrigation blocks of Simijaca (No. 12), Upper Honda (No. 16) and Upper Susa (No. 17) will be developed and some lower part (344 ha) of the existing Lenguazaque block (No. 4) will be transferred to Suta irrigation block (No. 1). For location of the future irrigation blocks, see Fig. 3.3.

Even in 2010, the irrigation area will mostly be used for pasture. Crop (maize) cultivation will be limited to some part of Suarez and Simijaca irrigation blocks (Suarez: 3,141 ha, Simijaca: 83 ha).

The future surface water requirement for irrigation use is estimated by using the same unit on-farm water requirement and project efficiency as the present ones. The estimated surface water requirement by irrigation block are shown below.

Irrigation Block	Existing Irrigation Area (ha)	Future Irrigation Area (ha)	Crop	Surface Water Requirement ($10^3 x m^3$/year)	Main Water Source
1. Suta	832	1,277	Pastures	8,641	R. Suta/Hato Dam
2. Cap-1	634	1,365	Pastures	9,237	Hato Dam/R. Ubate
3. Cucunuba	1,892	1,892	Pastures	9,218	L. Cucunuba
4. Lenguazaque	1,751	2,309	Pastures	14,062	R. Lenguazaque
5. Cap-2	316	1,582	Pastures	10,705	Hato Dam/R. Ubate
6. Marino	700	700	Pastures	4,263	Marino Canal/ R. Ubate
7. Marino-Ubate	387	387	Pastures	2,357	Marino C/R. Ubate
8. Fuquene	2,537	2,537	Pastures	15,451	L. Fuquene
9. Honda	509	509	Pastures	3,100	R. Honda/ L. Fuquene
10. Susa	563	563	Pastures	2,678	R. Susa/ L. Fuquene
11. Suarez	8,309	8,309	Pastures/Maize	30,319	R. Suarez/ L. Fuqune
12. Simijaca*	-	417	Pastures/Maize	1,998	R. Simijaca
13. Old-Suarez	228	228	Pastures	982	R. Old Suarez/R. Suarez
14. Madron	1,359	1,359	Pastures	5,854	R. Madron
15. Merchan	320	640	Pastures	2,758	Small River/R. Suarez
16. Upper Honda*	-	349	Pastures	2,125	R. Honda
17. Upper Susa*	-	426	Pastures	2,026	R. Susa
Total	20,337	24,849		125,774 (3.99 m^3/s)	

*: New irrigation block.

3.3.2 Livestock Water Use

The livestock water demand will increase in proportion to the increase of livestock number. The future water demand is estimated by the product of the projected livestock number and unit water consumption. The standard unit water consumption of CAR is employed in this estimation. The total future water demand of the Study Area is estimated at 6,219 m^3/day (0.07 m^3/s). For projection of the future livestock number, see Appendix A, Chapter II, Section 2.3.

3.3.3 Municipal Water Use

(1) Domestic Water Demand

The domestic water demand will increase in proportion to the growth of population. The future water demand is estimated by multiplying the projected population by unit water consumption. The standard unit water consumption of CAR is employed in this estimation. For projection of the future population, see Appendix A, Chapter II, Section 2.2.

(2) Institutional Water Demand

The future institutional water demand is assumed at 10% of the future domestic water demand.

(3) Industrial Water Demand

The industrial water is mainly used for slaughterhouses and dairy factories. The future water demand for slaughterhouse is estimated by the product of the slaughtered animal heads projected and unit water consumption. Similarly, the future water demand for dairy factory is estimated by the product of the dairy production projected and unit water consumption. The unit water consumption rates of CAR are employed in the water demand estimation of slaughter house and dairy factory, respectively.

The number of slaughtered animals is assumed to grow in proportion to the population growth. Dairy production is assumed to increase by 4% during 1998 to 2010 (see, Appendix A, Chapter II, Section 2.5).

(4) Total Water Demand

The total water demand of municipal water in the Study Area is estimated at 37,342 m^3/day (0.43 m^3/s) with the following break-down.

(m^3/day)

Item	Ubate	Chiquinquira	Others	Total
Domestic	7,774	10,292	13,427	31,493
Urban	4,462	9,431	3,778	17,671
Rural	3,312	861	9,649	13,822
Institutional	777	1,029	1,343	3,149
Urban	446	943	378	1,767
Rural	331	86	965	1,382
Industrial	991	21	1,688	2,700
Urban	855	19	1,454	2,328
Rural	136	2	234	372
Total	9,542	11,342	16,458	37,342
Urban	5,763	10,393	5,610	21,766
Rural	3,779	949	10,848	15,576

(5) Source Demand

The above estimated water demand is that of customers. The water supply loss is expected to decrease according to the improvement of the existing systems in the future. The future demand for raw water source is estimated by adding 20% of unaccounted-for water, based on the design standards of CAR concerning water loss ratio.

3.4 Existing Water Storage and Intake System

3.4.1 Salient Features of Structures

There are one (1) reservoir (Hato), three (3) lakes (Palacio, Cucunuba and Fuquene) and three (3) gates (Cartagena, Cubio and Tolon) in the Study Area. They are operated for irrigation and municipal water supply, and flood control. Their locations are shown in Fig. 3.4.

Salient features of the above reservoir, lakes and gates are summarized below.

Name	Major Purpose	Dimension	Remarks
Hato Reservoir	Irrigation for Ubate area Municipal water for Ubate City Flood control for Fuquene Lake	Dam Height: 33 m Total Storage: 14.4 x 10^6 m^3 Water Supply Storage: 7.7 x 10^6 m^3 Flood Control Storage: 4.7 x 10^6 m^3	Dead water: 2 x 10^6 m^3
Palacio Lake	Irrigation for Cucunuba area	Surface Area: 0.4 km^2 Total Storage: 290 x 10^3 m^3	Almost dead by sediment deposits
Cucunuba Lake	Irrigation for Cucunuba area	Surface Area: 2.5 km^2 Total Storage: 6.8 x 10^6 m^3	Active storage is not defined
Fuquene Lake	Irrigation for Fuquene Lake and Suarez River areas Municipal water for Chiquinquira City	Surface Area: 29.8 km^2 at EL. 2,539 m. Total Storage: 50.0 x 10^6 m^3 at EL. 2,539 m.	Active storage is not defined
Cartagena Gate	Water control of Palacio and Cucunuba lakes	Height: 1.74 m	
Cubio Gate	Water control of Palacio and Cucunuba lakes	Height: 2.53 m	
Tolon Gate	Water control of Fuquene Lake	Height: 2.52 m	

The longitudinal profile of the Cucunuba Lake - Ubate River - Fuquene Lake - Suarez River system with the control gates is shown in Fig. 3.4.

3.4.2 Existing Operation Rules

(1) Hato Reservoir

The design water levels are fixed as follows.

Highest high water level (H.H.W.L): El. 2,847.29 m
Normal high water level (N.H.W.L): El. 2,842.70 m
Low water level (L.W.L) : El. 2,828.00 m

Irrigation and municipal water is supplied by using a storage capacity of 7.7 million m^3 between El. 2,828.0 m and El. 2,842.70 m. Water is released by the operation of a valve. Floods are controlled by using a storage capacity of 4.7 million m^3 between El. 2842.70 m and El. 2,847.29 m. Flood water is discharged through the same valve as water supply at a normal flood time, however, it is discharged through the spillway at a large flood time. No special flood control gate is provided.

(2) Control Gates

Cubio Gate and Cartagena Gate are integrally operated as follows in principle. In dry season, Cubio Gate is closed and Cartagena Gate is opened to introduce the surplus water of the Ubate and Lenguazaque rivers into the Cucunuba Lake. On the other hand, in rainy season, Cubio Gate is opened to discharge the flood water of the Ubate and Lenguazaque rivers downstream and Cartagena Gate is closed to prevent the floodwater to flow back into the Cucunuba channel.

Tolon Gate is operated to control the water level of the Fuquene Lake and Suarez River as follows in principle. In dry season, it is closed to maintain the required water level to supply irrigation and municipal water. On the other hand, in rainy season, it is opened to discharge the floodwater of the Fuquene Lake, and Susa and Simijaca rivers downstream. The target water level of the Lake is not officially fixed and the gate operation is optionally done according to the hydrological situations of the Lake and upstream basin.

3.5 Water Balance under Existing Condition

Water balance of the Study Area under the existing water use conditions is simulated to prepare the optimum integrated reservoir and gate operation rules. The proposed simulation model of the Study Area is shown in Fig. 3.5. Water balance is evaluated based on the hydrological data (river flow rate and lake water level) during 20 years in the past (1978-1997).

3.5.1 Construction of Simulation Model

(1) Conditions of Simulation Model Construction

(a) The existing surface area - elevation curve and storage water - elevation curve of Hato Reservoir, Cucunuba Lake and Fuquene Lake are shown in Fig. 3.6. Palacio Lake is not considered since it has already been dead due to sediment deposition.

(b) Evaporation from the reservoir and lake surfaces is considered. For the evaporation rates of the reservoir and lakes, see Appendix C, Chapter III, Section 3.3.

(c) The following existing operation rules of the dam and gates are applied in the water balance simulation.

(i) Hato Dam

Hato Dam releases the water necessary to meet the irrigation use of Cap-1 and Cap-2 irrigation blocks and the municipal use of Ubate City in normal time when the water level stays between L.W.L. (EL. 2,828.00 m) and N.H.W.L. (EL. 2,842.70 m). When the water level of the reservoir exceeds EL. 2,842.70 m at a flood time, the dam discharges water as follows after regulating inflow floodwater.

Water Level (m)	2,842.7	2,842.9	2843.1	2843.3	2,843.5	2,843.7
Discharge (m^3/s)	0.0	1.0	2.0	3.0	4.0	5.0

(ii) Cartagena Gate

It is closed during March-May and August-October. When the water level of Cucunuba Lake exceeds El. 2,544.0 m, the lake water is immediately discharged downstream to lower the water level to El. 2,544.0 m.

(iii) Cubio Gate

It is operated to maintain the upstream water level of the gate at a certain level.

(iv) Tolon Gate

It is operated corresponding to its upstream water level as follows.

Water Level (El. m)	Operation
Higher than 2,539.4	Completely Opened
2,539.0 – 2,539.4	Partially Opened
Lower than 2,539.0	Completely Closed

(d) Some portions of the extracted irrigation water usually return to the downstream rivers and lakes. This return is also considered in this simulation. For details, see Appendix C, Chapter III, Section 3.3.

(2) Applicability of the Proposed Simulation Model

Applicability of the proposed simulation model is checked by comparing the simulated water level of Lake Fuquene with the recorded one during six (6) years (Jan. 1992 to Dec. 1997) after the completion of Hato Dam. The lake water level is calculated based on the following equation.

$$\Delta S = Di - Do + R - E$$

Where, ΔS: Change of water storage in the lake
Di: Inflow to the lake
Do: Outflow from the lake
R: Rainfall on the lake surface
E: Evaporation from the lake surface

The outflow rate of Lake Fuquene varies depending on the lake water level. It is estimated based on non-uniform flow calculations of the Suarez River. The calculation was made in due consideration of the existing river conditions with densely growing Elodea (Manning's roughness coefficient is assumed at n=0.036). The outflow rate – lake water level curve is shown below.

Lake Water Level (m)	2,537.5	38.7	39.1	39.6	39.9	40.2
Outflow Rate (m^3/s)	0.0	2.7	5.7	11.1	13.9	16.8

The simulated water level is in well agreement with the recorded one as shown in Fig. 3.7.

3.5.2 Water Balance Simulation

Water balance of the Study Area is simulated for the hydrological series of 20 years in the past (1978–1997) under the present conditions of water use, river/lake hydraulic features and dam/gate operation rules.

The following water uses are considered in the water balance simulation.

(1) Irrigation water for 20,337 ha in the 14 irrigation blocks mentioned in Subsection 3.2.1: The surface water use is estimated at 97.76 million m^3/year (3.10 m^3/s). See, Subsection 3.2.1 (4).

(2) Livestock water for 50,000 bovines being raised on the above irrigation blocks: The surface water use is estimated to be 1,250 m^3/day (0.01 m^3/s)

(3) Municipal water for Ubate and Chiquinquira cities. The surface water use is assumed to be 196,992 m^3/month (0.076 m^3/s) for Ubate City and 518,400 m^3/month (0.20 m^3/s) for Chiquinquira City based on the questionnaire survey results. See, Subsection 3.2.3 (1).

(4) The other water uses are neglected since they are small in quantity and sparsely distributed over the Study Area.

The yearly water balance at the 14 irrigation blocks are simulated as shown in Table 3.1. In this table, the municipal water uses of Ubate City and Chiquinquira City are included in the irrigation blocks of Cap-1 and Suarez, respectively, and the livestock water use is distributed to all the irrigation blocks in proportion to the size of pasture area.

Water deficit occurs in the seven (7) irrigation blocks of Suta, Lenguazaque, Mariño, Susa, Old-Suarez, Madron and Merchan with a total area of 5,753 ha in a drought of 5 year probability as shown below. The total yearly water deficit in such a drought year is estimated to be 15.85 million m^3. These water deficits occur due to not only shortage of water sources but also lack of irrigation facilities such as gate, channel, etc.

Block Block	Irrigation Area (ha)	Yearly Deficit ($10^3 m^3$/year)	Unit Yearly Deficit (m^3/ha)
1. Suta	832	2,442	2,935
4. Lenguazaque	1,751	2,464	1,407
6. Mariño	700	3,826	5,466
10. Susa	563	972	1,726
13. Old-Suarez	228	928	4,070
14. Madron	1,359	4,520	3,326
15. Merchan	320	693	2,166
Total	5,753	15,845	

Among these blocks, Suta, Mariño, Old-Suarez, Madron and Merchan are prone to severe drought with a water deficit ranging 2,000 – 5,000 m^3/ha in a drought of 5-year probability.

3.5.3 Optimum Operation Rule under Existing Condition

Hato Dam and Lake Fuquene are the largest water sources in the Study Area. Their optimum operation rules under the existing water use conditions are studied hereunder in order to attain an effective use of the water resources in the Study Area.

(1) Hato Dam

Hato Dam is a multipurpose dam including irrigation water supply, municipal water supply and flood control. The optimization policy of water supply operation is to release the water just to satisfy the requirement in the downstream and to reserve the water storage as much as possible within the allocated storage capacity. That of flood control operation is to minimize the flood water release to downstream by using the allocated storage capacity. However, the operation rule must be determined so that it can secure a sufficient safety of the dam against abnormally large floods.

(a) Water Supply

The water is released to meet the water requirement in the downstream without any deficiency or any excess to the possible extent. Actual irrigation water demand for the dam is not constant. It always fluctuates according to the variation of rainfall on farmland and available river flow rate outside the catchment of the dam. However, it is generally difficult to release the water to meet such fluctuating water demand without any deficit or excess.

Hence, the constant water release is determined for dry and rainy seasons, respectively, based on the water balance data simulated by using the hydrological series during 20 years in the past. When the releasing water quantity is set to be too small, it can not frequently meet the water demand. On the other hand, when the releasing water is set to be too large, it can satisfy the water demand even in a severe drought year. However, a large quantity of useless water is released in normal years.

The released water quantity is determined to meet the water demand in the drought year with a proper probability. The monthly released water quantities to meet 5-year and 10-year droughts are calculated as shown below.

(m^3/s)

Return Period	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
5-year	0.10	0.10	0.10	0	0.05	0.05	0.10	0.10	0	0	0	0.10
10-year	0.20	0.20	0.20	0	0.10	0.10	0.20	0.20	0	0	0	0.20

The following table shows the ratio of total water shortage to total irrigation water requirement and the ratio of total water shortage period to total irrigation period during 20 years under the above water release rules.

Return Period	5-year	10-year
Ratio of Shortage Volume	Less than 1%	Less than 1%
Ratio of Shortage Period	Less than 1%	Less than 1%

As shown in the above table, the water shortage ratio during 20 years is almost the same in both cases of smaller water release (determined to meet 5-year drought) and larger water release (determined to meet 10-year drought). Hato dam does not need to release large water to meet the drought with a high probability, taking into consideration the kind of water use (mainly pasture irrigation).

Therefore, the water supply operation to meet a 5-year drought is proposed in this Study.

(b) Flood Control

When the dam water level is below 2,842.70 m, all the floodwater is stored for water supply use. The floodwater release starts when the water level exceeds 2,842.70 m and the releasing quantity gradually increases according to rising of the water level. The flood releasing quantity – water level curve is determined so that the water level may rarely reach the crest level of spillway (2,847.00 m).

The flood release rule of the dam is proposed as follows, compared with the existing one.

Dam Water Level (m)*	42.7	42.8	42.9	43.0	43.1	43.2	43.3	43.4	43.5	43.6	43.7
Proposed (m^3/s)	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
Present (m^3/s)	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0

*: Base of water level is 2,800 m

For the dam water level simulated under the above optimum operation rules, see Fig. 3.8.

The largest flood during the past 20 years occurred in 1979 and its probability is estimated to be approximately 100 year. According to the proposed flood operation rule, even this flood does not reach the crest elevation of spillway. The proposed operation rule is considered to secure enough safety of the dam.

(2) Lake Fuquene

The optimum operation rule of the Lake is studied under the optimized operation rule of Hato Dam in the previous Subsection. The optimization policy of the operation rule of the Lake is to maintain the lake water level as high as possible to protect the lake environment during dry season and to control flood peak water level below a certain level during rainy season.

(a) Control of High Water Level

Probability of the recorded water level in the past is evaluated as follows.

Probability	Maximum Level (El. m)	Minimum Level (El. m)
2-year	2,539.64	2,538.55
5-year	2,539.95	2,538.39
10-year	2,540.15	2,538.32
20-year	2,540.35	2,538.27

According to the water level - inundation area data, flooding begins to occur at 2,539.75 m in the surrounding areas of the Lake. As shown in the above table, the lake water level has reached 2,539.64 m once in two (2) years in the past. Hence, the high water level is controlled not to exceed 2,539.5 m in 2-year probability. For the water level - inundation area curve, see the previous Section 3.1.2 (3).

(b) Suarez River Condition

The lake water level is governed by the discharge capacity of Suarez River. Hence, the control of the lake water level is studied for the following four (4) cases of the channel condition of Suarez River.

Case-1: Present condition

Case-2: Elodea is removed from the river channel, then the discharge capacity is increased due to the decrease of Manning's roughness coefficient (decrease from n=0.036 to n=0.025).

Case-3: The discharge capacity is increased by dredging (0.5 m depth dredging from the existing riverbed with a dredging volume of 1.1 million m^3).

Case-4: Combination of Case-2 and Case-3

(c) Operation Water Level

The lake water level fluctuates, depending on the climatic conditions. The water level draws down from the original level at a drought time, on the other hand, it rises from the original level at a flood time. Hence, it is essential to set a proper original level during dry and rainy seasons, respectively. In this Study, this original water level is defined as the operation water level.

A higher operation water level during dry season may cause a higher flood water level during the succeeding rainy season, while a lower operation water level during rainy season may result in a lower water level during the next dry season. Hence, various combinations of the operation water level during dry and rainy seasons are studied to obtain the optimum operation water levels during both seasons.

Further, these various combinations of the operation water level are studied for the above mentioned four (4) cases of Suarez River.

(d) Tolon Gate Operation

Tolon gate is immediately closed when the lake water level lowers than the operation level and it is opened without delay when the lake water level rises above the operation level. This rule is applied for both seasons.

(e) Optimum Operation Water Level

The optimum operation water levels during dry and rainy seasons are obtained for the four (4) cases of Suarez River as shown below. In the following table, mode indicates the most frequent water level and its percentage.

Case	Operation Water Level (m)		Max. Water Level (m)		Min. Water Level (m)		Mode (m)
	Dry Season	Rainy Season	Probability	Water Level	Probability	Water Level	
Case-1	2,538.9	2,538.7	2-Year	2,539.50	2-Year	2,538.43	2,538.8 - 38.9
			5-year	2,539.83	5-year	2,538.27	(19.4%)
Case-2	2,539.1	2,538.9	2-Year	2,539.46	2-Year	2,538.52	2,539.0 - 39.1
			5-year	2,539.75	5-year	2,538.36	(26.0%)
Case-3	2,539.3	2,538.9	2-Year	2,539.49	2-Year	2,538.59	2,539.1 - 39.2
			5-year	2,539.75	5-year	2,538.40	(16.5%)
Case-4	2,539.1	2,539.1	2-Year	2,539.44	2-Year	2,538.54	2,539.0 - 39.1
			5-year	2,539.69	5-year	2,538.37	(30.4%)

(f) Effects of Suarez River Improvement

The improvement of Suarez River increases the discharge capacity, lowering the high water level of the Lake.

The lowering of the high water level due to the Suarez River improvement is evaluated by comparing the maximum water levels with a 2-year probability of Case-2, Case-3 and Case-4 with that of Case-1. In this comparison, the optimum operation water level of Case-1 is applied for all the other cases. The results are shown below.

Case	2-year Max. Water Level (El. m)	Effect (m)
Case-1 (Present Condition)	2,539.50	------
Case-2 (Aquatic Plant Removal)	2,539.39	0.11
Case-3 (Dredging)	2,539.33	0.17
Case-4 (Plant Removal and Dredging)	2,539.26	0.24

(g) Conclusion

Dredging of the Suarez River will not so much contribute to the lowering of high water level of the Lake although it requires a large dredging volume of 1.1 million m^3. Hence, only clearing of the aquatic plants is proposed for the Suarez River improvement (Case-2).

The proposed operation rule is summarized below.

(i) Target water level of the Lake is proposed as follows.

Water Level	Elevation (m)	Return Period
High Water Level	2,539.46	2-year
Low Water Level	2,538.52	2-year
Most Frequent Water Level	2,539.0 - 2,539.1	

(ii) Operation water level is determined as follows: dry season: 2,539.1 m and rainy season: 2,538.9 m

(iii) Tolon gate should be opened immediately when the lake water level exceeds the operation water level and be closed without delay when the lake water level lowers below the operation water level.

(iv) The Suarez River should be kept clean with no aquatic plants to attain the target lake water level.

For the lake water level simulated under the above optimum operation rules, see Fig. 3.9.

3.6 Water Balance under Future Condition

3.6.1 Water Balance Simulation

(1) Proposed Future Irrigation System

The existing irrigation system of the Study Area must be changed by constructing some new irrigation facilities including gate, turnout, pump and others to meet the future irrigation water demand.

The future irrigation area is divided into 17 irrigation blocks in consideration of the available water sources as shown in Fig. 3.3. Three (3) new irrigation blocks of Simijaca, Upper Honda and Upper Susa are created. The major irrigation facilities required to supply water to the above blocks are also shown in the same figure.

(2) Proposed Simulation Model

The simulation model under the future irrigation system is proposed as shown in Fig. 3.10.

(3) Water Balance Simulation

Water balance of the Study Area is simulated for the hydrological series of 20 years in the past (1978 – 1997) under the conditions of future water demand, future proposed irrigation system and present river/lake hydraulic features.

The following water uses are considered in the water balance simulation.

(a) Irrigation water for 24,849 ha in the 17 irrigation blocks mentioned in Subsection 3.3.1. The surface water use is estimated at 125.77 million m^3/year (3.99 m^3/s).

(b) Livestock water for 66,740 cattle to be raised on the above irrigation blocks. The surface water use is estimated to be 1,670 m^3/day (0.02 m^3/s).

(c) Municipal water for Ubate and Chiquinquira cities. The surface water use is assumed to be 0.1 m^3/s for Ubate City and 0.20 m^3/s for Chiquinquira City.

(d) The other water uses are neglected since they are small in quantity and sparsely distributed over the Study Area.

The yearly water balance at the 17 irrigation blocks are simulated, as shown in Table 3.2.

In Table 3.2, the municipal water uses of Ubate City and Chiquinquira City are included in the irrigation blocks of Cap-1 and Suarez, respectively, and the livestock water use is distributed to all the irrigation blocks in proportion to the size of pasture area.

Water deficit occurs in the nine (9) irrigation blocks of Suta, Lenguazaque, Cap-2, Mariño, Mariño-Ubate, Simijaca, Madron, Upper Honda and Upper Susa with a total area of 8,806 ha in a drought of 5 year probability as shown below. The total yearly water deficit in such a drought year is estimated to be 14.07 million m^3.

Block No.	Irrigation Area (ha)	Yearly Deficit (10^3m^3/year)	Unit Yearly Deficit (m^3/ha)
1. Suta	1,277	218	171
4. Lenguazaque	2,309	4,610	1,997
5. Cap-2	1,582	62	39
6. Mariño + 7. Mariño-Ubate *	1,087	3,580	3,293
12. Simijaca	417	168	403
14. Madron	1,359	4,522	3,327
16. Upper Honda	349	321	920
17. Upper Susa	426	588	1,380
Total	8,806	14,069	

*: Block No. 6 Mariño and No. 7 Mariño-Ubate are integrated to maximize the water use efficiency.

Among these blocks, Lenguazaque, Mariño + Mariño-Ubate and Madron are prone to severe drought with a water deficit ranging 2,000 – 3,000 m^3/ha in a drought of 5-year probability.

Water deficit will be mitigated or solved in several irrigation blocks by improvement of the irrigation system, construction of gate, channel, etc. and full operation of Hato Dam. Such irrigation blocks are Suta, Susa, Old-Suarez and Merchan. However, the irrigation blocks of Lenguazaque, Mariño + Mariño-Ubate, Simijaca, Madron, Upper Honda and Upper Susa will still be prone to severe drought due to lack of water sources (lack of water storage dam).

3.6.2 Optimum Operation Rule under Future Condition

(1) Possibility of Integral Operation of Hato Dam and Lake Fuquene

Integral operation of Hato Dam and Lake Fuquene is not considered effective from the following facts and considerations.

(a) A considerable portion of the allocated storage capacity for water supply is reserved at present since the originally planned irrigation system is not yet completed. However, this reserved storage will completely be used to supplement irrigation water to the irrigation blocks of Suta, Cap-1 and Cap-2 in the future. No room remains to release water to mitigate the water lever lowering of Lake Fuqune.

(b) The water level reaches 2,845 m, filling half of the allocated storage capacity for flood control (50% of 4.7 million m^3) at a medium scale flood. The remaining storage capacity can be used for flood control of the Lake by reducing the flood water released from the dam. However, the effect on the lake water lowering is only 7-8 cm at most. On the other hand, this integral operation will increase the risk of Hato Dam at such a large flood as 1979 flood. See, Fig. 3.8.

Then, the optimum operation rule of Hato Dam is determined, considering the effects on only the upstream beneficial areas of Lake Fuquene. The optimum operation rule of Lake Fuquene is studied under the optimum water release of Hato Dam.

(2) Hato Dam

(a) Water Supply

(i) Operation Rule at Normal Time

The optimum water supply operation is determined based on the same methodology as the case under present condition [see, Subsection 3.5.3 (1)].

The released water quantity is determined to meet the water demand in the drought year with a proper probability. The monthly released water quantities to meet 5-year and 10-year droughts are calculated as shown below.

(m^3/s)

Return Period	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
5-year	1.50	0.95	0.50	0	0.05	0.05	0.50	0.80	0.35	0	0	0.60
10-year	1.65	1.10	0.65	0	0.10	0.10	1.00	1.10	0.50	0	0	0.85

The following table shows ratio of total water shortage to total irrigation water requirement and ratio of total water shortage period to total irrigation period during 20 years under the above water release rules.

Return Period	5-year	10-year
Ratio of Shortage Volume	Less than 5%	Less than 5%
Ratio of Shortage Period	Less than 16%	Less than 14%

As shown in the above table, the water shortage ratio during 20 years is almost the same in both cases of smaller water release (determined to meet 5-year drought) and larger water release (determined to meet 10-year drought). Hato dam does not need to release large water to meet the drought with a high probability, taking into consideration the kind of water use (mainly pasture irrigation).

Therefore, the water supply operation to meet a 5-year drought is proposed in this Study.

(ii) Regulation Rule to Meet Abnormal Drought

The above operation rule is prepared to meet 5-year drought. Hence, the water level draws down to the low water level (L.W.L.) once in five (5) years. In a severer drought time than 5-year probability, no water can be supplemented from the stored water in the dam after the water level falls to L.W.L. Therefore, the water supply from the dam (demand to the dam) should be gradually reduced so that no fatal water shortage may occur even at the most serious drought recorded during the recent 20 years. The proposed reduction rate of water supply (demand) is shown below.

Water Level (m)	Higher than 2,832	2,832 – 2,830	2,830 – 2,828
Reduction Rate of Water Supply (Demand) (%)	0	40	50

(b) Flood Control

The optimum flood release rule is proposed in due consideration of the water level lowering due to the increased quantity released for water supply. The proposed flood release quantity – water level curve is shown below.

Dam Water Level (m)*	42.7	42.8	42.9	43.0	43.1	43.2	43.3	43.4	43.5	43.6	43.7
Proposed (m^3/s)	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50

*: Base of water level is 2,800 m

For the dam water level simulated under the above optimum operation rules, see Fig. 3.8.

(3) Lake Fuquene

The optimum operation rule of the Lake is determined based on the same policies and methodologies as the case under present condition, as described below.

(a) The optimization policy of the lake operation is to maintain the lake water level as high as possible to protect the lake environments during dry season and to control flood peak water level below a certain level during rainy season.

(b) High water level is controlled not to exceed 2,359.5 m in 2-year probability.

(c) Dredging of the Suarez River will not so much contribute to the lowering of high water level in the Lake. Hence, only clearing of the aquatic plants is considered for the improvement of the River.

(d) Tolon Gate is operated to keep the operation water level as long as possible.

(e) The optimum operation water levels of the Lake for dry and rainy seasons are determined through various combination of operation water levels during both seasons.

The obtained optimum operation water levels during dry and rainy seasons are shown below along with the probable maximum and minimum water levels.

Operation Water Level (m)		Max. Water Level (m)		Min. Water Level (m)		Mode (m)
Dry Season	Rainy Season	Probability	Water Level	Probability	Water Level	
2,539.1	2,538.9	2-Year 5-year	2,539.41 2,539.67	2-Year 5-year	2,538.56 2,538.36	2,539.0- 39.1 (26.5%)

The proposed operation rule is summarized below.

(a) Target water level of the Lake is proposed as follows.

Water Level	Elevation (m)	Return Period
High Water Level	2,539.41	2-year
Low Water Level	2,538.56	2-year
Most Frequent Water Level	2,539.0 - 2,539.1	

(b) Operation water level is determined as follows: dry season: 2,539.1 m and rainy season: 2,538.9 m

(c) Tolon Gate should be opened immediately when the lake water level exceeds the operation water level and be closed without delay when the lake water level lowers below the operation water level.

(d) The Suarez River should be kept clean with no aquatic plants to attain the target lake water level.

For the lake water level simulated under the above optimum operation rules, see Fig. 3.9.

3.7 Improvement of Water Resources and Use Management System

3.7.1 Irrigation System

The irrigation area in the Study Area will be extended from 20,337 ha in 1999 to 24,849 ha in 2010. As the results, the surface water requirement will increase from 3.10 m^3/s in 1999 to 3.99 m^3/s in 2010. To meet the future water requirement, some irrigation facilities will be constructed for the 11 irrigation blocks along with the optimum operation of Hato Dam and Lake Fuquene.

The total number of proposed irrigation facilities and benefited area in the Study Area are as follows.

Total Future	Proposed Facilities				Total Beneficial
Irrigation Area (ha)	Ditch (km)	Gate (nos.)	Pump (nos.)	Turnout (nos.)	Area (ha)
24,849	152.0	14	1	2	6,971

The proposed irrigation facilities and beneficial area of each irrigation block are shown in Table 3.3. For their location, see Fig. 3.3.

3.7.2 Drainage

The low pasturelands around the Lake Fuquene are habitually inundated. This flooding problems will be mitigated by clearing the Suarez River (removal of aquatic plants) and optimum operation of the Lake. The lake water level – inundation area curve and excess probability of the lake water level are calculated for the without project and with project, as shown below.

Lake Water Level (m)	2,539.75	2,540.00	2,540.25	2,540.50	2,540.75
Inundation Area (ha)	0	500	3,250	6,000	8,000
Excess Probability w/o Project	0.400	0.140	0.045	0.011	0.002
Excess Probability w/ Project	0.145	0.050	0.010	0.002	0.0002

The average annual expected inundation area without project and with project are calculated to be 228 ha and 58 ha, respectively, from the above table. Then, the average annual inundation area of 170 ha will be reduced by the proposed project.

3.7.3 Municipal Water Supply

There are 14 municipal water supply systems in the Study Area. There are no major problems on the existing intake quantity and quality in the above 14 water supply systems except Chiquinquira City. Then, improvement of the intake facilities and water purification plant of the Chiquinquira water supply system are proposed in this Study. The design served population is assumed at 45,500 in 2010.

(1) Improvement of Intake Facilities

The raw water for the municipal water supply of Chiquinquira City is taken by pump immediately upstream of Tolon Gate. The water is pumped up by 90 m to the water purification plant located 1,800 m from the intake site.

However, the pump has suffered from cavitation when the lake water level drew down below a critical level in dry season. Hence, the replacement of the existing three (3) pumps excluding motors is proposed.

(2) Improvement of Water Purification Plant

The existing plant consists of aerator (1 set), coagulation tank (2 sets), flocculation tank (5 sets), sedimentation tank (3 sets) and filtration tank (6 sets).

However, the plant does not satisfactorily treat the raw water to meet the national standard stipulated in 1998. The major parameters of the treated water quality in September, 1999 are shown below, compared to the national standards.

Parameter	Unit	Range (Average)	Standard	Meeting Rate of Standard (%)
Turbidity	UNT	3 – 14 (6.7)	5	33
NO^2	mg/l	0.0132 – 0.0484 (0.0285)	0.1	100
pH	-	4.0 – 6.0 (5.3)	6.5 – 9.0	0
Fe	mg/l	0.21 – 0.47 (0.33)	0.3	33
Cl^-	mg/l	7.8 – 15.8 (9.9)	250	100

The treated water meets the standard by only about 30% in the parameters of turbidity and Fe. pH does not satisfy the standard at all.

The existing treatment plant needs to be improved to meet the standards. The proposed improvements are given below.

(a) Installation of additional one (1) aerator to reduce Fe concentration.

(b) Improvement of the existing sedimentation tank and installation of additional one (1) filtration tank to decrease turbidity

(c) Satisfactory performance of the present pH control process

3.8 Project Cost for Improvement of Water Resources and Use Management System

3.8.1 Investment Cost

The investment cost for the proposed projects are estimated based on the following assumptions.

(1) The investment cost comprises direct construction cost, land acquisition/compensation, engineering and administration cost, and physical contingency.

(2) The cost is estimated based on the prevailing unit prices of material, equipment and labor as of October, 1999.

(3) Value added tax (IVA) is not included and currency exchange rate is assumed to be 1 US$ = 106 ¥ = 1,920 Col$ (October,1999)

The total investment cost is estimated at 15,829 million Col$ (8.25 million US$) with the following breakdown.

(unit: million Col$)

Item	Irrigation	Drainage*	Municipal Water Supply	Total
Direct Construction	9,181.0	-	600.1	9,781.1
Intake	5,690.0	-	130.1	5,820.1
Ditch	3,491.0	-	-	3,491.0
Purification Plant	-	-	470.0	470.0
Land Acquisition	2,395.0	-	-	2,395.0
Engineering / Administration	2,315.0	-	120.0	2,435.0
Physical Contingency	1,158.0	-	60.0	1,218.0
Total	15,049.0	-	780.1	15,829.1
Total (million US$)	(7.84)	-	(0.41)	(8.25)

*: No investment cost is required.

The investment cost for the irrigation improvement by irrigation block are shown below.

(unit: million Col$)

Irrigation Block	Investment Cost	Irrigation Block	Investment Cost
1. Suta	1,573	11. Suarez	-
2. Cap-1	1,582	12. Simijaca	1,113
3. Cucunuba	-	13. Old Suarez	293
4. Lenguazaque	2,735	14. Madron	-
5. Cap-2	1,861	15. Merchan	2,290
6. Marino + 7. Marino-Ubate	651	16. Upper Honda	1,027
7. Fuquene	-	17. Upper Susa	999
9. Honda	-	Total	15,049
10. Susa	925		

For details, see Appendix C, Chapter V, Section 5.4 and Chapter VI, Section 6.1 and 6.2.

3.8.2 O&M Cost

The estimated annual O&M cost includes labor, fuel, repairing, management and other costs but excludes replacement cost of equipment.

The total annual O&M cost is estimated at 200.8 million Col$/year (0.10 million US$/year) with the following breakdown.

Item	Annual O&M Cost (million Col$/year)	Remarks
Irrigation	162.3	For proposed irrigation facilities
Drainage	38.5	For clearance of Suarez River
Municipal Water Supply*	0.0	For proposed project of Chiquinquira
Total	200.8	
Total (million US$/year)	(0.10)	

*: Additional O&M cost by the proposed project is negligible.

CHAPTER IV WATERSHED MANAGEMENT AND SEDIMENT RUNOFF

4.1 Geology

The Study Area comprises mainly sedimentary rocks of the Cretaceous form synclines and anticlines oriented NE-SW. The oldest rocks crop out in the eastern part of the Study Area, around Cucunuba. The Study Area has the following 18 major geological formations:

Formation	Composition of the Formation
(1) Simiti Formation	Black lutites and limonites with sandstones intercalated with thin layers of lutites
(2) Chiquinquira Formation	Layers of fine grain sandstones and black lutites
(3) Simijaca Formation	Lutites and limonites with thin layers of sandstones
(4) La Frontera Formation	Gray or black limonites with layers of chart, iodolitas and black arcillolite
(5) Conejo Formation:	Black or gray lodolites with intercalation of micaceous limonites and sandstones
(6) Hard Gritty Formation	Quartzoce of fine gray gritty with claystone intercalation
(7) Plaeners Formation	Gray siliceous limonites intercalated with layers of clay
(8) La Regadera Formation	Quartzoce, from fine grain to middle, conglomeratic commonly with crossed stratification
(9) Bogota Formation	Mottled mudstones and silty claystone with gritty lens, generally friable , motley, from fine to middle grain silty claystone, with rarely sandy conglomerate lens and thin layers of low quality coal
(10) Guaduas Formation	Motley claystones and clays with gritty intercalation
(11) Upper Guadalupe Formation	Quartzoce hard to friable from middle to gross grain, quartzoce mudstone with ciliceous in thin layers and quartzoce generally solid of middle grain light gray gritty
(12) Chipaque Formation	Light gray to dark gray claystones with thin layers of fine grain gritty
(13) Guadalupe Lower Formation	Light gray to dark gray silty claystone and clay mudstone, siliceous, kaolinitic, light gray, in thin layers mudstone and light gray quartzoce gritty
(14) El Cacho Gritty	Quartzoce of gross to conglomerated grain with reddish claystone intercalation
(15) Soft Gritty Member	Quartzoce, white solid gritty with gray lutite intercalation
(16) Labor and Los Pinos Gritty Member	Black lutites and mudstones with intercalation of few centimeters of thickness gritty
(17) Talita Formation	Gritty and fine to coarse grain sand, whitish to reddish sand, solid conglomerate gritty and gravel
(18) Alluviam and Colluvium	Silt, lacustrine and fluvial clay, glacier deposits and no consolidated material terrace

For the distribution of the above geologic formations in the Study Area, see Appendix D, Fig. D.1.1.

4.2 Land Use

Two (2) maps are available for the Study Area. One is of land use and the other is of classification of soil erosion grades. The first map with a scale of 1:250,000 covers the whole area under CAR administration and was published in 1985. Land use in the map is classified into seven (7) categories.

The second was prepared by the Checua Project in 1990 and 1993. The map is classified in details (12 categories), considering the grades of erosion of the soils. The map covers the central part of the Study Area (equivalent to approximately 60% of the Study Area).

The second map is comparatively new and no significant difference was identified between the existing land use and the map. This map is considered to show the actual existing erosion grade conditions. However, the first map is old and some land uses are different from the existing conditions. Then, this map was updated by using the latest aerial photos and satellite print, and through a field reconnaissance for the upper (southern) and lower (northern) part of the Study Area which are not covered by the second map.

Finally, an integrated existing land use map for the Study Area was prepared by combining the updated first map and the second map. The updated existing land use area by category in the Study Area is shown below.

Category	Area (km^2)	(%)
Primary/Secondary Forest	97	5.6
Shrub Land	72	4.1
Pasture in Flat Land	301	17.2
Pasture in Sloppy Land	314	17.9
Pasture/Agricultural Rotation Land	929	53.0
Lake	30	1.7
Urban Area	9	0.5
Total	1,752	100.0

For the land use by river basin, see Appendix D, Table D.1.1.

The updated existing land use map for the Study Area is shown in Fig. 4.1.

4.3 Reserved Area

The reserved area consists of forest reserve and integrated management district. The forest reserve is further classified into protective forest zone and protective-productive forest zone.

In both forest zones, agricultural use, livestock farm, industrial use, urban development and mining are not permitted. Further, such activities as tree cutting, tree burning, hunting and fishing are prohibited. In the integrated management district, mechanized agricultural and livestock use, large scale recreation, division for farm housing, mining and extraction of construction materials are prohibited.

In the Study Area, four (4) reserved areas have been designated and one (1) area is under processing for reserved area. They are shown below.

Name	Basin	Municipality	Area (ha)	Category
El Robledal	Lake Fuquene	Guacheta and Raquira	400	Protective Forest Zone
Paramo de Rabanal	Lake Fuquene	Guacheta-Raquira and Lenguazaque	2,681	Protective Forest Zone
Juaitoque	Lake Cucunuba	Cucunuba	400	Integrated Management District
Paramo de Telecom and Merchan	Suarez River	Saboya	1,857	Protective Forest Zone
Paramo de Guerrero and Laguna Verde	Bogota River and Lake Fuquene	Tausa, Carmen de Carpa, Cogua and Zipaquira	23,573	(Under Processing)

For the locations, see Fig. 4.2.

4.4 Erosion Control for the Study Area

In 1982, CAR started a project named Checua (Checua Project I) aiming to control the soil erosion in the upstream of the Checua River (an upstream tributary of Bogota River). The project was extended to the Study Area for the basins of Suta River (11,200 ha), Ubate River (22,800 ha) and Cucunuba Lake (9,200 ha) with a total area of 43,200 ha in 1989. The Checua Project I including the extension project was completed in 1995. The project works implemented by Checua Project I in the Study Area are summarized as follows.

Structural Works: Contour Line Ditch (8,129 km), Sump (584 x 10^3 m^3), Brick Check Dam (46 m^3), Sand Bag Check Dam (8,147 x 10^3 m^3)
Vegetation : Seeds (1,020 x 10^3 holes), Tree (201 x 10^3)

In addition to the above project works, farming and social integrated assistance were given to the farmers.

Further extension of the Checua Project I started under the name of Project II to cover 125,000 ha in the Study Area in 1995 and it will be completed in 2004. The Project II covers all the existing critical soil erosion areas in the Study Area including the municipalities of Simijaca, Susa, Fuquene, Guacheta, Raquira, Ubate, San Miguel de Sema, Lenguazaque and Carmen de Carupa. The total project works done or planned up to 1999 are as follows.

Structural Works: Contour Line Ditch (2,908 km), Sump (44 x 10^3 m^3), Reservoir (603 x 10^3 m^3)
Vegetation : Seeds (3,415 x 10^3 holes), Tree (430 x 10^3)

Soil erosion of all the critical areas in the Study Area will be controlled by 2004, resulting in a significant reduction of the sediment inflow into the Fuquene Lake.

4.5 Estimation of Sediment Runoff to Lake Fuquene

Sediments are transported to the Lake from the upstream basin in three (3) types: bed load, suspended load and wash load.

The bed load is transported downwards by rolling or sliding on the riverbed. It is always in contact with the riverbed and is not suspended by all means. The suspended load is transported downwards, floating in the river water. It does not contact with the river bed all the time. The wash load is finer in size compared with the suspended load. It is yielded by erosion at hilly areas not covered by vegetation and runs off to the Lake without depositing on the riverbed.

The bed load and suspended load runoffs at Colorado of the Ubate River were analyzed by using the equations widely employed in Japan. Through this analysis, the relationships of Q–Q_B and Q–Q_S were established. With regard to the wash load runoff, the Q–Q_W curve was obtained through the field observation. Here, Q: river flow rate, Q_B: bed load runoff, Q_S: suspended load runoff, Q_W: wash load runoff. For the calculation methodology, see Appendix D, Chapter II, Section 2.3.

The average annual bed, suspended and wash load runoff volumes at Colorado of Ubate River (722.4 km^2) are estimated by applying the above Q–Q_B, Q–Q_S and Q–Q_W curves for the river flow series in the hydrological average year. The calculated annual sediment runoff volumes are as below.

Load	Runoff Volume of Ubate River (m^3/year)
Bed Load	11
Suspended Load	8,048
Wash Load	3,640
Total	11,699

The average annual sediment runoff to the Lake is estimated to be 16,068 m^3/year by assuming the same specific sediment runoff rate for the residual basin (269.8 km^2).

The average annual sediment deposition on the lake bed is estimated to be 1.6 mm/year by assuming the sediment deposition area as 3,000 ha and the deposit porosity as 0.67.

The existing sediment runoff to the Lake is not large. In the future, it will be decreased to a significant extent after completion of the ongoing Checua Project II since the Project covers all the severe erosion areas in the Study Area.

CHAPTER V WATER QUALITY AND POLLUTION CONTROL

5.1 Existing River and Lake Water Quality

5.1.1 Available Water Quality Data

(1) Sampling Location and Frequency

CAR has analyzed the river and lake water quality of the Study Area since 1993 only on ad hoc basis under the direct management. Apart from this, CAR commissioned a local consultants to analyze the water quality once in May, 1997. However, the sampling locations and frequency are not sufficient and therefore, existing available data are limited.

For the sampling locations and frequency in the past, see Appendix E, Chapter I, Subsection 1.1.1 and Fig. E 1.1.

(2) Water Quality in the Past

The analyzed water quality parameters are as follows.

Water Temperature, EC, pH, DO, BOD, COD, SS, Heavy Metals (Cd, Pb, Cr, Zn, Hg), NH_4, NO_3, NO_2, Kje-N, T-N, PO_4, T-P, T-Fe, Mg, Hardness ($CaCO_3$), Fecal Coli.

For the water quality data at the above sampling locations during 1993-1999, see Appendix E Table E.1.1.

Among the above locations, Ubate River (lower end), Suarez River (before Tolon Gate) and Lake Fuquene are the key locations for evaluation of the water quality in the Study Area. The average water quality of the three (3) key locations in the past are summarized below.

Parameter	Ubate River (Lower End)	Suarez River (Before Tolon)	Lake Fuquene (Average)
Water Temp.(^oC)	16.30	17.50	17.70
pH	7.10	6.70	7.20
DO (mg/l)	4.10	3.90	6.40
BOD (mg/l)	3.80	2.00	2.50
COD (mg/l)	31.10	46.00	25.60
NH_4 (mg/l)	0.76	0.58	0.52
T-N (mg/l)	3.11	3.68	1.98
T-P (mg/l)	0.18	0.18	0.10
T-Fe (mg/l)	1.45	2.73	0.75
Heavy Metals (mg/l)	N.D. or Negligible	N.D. or Negligible	N.D. or Negligible

N.D.: Not detected

As shown in the above table, the water quality are characterized as follows.

(a) The water temperature is moderate and little varies throughout the year.

(b) T-Fe is considerably high.

(c) COD is also high.

(d) NH_4 is very high. It is considered mainly due to the large wastewater of cattle raising.

(e) Lake Fuquene is considered highly eutrophic, judging from the fact that T-N and T-P much exceed the ordinary criteria of lake eutrophication (T-N>0.2 mg/l, T-P>0.02 mg/l).

5.1.2 Supplementary Water Quality Observation

Observations of the river/lake water quality, deposit quality in the river/lake, biological features in the Lake, transparency/releasing/production/settling rates in the Lake and wastewater quality of sewerage/factories were conducted during the rainy season (April to May) and dry season (July to September) in 1999 to supplement the existing available data. The observed locations, parameters and frequency are described below.

(1) Water Quality Observation

(a) Water Quality Observation in the Lake

The water quality of the Lake was observed at four (4) locations: Near Ubate River Mouth (QL-1), Near Port (QL-2), Center (QL-3) and Near Suarez Outlet (QL-4) for 34 quality parameters in the rainy season and 37 quality parameters in the dry season. For the sampling location, see Appendix E, Fig. E.1.2.

The observation was done two (2) times in the rainy season and one (1) time in the dry season.

For the observed parameters and results, see Appendix E, Table E.1.2 and Table E.1.12.

(b) Water Quality Observation at the Principal River Stations

The river water quality at 10 principal stations was observed for 36 quality parameters in the rainy season and 39 quality parameters in the dry season. For the sampling location, see Appendix E, Chapter I, Subsection 1.2.1/1.3.1 and Fig. E.1.2.

The observation was done three (3) times in the rainy season and two (2) times in the dry season.

For the observed parameters and results, see Appendix E, Table E.1.3 and Table E.1.13.

(c) Water Quality Observation at the Secondary River Stations

The river water quality at 10 secondary stations was observed for 13 quality parameters in both rainy and dry seasons to analyze non-point pollution load runoff. For the sampling location, see Appendix E, Chapter I, Subsection 1.2.1/1.3.1 and Fig. E.1.2.

The observation was done two (2) times each in both rainy and dry seasons.

For the observed parameters and results, see Appendix E, Table E.1.4 and

Table E.1.14.

(d) Continuous Water Quality Observation at Ubate River

The river water quality at Colorado of the Ubate River was continuously observed during a flood to analyze the relationship between river discharge and pollution load inflow to the Lake. For the sampling location, see Appendix E, Fig. 1.2. For the observed parameters and results, see also Appendix E, Table 1.5.

(e) Groundwater Quality Observation

The groundwater quality at two (2) locations was observed for 39 quality parameters in the dry season. For the sampling location, see Appendix E, Chapter I, Subsection 1.3.1 and Fig. E.1.2.

The observation was done two (2) times. For the observed parameters and results, see Appendix E, Table E.1.13.

(2) Deposit Quality Observation

The deposit quality in the lake bed was observed at the same locations as water quality observation in the rainy season. The deposit quality in the river bed was also observed at most of the principal stations of water quality observation in the rainy season. The observation was done once. The observed parameters are 26.

For the observed parameters and results, see Appendix E, Table E.1.6.

(3) Biological Observation in the Lake

The biological observation was done at the same locations as water quality observation in the Lake in both rainy and dry seasons. The observation includes sampling/analyses of the following features. The observation was done once for each rainy and dry seasons.

Sampling/Analysis	Chlorophyl-a, Phytoplankton, Zooplankton, Benthos

For the observation results, see Appendix E, Table E.1.7 and Table E.1.15.

(4) Transparency, Releasing, Production and Settling Test

The following tests and observations were done in the Lake once for each rainy and dry seasons.

Test/Observation	Location	Remarks
Transparency Observation	Same 4 locations as water quality observation	
Releasing Test	1 location near port	Releasing test of phosphorus and other substances from the lake bed, one (1) time in rainy season only
Production Test	Same 4 locations as water quality observation	observation of primary production of phytoplankton (absorption and emission of oxygen)
Settling Test	Same 4 locations as water quality observation	Observation of the settling of detritus (including inorganic particles)

For the test and observation results, see Appendix E, Table E 1.8 - E.1.10, Table E 1.16 - E.1.17 and Fig. E.1.3 - E.1.4.

(5) Wastewater Quality Observation of Sewerage and Factories

The wastewater quality of sewerage and factories was observed at 13 locations (sewerage: 4, factory: 9) once for each rainy and dry seasons. The observed parameters are 17. For the sampling locations, see Appendix E, Chapter I, Subsection 1.2.5.

For the observation results, see Appendix E Table E 1.11 and Table E 1.18.

5.1.3 Evaluation of the Supplementary Observation Results

(1) River and Lake Water Quality

(a) Average Water Quality

The average water quality at the key river stations and Lake in the rainy and dry seasons are summarized as follows.

Parameter	Hato Dam (Outlet)		Ubate River (Colorado)		Suarez River (Before Tolon)		Lake Fuquene (Average)	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Water Temp.(C^o)	14.0	14.4	16.0	18.4	16.1	18.2	16.6	17.2
PH	7.0	7.6	7.0	6.95	6.9	6.7	6.7	6.74
DO (mg/l)	6.0	6.2	6.3	0.7	0.3	2.3	3.3	4.5
BOD (mg/l)	2.5	1.0	3.5	6.2	1.5	2.3	-	-
COD (mg/l)	17.7	21.5	22.7	64.0	51.7	41.1	34.3	28.5
T-N (mg/l)	1.12	3.25	2.18	6.9	2.44	2.5	2.10	1.55
T-P (mg/l)	0.08	0.14	0.30	0.78	0.12	0.07	0.10	0.04
NH_4 (mg/l)	0.77	0.43	0.68	2.34	1.24	0.53	0.88	0.54
T-Fe (mg/l)	1.68	1.46	3.46	2.84	18.3	5.89	1.46	1.72
Heavy Metals (mg/l)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pesticides (mg/l)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total Coli. (MPN)	70	$<20 \times 10^2$	$>24 \times 10^6$	16×10^4	15×10^2	17×10^2	37×10^2	15×10^2

N.D.: Not detected

As shown in the above table, the river and lake water quality are characterized as follows.

(i) Generally speaking, the water quality at Hato Dam is good and shows little difference between the rainy and dry seasons. The water quality in the lower reaches of the Ubate River becomes worse in the dry season according to the decrease of river flow rate. On the other hand, those in the Suarez River (upstream of Tolon gate) and Lake are better in the dry season than in the rainy season.

(ii) DO in the Lake and Suarez River (upstream of Tolon gate) is low, especially in the rainy season and do not satisfy the raw water standard of CAR for drinking use (use with disinfecting: >6.0 mg/l, use with conventional treatment: >4.0 mg/l). Average DO in the Lake excluding the central area is further decreases to a level of 2.8 mg/l in the rainy season. This low DO is considered mainly due to the fact that decomposition of withered aquatic plants (especially Elodea) and detritus consumes a lot of the dissolved oxygen in the water.

Further, low DO is also observed at the lower reaches (Colorado) of the Ubate River in the dry season. It is definitely due to the sewerage effluent of Ubate City.

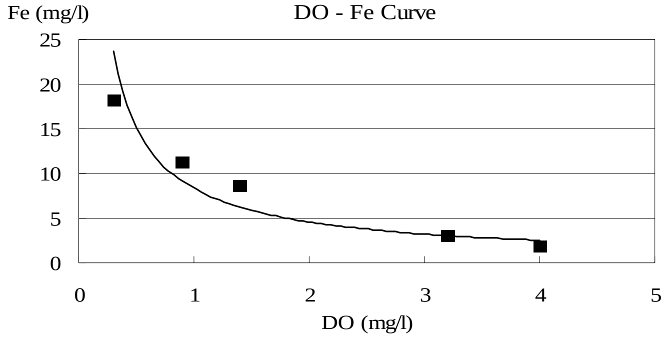
(iii) BOD in the river water is comparatively low. However, COD in both river and lake water is very high. It is considered due to a high content of humic acid in the water. For details, see Appendix E, Chapter I, Subsection 1.4.1.

(iv) Fe concentration in both river and lake water is also high. It is considered due to the fact that soils of the Study Area contains a high degree of Iron. This can be proved from the fact that the groundwater in the Study Area shows a high concentration of Fe as shown below.

No.	Location	Well Name	Ave. Fe (mg/l)
QU-1	Near Colorado	Albaida II (Pozo No.4)	94.0
QU-2	Saboya	Sugamuxi Pozo	66.9

Fe in the rivers of Ubate, Lenguazaque, Susa, Simijaca and Chiquinquira shows a comparatively small variation of 0.59 - 3.46 mg/l (average: 1.99 mg/l). It is considered due to the comparatively high content of DO (average: 5.1 mg/l) in the rivers.

However, Fe in the Suarez River (lake outlet - Tolon gate) much varies ranging from 1.75 mg/l to 18.30 mg/l (average: 7.50 mg/l). The Fe value indicates a sudden increase according to the decrease of DO as shown below.



It is considered due to the fact that the deposits in the River are under a high anaerobic condition.

(v) Neither heavy metals nor pesticides are identified in both river and lake water.

(vi) NH_4 and Coliforms with a high content are observed in both river and lake water. It is considered mainly due to the large wastewater of livestock in the Study Area.

(vii) T-N and T-P in the Lake much exceed the ordinary criteria of lake eutrophication (T-N>0.2 mg/l, T-P>0.02 mg/l).

(b) Specific Water Quality Problems

(i) The wastewater from the sewerage systems of Ubate and Chiquinquira cities much affects the water quality in the downstream river sections at a drought time. The observed water quality at a drought time is summarized below. The water in the river sections immediately after the sewerage effluents of Ubate and Chiquinquira cities is much polluted with black color and bad odor, further emitting a toxic substance of H_2S.

Location	Q (m^3/s)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	H_2S (mg/l)
Ubate River before Suta River Confluence	0.47	6.3	2.0	5.8	
Suta River after Ubate Sewerage Effluent	0.08	0.9	183.0	403.0	3.00
Ubate River after Suta River Confluence	0.55	5.3	24.1	44.1	
Ubate River after Lenguazaque River Confluence		4.5	3.1	24.5	
Suarez River after Chiquinquira Sewerage Effluent	0.68		137.0	399.0	

(ii) Decomposition of the withered aquatic plants and detritus consumes a lot of oxygen in the lake water, resulting in the water unaerobic condition. A wide lake area where aquatic plants densely grow is under unaerobic condition at present. In such area, the lake water is colored black, emitting a highly concentrated toxic substance of H_2S. Such conditions were confirmed as shown below in the three (3) representative locations.

Location	Lake Surface		Lake Bottom	
	DO (mg/l)	H_2S (mg/l)	DO (mg/l)	H_2S (mg/l)
Near Port	0.0	1.20		
Between Port and Suarez Outlet	0.4	0.40	0.0	0.50
Near Suarez Outlet	1.9	0.01	0.0	2.60

(c) Relationship between Water Quality and Water Depth in the Lake

The relationship between the water quality and water depth in the Lake is summarized below.

(i) Temperature of the lake water is nearly constant (16-18^{o}C) regardless of water depth in both rainy and dry seasons.

(ii) Turbidity is high only in the rainy season. In the rainy season, turbidity of the lake water is 20 mg/l regardless of water depth except near the Ubate river mouth. The surface water near the Ubate river mouth is as turbid as 60 mg/l.

(iii) Transparency of the lake water decreases at a high rate as the water depth increases. The relative illumination rate decreases to 1.0% of the surface one at approximately 1.0 m depth in the rainy season. However, the transparency is comparatively large in the dry season and 1.0% relative illumination extends to 1.5 - 3.5 m in depth.

(iv) DO value at a certain location is affected by the growing condition of aquatic plants in the surrounding area. However generally speaking, DO varies little or gradually decreases according to the increase of water depth in the dry season. While, it suddenly decreases according to the increase of water depth in the rainy season.

(v) DO values in the daytime and at night were compared in a location near the Port in the rainy season. The DO in the daytime was constant regardless of water depth. On the other hand, the DO at night decreased at a high rate according to the increase of water depth and it became zero at 2.5 m depth. It is due to the respiration effects of Elodea at night.

Fig. 5.1 shows the relationship between water quality and water depth.

(2) Deposit Quality in the River and Lake Bed

The deposit quality at the principal river stations and Lake are summarized below.

Item	Lake (Average)	Ubate Rivr (Colorado)	Suarez Rivr (Tolon Gate)
Color	Black/Dark Gray	Dark Brown	Dark gray
COD (mg/dry-g)	87.1	208.2	99.4
T-N (mg/dry-g)	4.60	1.01	3.80
T-P (mg/dry-g)	0.148	0.454	0.037
Ignition Loss (%)	16.4	45.2	17.8
Sulfide (mg/dry-g)	0.98	0.84	1.24
ORP* (mV)	-132	-95	-142

* ORP: Oxidation-Reduction Potential

(a) Ignition loss of both river and lake deposits are more than 15%. It means that the deposits contain a high content of organic substances. It is also confirmed by the high contents of COD, T-N and T-P in the deposits.

(b) Oxidation-Reduction Potential (ORP) of the river and lake deposits is as low as - 95 to - 100 mV. It indicates a high anaerobic condition of the deposits. The deposits contain much sulfide (H_2S) and are colored black or dark gray.

(c) Among the nine (9) major heavy metals (As, Cd, CN, Cr^{6+}, Cu, Hg, Ni, Pb and Zn), Cd, CN, Cr^{6+} and Hg are not detected in the river and lake deposits, while a certain concentration level of As, Cu, Ni, Pb and Zn are identified. However, this concentration level is as low as that of ordinary soils, causing no problems on the water environments.

(d) No pesticides are detected in both river and lake deposits.

(3) Plankton and Benthos in the Lake

(a) Plankton

(i) The existing phytoplankton in the Lake is small in number throughout the year and they count 32 species with an average population density (number of cells) of 5,408 cells/ml. The average concentration of Chlorophyll-a is as low as 0.92 mg/m^3. These low values may be attributable to the comparatively low water temperature of the Lake. The water temperature of the Lake stays around 17℃ throughout the year and it never reaches 20℃.

(ii) In the typical eutrophic lakes in Japan, the population of phytoplankton usually make an explosive increase when the water temperature exceeds 20℃ in summer season. And they returns to the original population level when the water temperature lowers in winter season. The phytoplankton population and Chlorophyll-a concentration of Lake Fuquene are compared with those of the typhical eutrophic lakes in Japan as below. For the seasonal variation of the phytoplankton population in the typical eutrophic lakes in Japan, see Appendix E, Fig. E.1.5.

Lake	Phytoplankton (cells/ml)	Chlorophyll-a (mg/m^3)	Water Temp. (℃)	Average T-N (mg/l)	Average T-P (mg/l)
Fuquene	5,408	0.92	16.9	1.83	0.07
South Biwa (Japan)	650-79,000	3.6-30.3	5.0-30.2	0.40	0.02
Kasumigaura (Japan)	10,000-270,000	56-110	4.5-30.2	0.86	0.08

(iii) Population of the existing zooplankton in the Lake Fuquene is also small throughout the year. It counts only four (4) species with an average population density of 2.0 cells/ml.

(b) Benthos

No benthos are identified in the deposits of the Lake since even the surface layer of the lake bed is under an anaerobic condition. This anaerobic condition may be caused by decomposition of the deposited aquatic plants and detritus on the lake bed. Generally, clean lakes contain oxygen in the surface layer of the bed where shellfish and various species of benthos live.

(4) Settling, Releasing and Production Rate in the Lake

(a) The average settling rate of particles in the Lake is estimated to be SS = 2.32 g/m^2/d in the rainy season and SS = 1.09 g/m^2/d in the dry season.

(b) The deposited chemical elements on the lake bed dissolve in the water again. The releasing rates of COD, T-N and T-P from the lake bed are estimated as follows; COD = 900 mg/m^2/day, T-N = 60 mg/m^2/day, T-P = 0.55 mg/m^2/day.

(c) The average production rate of phytoplankton in the Lake is estimated at 2.23 Cg/m^2/day.

5.1.4 Standards of Surface Water Quality and Wastewater Effluents

(1) National Standards

The Government of Colombia stipulated the national standards of surface water quality (permissible water quality concentration for domestic, agriculture, stockbreeding and recreation uses) and wastewater effluents (permissible wastewater concentration into river and sewerage) through Decree 1594 of 1984. The national standards give the minimum values to be conformed nationwide. They are shown in Appendix E, Table E.1.19.

(2) CAR Standards

CAR stipulated the standards of surface water to be applied for their administration area through Agreement 58 of 1987, based on the national standards. They are shown in Appendix E, Table E.1.20. Further, CAR categorized the target river water quality into four (4) classes of A, B, C and D in accordance with the water use level of rivers and designated the class of the rivers under their jurisdiction through Agreement 58 of 1987. The major parameters of the target water quality in each class are shown below. The river sections in the Study Area are classified as shown in Fig. 5.2.

Parameter	Unit	Class-A	Class-B	Class-C	Class-D
pH		6.5-8.5	5.0-9.0	4.5-9.0	4.5-9.0
DO (O_2)	mg/l	6.0	5.0	2.0	-
BOD (DBO)	mg/l	5.0	10.0	30.0	100.0
Total Col.	MPN	5,000	5,000	10,000	-

5.2 Point Pollutant Sources and Loads

5.2.1 Inventory of Existing Point Pollutant Sources

(1) Sewerage System

The Study Area partly or fully covers 17 municipalities of which the urban centers of 14 municipalities are located in the Study Area. These 14 municipalities are Carmen de Carupa, Ubate, Tausa, Susatausa, Cucunuba, Lenguazaque, Guacheta, San Miguel de Sema, Fuquene, Susa, Simijaca, Caldas, Chiquinquira and Saboya. Fuquene municipality has two (2) urban centers, Fuquene and Capellania. The other municipalities have one (1) urban center each. All the 15 urban centers are provided with sewerage system. Inventory of the existing sewerage system was prepared through questionnaire and interview surveys with concerned officials and the available data. The inventory is summarized below.

Municipality/Urban Center	Urban Pop.	Served Pop.	Served Area (ha)	No. of Served Factories	Collection System	Treatment System	Receiving River
C. de Carupa	1,511	1,300	38	0	Combined	None	Q. Suchinlaca
Ubate	16,883	16,750	158	88	Combined	R.A.P*	R. Suta
Tausa	955	955	25	2	Separate	None	R. Suta
Sutatausa	1,104	582	35	0	Combined	None	R. Suta
Cucunuba	1,226	1,153	26		Combined	Lagoon	R. San Isidro
Lenguazaque	2,133	1,800	49	0	Separate	A.S.*	R. Lenguazaque
Guacheta	3,621	3,366	57	7	Combined	None	Q. Gualacia
S. M. de Sema	525	500	31	1		S. P.*	Q.Santa Ana
Fuquene (Fuquene)	348	500	15	0	Separate	None	Irrigation
Fuquene (Capllania)	500	800			Separate	None	Q. Bautista
Susa	1,368	1,300	60	1	Separate	None	R. Susa
Simijaca	4,215	4,500	85	1	Combined	None	R. Simijaca
Caldas	275	86	14	0	Combined	None	R. Chiquinquira
Chiquinquira	41,021	42,000	458	12	Combined	None	R. Suarez
Saboya	979	1,098	40	0	Separate	S. P.*	Q. La Ruda

* R.A.P: Anaerobic piston reactor, A.S.: Activated sludge, S.P.: Stabilization pond

As shown in the above table, nearly 100% of the urban population is served by sewerage system. However, only five (5) municipalities are provided with treatment system.

For details, see Appendix E, Table E.2.1.

(2) Slaughterhouses

All the 14 municipalities in the Study Area have slaughterhouse of livestock one (1) each. Inventory of the existing slaughterhouses was prepared through questionnaire/interview surveys with the concerned officials and the available data. The results are summarized below.

Municipality	Animal	Animal Nos. (head/week)	Treatment System	Receiving Body
C. de Carupa	Cattle	15	Septic tank	Sewerage
Ubate	Cattle	150	Septic tank and	Sewerage
	Pig	72	Anaerobic treatment	
	Sheep	72		
Tausa	Cattle	18	Septic tank	Sewerage
Sutatausa	Cattle	11	Septic tank	Q. Chiritoque
Cucunuba	Cattle	5	Sedimentation tank	Sewerage
Lenguazaque	Cattle	24	Septic tank	Sewerage
Guacheta	Cattle	21	Septic tank	Sewerage
S. M. de Sema	Cattle	2	Septic tank	Q.Los Cerezos
Fuquene	Cattle	21	Blood well only	R. Fuquene
Susa	Cattle	22	Septic tank	Sewerage
Simijaca	Cattle	35	Septic tank	Q. El Capitodio
Caldas	Cattle	4	Blood well only	Q. La Raya
Chiquinquira	Cattle	115	Blood well only	R. Suarez
Saboya	Cattle	21	Septic tank	Q. EL Cantoco

(3) Industrial Establishment

The existing industrial establishments in the Study Area are classified into five (5) categories: (i) dairy processing, (ii) milk cooling, (iii) gas stations, (iv) other factories, and (v) mining. Among them, the industries which discharge significant pollution loads to affect the river water quality are considered to be dairy processing and milk cooling.

There are 44 dairy processing factories and six (6) milk cooling factories in the Study Area with the following breakdown. As shown in the table below, the wastewater of the factories are mostly discharged into the sewerage system.

Municipality	Nos. of Factories		Receiving Body of Wastewater
	Dairy Processing	Milk Cooling	
Ubate	27	2	Sewerage: 26, Irrigation: 3
Tausa	1	0	River: 1
Guacheta	1	0	River: 1
S. M. de Sema	0	1	Sewerage: 1
Fuquene	2	0	Irrigation: 1, River: 1
Simijaca	4	2	Sewerage: 4, Irrigation: 1, River: 1
Chiquinquira	9	1	Sewerage: 10
Total	44	6	

For details, see Appendix E, Table E.2.2.

5.2.2 Existing Generated and Effluent Pollution Loads

(1) General

The point pollution load includes domestic, slaughterhouse and factory loads. All the domestic and most of slaughterhouse/factory loads are discharged into the rivers through the sewerage system. Some slaughterhouse and factory loads are directly discharged into the rivers.

In this Subsection, firstly, the generated pollution load at the above sources are estimated respectively and thereafter, the influent load to sewerage, effluent load from sewerage and direct discharging load from slaughterhouse and factory to river are estimated.

The pollution loads of point sources are estimated in parameters of BOD, COD, T-N and T-P in this simulation study of pollution load.

(2) Generated Domestic Pollution Load

The generated domestic pollution load of each municipality is obtained as the product of the sewerage served population and per capita unit pollution load. Unit BOD load is assumed to be 50 g/person/day based on the design values adopted for the existing sewerage systems in the Study Area. Unit pollution loads of COD, T-N and T-P are assumed referring to the standards in Japan as follows.

(g/person/day)

BOD	COD	T-N	T-P
50	63	9.5	1.0

For the domestic pollution load generation of each municipality, see Appendix E,

Table E.2.3.

(3) Generated and Effluent Slaughterhouse Pollution Load

The generated slaughterhouse pollution load of each municipality is obtained as the product of the number of slaughter animals and unit pollution load. The slaughter animals are mostly cattle and the other animals are negligible. Then, the pollution load of slaughterhouse is estimated for cattle.

Unit generated BOD load of cattle is assumed to be 7,500 g/head/day (wastewater volume: 1,000 l/head/day, concentration: 7,500 mg/l), based on the design standards of CAR.

On the other hand, the existing slaughterhouses are all provided with some simple treatment processes. Then, the generated pollution loads are treated to some extent. Effluent quality of BOD, COD, T-N and T-P are estimated, based on the analysis conducted by CAR in eight (8) municipalities near Bogota and sampling observation conducted by the Study Team in the Study Area. The estimated effluent quality are as shown below.

Parameter	BOD	COD	T-N	T-P
Concentration (mg/l)	2,500	4,000	500	10

For the pollution load effluent from each slaughterhouse, see Appendix E, Table E. 2.6.

(4) Generated and Effluent Factory Pollution Load

The factory pollution load includes those of milk processing and milk cooling factories. The generated pollution load of each factory is obtained as the product of the milk processed quantity and unit pollution load.

Unit generated BOD load of milk processing factory and milk cooling factory are assumed as follows, based on the design standards of CAR.

Activities	Wastewater Volume	BOD (mg/l)
Milk Processing	5.0 l/L of milk	2,700
Milk Cooling	2.5 l/L of milk	800

Among the existing 50 milk processing and milk cooling factories, only eight (8) factories are provided with treatment system. Their treatment efficiency for BOD is assumed to be 40%.

Effluent COD, T-N and T-P loads are estimated, based on the relationship of BOD - COD, BOD - T-N and BOD - T-P obtained from the sampling water quality observation made by the Study Team.

Unit BOD, COD, T-N and T-P effluent loads of milk processing and milk cooling factories with and without treatment are estimated as below.

(g/mik-L/day)

	Treatment	BOD	COD	T-N	T-P
Milk Processing	Without	13.5	16.53	3.49	1.69
	With	8.1	9.92	2.10	1.01
Milk Cooling	Without	2.0	2.45	0.52	0.25
	With	1.2	1.47	0.31	0.15

For the pollution load effluent from each factory, see Appendix E, Table E.2.7.

(5) Effluent Pollution Load from Sewerage System

All the domestic pollution loads inflow to sewerage system. Seven (7) slaughterhouse pollution loads inflow to sewerage system, while the remaining seven (7) slaughterhouses are directly discharged into rivers. Pollution loads of 41 factories enter sewerage system and those of nine (9) factories are discharged into rivers or irrigation system.

The total influent pollution loads of domestic, slaughterhouse and factory to sewerage system are calculated as shown in Appendix E, Table E.2.8.

Among 15 sewerage systems in the Study Area, five (5) systems (Ubate, Cucunuba, Lenguazaque, San Miguel de Sema and Saboya) are provided with treatment process. Hence, the effluent pollution loads from the five (5) systems are calculated in consideration of the effects of treatment process. On the other hand, the effluent loads from the remaining 10 sewerage systems are equal to the influent ones.

The effluent BOD loads from the above five (5) systems are estimated, based on the observed BOD concentration data by the Study Team and CAR. The effluent COD, T-N and T-P loads are estimated based on the following relationship of BOD - COD, BOD - T-N and BOD - T-P obtained from the concentration data observed in this Study.

COD = 2.2389 x BOD, T-N = 0.394 x BOD, T-P = 0.0498 x BOD

The pollution load effluent from sewerage to rivers are calculated, as shown in Table 5.1.

(6) Effluent Pollution Load to Rivers from Slaughterhouse and Factory

The effluent loads of slaughterhouses and factories directly discharged into rivers are also shown in Table 5.1.

5.2.3 Future Generated and Effluent Pollution Loads

The generated and effluent point pollution loads in the year 2010 are estimated for without and with projects of wastewater treatment, based on the following assumptions.

(1) Generated Domestic Pollution Load

(a) Sewerage system will serve all the urban area in 2010 since the existing sewerage system has already covered almost the all urban area. For the projected population of each urban center, see Appendix A, Table A.2.1.

(b) Per capita wastewater quantity is the same as the existing one.

(c) BOD, COD, T-N and T-P concentration are the same as the existing ones.

For the domestic pollution load generation of each municipality, see Appendix E, Table E.2.11.

(2) Generated and Effluent Slaughterhouse Pollution Load

(a) Number of the slaughter animals will increase in proportion to the population growth.

(b) Unit wastewater quantity is the same as the existing one.

(c) The generated BOD, COD, T-N and T-P concentration are the same as the existing ones.

(d) All the slaughterhouses are provided with pre-treatment process at present. The treatment efficiency is the same as the existing one. The wastewater discharging point will not change.

For the slaughterhouse pollution load effluent of each municipality, see Appendix E, Table E.2.12.

(3) Generated and Effluent Factory Pollution Load

(a) Number of the factories will not change.

(b) The wastewater quantity of each dairy factory will increase by 4% from the year 1998 to 2010 in proportion to the increase of milk production. For the projection of the milk production, see Appendix A, Chapter II, Section 2.5.

(c) The generated BOD, COD, T-N and T-P concentration are the same as the existing ones.

(d) At present, pre-treatment plant is installed in some limited factories. However, all the factories will be provided with pre-treatment process by 2010. The treatment efficiency is the same as the existing one. The wastewater discharging point will not change.

For the pollution load effluent of each factory without and with project, see Appendix E Table E.2.13.

(4) Effluent Pollution Load from Sewerage System

Based on the above estimation, the total influent pollution loads of domestic, slaughterhouse and factory to sewerage system are calculated for both without and with project cases as shown in Appendix E, Table E.2.14.

At present, only five (5) sewerage systems are provided with treatment system. However, all the sewerage systems in the Study Area will be installed with treatment plant by 2010. The wastewater effluent quality of the all treatment plants is assumed to be 40 mg/l in BOD.

The treated COD, T-N and T-P concentrations are estimated based on the relationship of BOD - COD, BOD - T-N and BOD - T-P in the existing treated wastewater concentration.

The pollution load effluent from sewerage to rivers for the cases of without and with projects are calculated in Table 5.2 and Table 5.3, respectively

(5) Effluent Pollution Load to Rivers from Slaughterhouse and Factory

All the slaughterhouses and dairy factories directly discharging into rivers are assumed to be treated to meet the CAR standards. The treated COD, T-N and T-P concentrations are estimated based on the relationship of BOD - COD, BOD - T-N and BOD - T-P in the existing treated wastewater concentration.

The effluent loads of slaughterhouses and factories directly discharged into rivers for the cases of without and with projects are also shown in Table 5.2 and Table 5.3, respectively.

5.3 Estimation of Pollution Load Generation in the Basin

5.3.1 Existing Pollution Load Generation

(1) General

The pollutant sources in the Study Area are classified into point sources and non-point sources. The point sources consist of sewerage wastewater and industrial wastewater (slaughterhouses and factories). The non-point sources include livestock wastewater, wastewater from lands (farmland, pasture and shrub/forest) and household wastewater in rural area. The urban area is only 9.0 km^2 and the air is clean, therefore, the pollutants from the urban lands and rainfall are assumed negligible.

In this Study, the pollution load generation are estimated in parameters of BOD, COD, T-N and T-P.

The pollution load generation are estimated for the important area in simulation of the water pollution of the Study Area. The objective area covers the entire upstream basin of the confluence of the Suarez River with the Chiquinquira River (1,462 km^2). The objective area is divided into nine (9) sub-basins as shown in Fig. 5.3.

(2) Point Pollution Load Generation

In this pollution load simulation study, the sewerage and industrial effluents (consisting of slaughterhouse and factory effluents) to rivers from cities and towns are defined as the point pollution load generation from the corresponding sub-basins. The point pollution load generation by source and by sub-basin are estimated as shown in Appendix E, Table E.3.3.

(3) Non-point Pollution Load Generation

The non-point pollutant sources consisting of livestock, lands and household in rural area by sub-basin are estimated as shown in Table 5.4. Unit pollution load generation of BOD, COD, T-N and T-P by each non-point source category are assumed as shown in Table 5.5, based on the various previous studies. The non-point pollution load generation of BOD, COD, T-N and T-P by pollutant source category in each sub-basin are obtained as the products of the values in Table 5.4 and Table 5.5. For the non-point pollution load generation of BOD, COD, N-T and N-P by sub-basin and by source, see also Appendix E, Table E.3.3.

(4) Total Pollution Load Generation

The total pollution load generation of point and non-point sources in the Study Area (simulation objective area: 1,462 km^2) are summarized below.

(unit: kg/d)

Load Parameter	Upper Basin of the Lake	Suarez River Basin	Total
BOD	68,541	44,026	112,567
COD	166,791	95,705	262,496
T-N	48,123	29,502	77,624
T-P	6,165	3,858	10,023

The pollution load generation by each source are shown in Table 5.6.

As shown in Table 5.6, the pollution loads in the Study Area are mostly generated from non-point sources. Livestock is the largest generation source and it shares a large percentage of the total pollution load generation as shown below.

Load Parameter	Upper Basin of the Lake (%)	Suarez River Basin (%)	Total (%)
BOD	91.7	88.0	90.3
COD	91.5	89.7	90.8
T-N	78.8	80.4	79.4
T-P	97.0	95.9	96.6

5.3.2 Future Pollution Load Generation

In this Subsection, the future point pollution load generation without and with projects are estimated. Here, with project is the case where sewerage and industrial waste are treated as described in Subsection 5.2.3. The future point pollution load generation by source and by sub-basin are estimated for the cases of without and with projects as shown in Appendix E, Table E.3.6 and Table E 3.7, respectively.

In this Study, no project is considered for the reduction of non-point pollution load generation. The future non-point pollution load generation of livestock, land and household are estimated considering the increase of livestock number and rural population as shown in Appendix E, Table E.3.6.

The total future pollution load generation of BOD, COD, T-N and T-P in the Study Area (Simulation objective area: 1,462 km^2) is summarized below.

(unit: kg/d)

Project	Pollution Load Parameter	Upper Basin of Lake Fuquene	Suarez River Basin	Total
Without Project	BOD	77,214	49,604	126,818
	COD	187,970	117,869	305,838
	T-N	53,415	32,823	86,238
	T-P	6,947	4,315	11,262
With Project	BOD	76,041	46,958	122,999
	COD	185,907	114,888	300,796
	T-N	53,065	32,380	85,445
	T-P	6,904	4,251	11,155

The future pollution load generation by each source for the cases of without and with projects are shown in Table 5.7 and Table 5.8.

Livestock is the largest generation source and it shares a large percentage of the total pollution load generation as shown below.

	Load Parameter	Upper Basin of the Lake (%)	Suarez River Basin (%)	Total (%)
Without Project	BOD	91.8	88.5	90.6
	COD	91.8	91.2	91.5
	T-N	80.5	82.1	81.1
	T-P	97.0	96.2	96.6
With Project	BOD	93.3	93.4	93.4
	COD	92.8	93.5	93.1
	T-N	81.1	83.2	81.9
	T-P	97.6	97.6	97.6

5.4 Estimation of Pollution Load Runoff in the Basin

5.4.1 Existing Pollution Load Runoff

(1) General

The non-point pollution loads in the Study area run off on lands or through small channels/ditches to the tributaries. On the other hands, the point pollution loads are directly discharged into the tributaries or main rivers with treatment or without treatment. Thereafter, both point and non-point pollution loads run off through the tributaries to enter the main river. Finally, they flow down the main river.

In the first runoff stage, the non-point pollution load is decreased to a large extent by the natural purification effects on lands and small channels. The runoff coefficient (R_1) is generally constant for each land use category. In the second runoff stage, the point and non-point pollution loads are reduced by the natural purification effects in the tributaries. The runoff coefficient (R_2) varies according to the tributary length.

In this Study, pollution load runoff is defined as the pollution load which enters the main river or Lake. The pollution load runoff to the main river or Lake is estimated by multiplying the above generated pollution load by runoff coefficients of R_1 and R_2. Here, R_1 is the runoff ratio of pollutants generated from each sub-basin to its discharging tributary. R_2 is the self purification ratio of pollutants in the tributary.

Among the four (4) pollution parameters (BOD, COD, T-N and T-P), BOD is decreased in the water courses to a considerable extent due to self-purification effects. On the other hand, reduction of COD, T-N and T-P in the ordinary streams is not significant. Therefore, the self purification rate in the tributary is evaluated only for BOD.

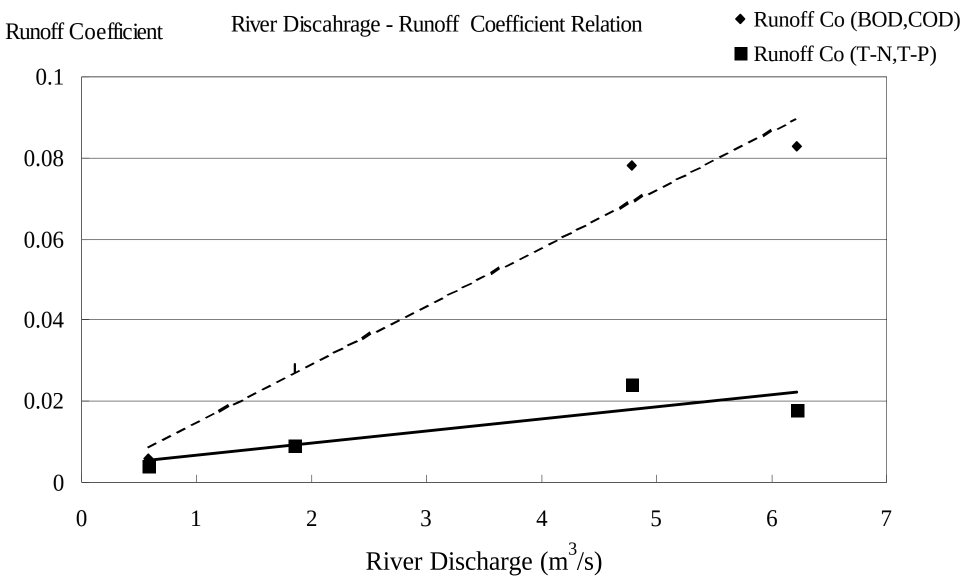
Among nine (9) sub-basins, seven (7) sub-basins discharge into the main river through each discharging tributary. Those tributaries are Ubate (upper reaches), Suta, Cucunuba, Lenguazaque, Susa, Simijaca and Chiquinquira rivers. However, the Lake Fuquene sub-basin and Suarez residual sub-basin are assumed to directly discharge into the Lake and the Suarez main river, respectively. Therefore, the self purification rate (R_2) of BOD is evaluated only for the above seven (7) rivers.

(2) Estimation of Runoff Coefficients

The runoff rate of pollution loads from the sub-basins generally varies depending on the topographical, geological and other environmental conditions. In this Study, the runoff coefficients R_1 and R_2 are determined so that the simulated pollution loads may coincide with the observed ones at Colorado station of Ubate River (after confluence of the Suta, Cucunuba and Lenguazaque rivers).

The generated non-point pollution loads (BOD, COD, T-N and T-P) in the sub-basins easily run off to the tributaries at a rainy time, while they stay more on the lands at a dry time. There is a certain relationship between the runoff coefficients (R_1) of non-point pollution loads and the river discharge. Generally, the runoff coefficients (R_1) proportionally increase according to the river discharge. Further, BOD and COD run off more easily than T-N and T-P.

Relationship between runoff coefficient (R_1) and river discharge at Colorado is established as shown below, based on the data observed by this Study.



Further, the self purification of BOD in the course of tributaries is estimated by using the formula of Streeter Helps. The average reduction rate of BOD (coefficient R_2) in the tributaries is estimated to be 3% per km.

(3) Estimated Pollution Load Runoff

The total annual pollution load runoff of point and non-point sources to the main rivers and the Lake in the Study Area (simulation objective area: 1,462 km^2) are summarized below.

(unit: kg/day)

Load Parameter	Pollutant Source	Upper Basin of the Lake	(%)	Suarez River Basin	(%)	Total	(%)
BOD	Point	880	30.4	2,759	66.2	3,639	51.5
	Non-point	2,019	69.6	1,410	33.8	3,429	48.5
	Total	2,899	100.0	4,169	100.0	7,068	100.0
COD	Point	1,456	12.7	3,480	36.4	4,770	22.8
	Non-point	10,016	87.3	6,087	63.6	16,103	77.2
	Total	11,472	100.0	9,567	100.0	20,873	100.0
T-N	Point	246	23.7	542	53.7	788	38.5
	Non-point	790	76.3	467	46.3	1,258	61.5
	Total	1,036	100.0	1,009	100.0	2,046	100.0
T-P	Point	30	22.9	81	56.4	110	40.0
	Non-point	101	77.1	63	43.6	165	60.0
	Total	131	100.0	144	100.0	275	100.0

For the pollution load runoff by each source, see Table 5.9.

As shown in the above tables, the pollution loads in the Study Area are mostly discharged from non-point sources. Livestock is the largest source of pollution load runoff followed by sewerage and their shares among the total pollution load runoff are shown below.

Load Parameter	Upper Basin of the Lake (%)			Suarez River Basin (%)			Total (%)		
	Livestock	Sewerage	Others	Livestock	Sewerage	Others	Livestock	Sewerage	Others
BOD	65.2	29.2	5.6	31.5	62.8	5.7	45.3	49.0	5.7
COD	80.6	12.3	7.1	60.0	34.0	6.0	71.8	21.7	6.5
T-N	60.5	23.0	16.5	37.8	50.6	11.6	49.3	36.6	14.1
T-P	75.5	21.4	3.1	42.4	50.0	7.6	58.6	35.6	5.8

5.4.2 Future Pollution Load Runoff

Similarly to the existing pollution load runoff, the future pollution load runoff are estimated for the cases of without and with projects. Here, with project is the case where sewerage and industrial waste are treated as described in Subsection 5.2.3.

(1) Future Pollution Load Runoff without Project

The total annual pollution load runoff of point and non-point sources to the main rivers and the Lake in the Study Area (simulation objective area: 1,462 km^2) are summarized below.

(unit: kg/day)

Load Parameter	Pollutant Source	Upper Basin of the Lake	(%)	Suarez River Basin	(%)	Total	(%)
BOD	Point	1,469	39.3	3,187	66.8	4,656	54.7
	Non-point	2,269	60.7	1,582	33.2	3,851	45.3
	Total	3,738	100.0	4,769	100.0	8,507	100.0
COD	Point	2,696	19.4	4,037	36.9	6,733	27.1
	Non-point	11,224	80.6	6,896	63.1	18,120	72.9
	Total	13,919	100.0	10,933	100.0	24,853	100.0
T-N	Point	462	34.6	625	54.1	1,087	43.6
	Non-point	875	65.4	531	45.9	1,406	56.4
	Total	1,337	100.0	1,156	100.0	2,493	100.0
T-P	Point	58	33.8	90	55.2	148	44.7
	Non-point	114	66.2	70	44.8	183	55.3
	Total	172	100.0	160	100.0	331	100.0

For the pollution load runoff by each source, see Table 5.10.

Livestock is the largest source of pollution load runoff followed by sewerage and their shares among the total pollution load runoff are shown below.

Load Parameter	Upper Basin of the Lake (%)			Suarez River Basin (%)			Total (%)		
	Livestock	Sewerage	Others	Livestock	Sewerage	Others	Livestock	Sewerage	Others
BOD	57.1	38.3	4.6	31.1	63.7	5.2	42.5	52.5	5.0
COD	75.1	19.0	5.9	59.5	35.0	5.5	68.2	26.0	5.8
T-N	53.1	33.4	13.5	38.5	51.1	10.4	46.3	41.9	11.8
T-P	64.7	32.1	3.2	42.5	50.0	7.5	54.1	40.8	5.1

(2) Future Pollution Load Runoff with Project

The total annual pollution load runoff of point and non-point sources to the main rivers and the Lake in the Study Area (simulation objective area: 1,462 km^2) are summarized below.

(unit: kg/day)

Load Parameter	Pollutant Source	Upper Basin of the Lake	(%)	Suarez River Basin	(%)	Total	(%)
BOD	Point	296	11.5	541	25.5	837	17.8
	Non-point	2,269	88.5	1,583	74.5	3,852	82.2
	Total	2,565	100.0	2,124	100.0	4,689	100.0
COD	Point	633	5.3	1,056	13.3	1,689	8.5
	Non-point	11,224	94.7	6,896	86.7	18,120	91.5
	Total	11,857	100.0	7,952	100.0	19,809	100.0
T-N	Point	112	11.4	182	25.5	294	17.3
	Non-point	875	88.6	531	74.5	1,406	82.7
	Total	987	100.0	713	100.0	1,700	100.0
T-P	Point	15	11.6	26	27.1	41	18.3
	Non-point	114	88.4	70	72.9	183	81.7
	Total	129	100.0	96	100.0	224	100.0

For the pollution load runoff by each source, see Table 5.11.

Livestock is the largest source of pollution load runoff followed by sewerage and their shares among the total pollution load runoff are shown below.

Load Parameter	Upper Basin of the Lake (%)			Suarez River Basin (%)			Total (%)		
	Livestock	Sewerage	Others	Livestock	Sewerage	Others	Livestock	Sewerage	Others
BOD	83.2	10.5	6.3	69.9	18.6	11.5	77.2	14.2	8.6
COD	88.1	5.0	6.9	81.8	11.2	7.0	85.6	7.5	6.9
T-N	71.9	10.7	17.4	62.4	21.9	15.7	67.9	15.4	16.7
T-P	86.0	10.1	3.9	70.8	20.8	8.4	79.9	14.7	5.4

5.5 Water Quality Simulation

5.5.1 Methodology

(1) General

The pollution loads generated in the four (4) sub-basins of Upper Ubate, Suta, Cucunuba and Lenguazaque rivers run off to the Colorado station of the Ubate main river through the respective tributaries. Thereafter, they flow down the main river to enter the Lake Fuquene. On the other hand, the pollution loads in the Lake Fuquene sub-basin is directly discharged into the Lake.

The pollution loads entering the Lake are drained to the Suarez main river after they are affected by the metabolic effects of the Lake.

The pollution load effluents from the Lake flow down the Suarez main river to the downstream of Chiquinquira City through the Tolong Gate. On the way to the downstream of Chinquira City, the pollution loads generated in the sub-basins of Susa, Simijaca, Suarez residual and Chiquinquira are discharged into the Suarez main river.

For the schematic diagram of the above pollution load runoff, see Fig. 5.4.

(2) Water Quality Simulation of Main River

The Ubate main river (Colorado St. – Entrance to the Lake) is only 2 km in distance, therefore, no water quality change is assumed in this reach. The river water quality simulation is made for the Suarez main river (Lake Fuquene outlet – Downstream of Chiquinquira City) with a river distance of 20 km. The river water quality is simulated in the parameters of BOD, COD, T-N and T-P.

In the Suarez River, BOD considerably decreases due to self-purification effects while flowing down the river. However, the self purification effects of COD, T-N and T-P are considered negligible since the retention time in the river is short. The reduction of BOD concentration in the river is calculated by the formula of Streeter Helps.

For the detailed simulation methodology, see Appendix E, Chapter III, Subsection 3.4.1.

(3) Water Quaity Simulation of Lake

The water quality of the Lake is simulated in the parameters of COD, T-N and T-P.

COD, T-N and T-P loads enter the Lake from the Ubate main river and the Lake Fuquene sub-basin. They are drained into the Suarez main river after they are affected by the metabolic process of the Lake including decomposition, settling on the bed, absorption by aquatic plants (transfer to outside of the lake) and releasing from the bed. Such metabolic process is shown in Fig.5.5.

The lake water quality is estimated by using the Vollenweider Model, considering the self purification effects in the Lake. COD, T-N and T-P concentration is expected to decrease while retarding in the Lake since the average retention time is as long as 3.3 months.

In this simulation, water quality variation due to the production and decomposition of plankton is not considered since the existing plankton population is small.

For the detailed simulation methodology, see Appendix E, Chapter III, Subsection 3.4.1.

5.5.2 Simulated River Water Quality

(1) Standard River Discharge for River Water Quality Evaluation

The river water quality becomes worse according to the decrease of river discharge. This relationship at Colorado of the Ubate River is shown below.

River Discharge (m^3/s)	6.22	4.78	0.58
BOD (mg/l)	3.0	4.0	7.0
COD (mg/l)	15.0	27.0	33.2

Hence, the river water quality should be evaluated for a proper standard river discharge. On the other hand, the river flow regime at Colorado is estimated as follows.

Probability	26% (95 days)	50% (185 days)	75% (275 days)	97% (355 days)	Ave. in Rainy Season	Ave. in Dry Season
Discharge (m^3/s)	4.49	2.05	1.14	0.23	6.21	2.27

In this Study, the river discharge with a probability of 75% is proposed as the standard one for evaluation of the river water quality.

(2) Existing River Water Quality

The water quality of the main river at the time of 75% probable discharge is calculated as below.

Item	Unit	Ubate River			Suarez River	
		After Confluence of Suta River	Pte. Colorado	Tolon Gate	After Chiquinquira City	After Chiquinquira City*
Discharge	m^3/s	0.60	1.14	1.15	1.50	0.35
BOD	mg/l	13.60	5.27	3.22	17.70	69.80
COD	mg/l	37.30	31.10	63.60	72.90	103.60
T-N	mg/l	5.50	4.37	5.26	7.66	15.60
T-P	mg/l	0.69	0.54	0.62	0.90	1.85

*: When no water is discharged from Tolon Gate.

(3) Future River Water Quality

The future water quality of the main river at the time of 75% probable discharge is calculated for without and with projects. In the case of with project, sewerage and industrial waste are treated as assumed in Subsection 5.2.3 (Sewerage is treated to 40 mg/l in BOD. Industrial waste is treated to meet the CAR regulation). The estimated river water quality is shown below.

Project	Item	Unit	Ubate River			Suarez River	
			After Confluence of Suta River	Pte. Colorado	Tolon Gate	After Chiquinquira City	After Chiquinquira City*
Without Project	Discharge	m^3/s	0.60	1.14	1.15	1.50	0.35
	BOD	mg/l	20.90	7.89	3.47	20.60	82.00
	COD	mg/l	53.20	44.60	68.50	81.00	122.00
	T-N	mg/l	8.49	6.59	5.77	8.67	18.20
	T-P	mg/l	1.07	0.78	0.69	1.02	2.10
With Project	Discharge	m^3/s	0.60	1.14	1.15	1.50	0.35
	BOD	mg/l	9.59	3.94	2.77	5.31	16.00
	COD	mg/l	27.40	27.30	60.80	56.20	41.10
	T-N	mg/l	4.02	3.58	4.56	5.01	6.51
	T-P	mg/l	0.52	0.47	0.42	0.50	0.77

*: When no water is discharged from Tolon Gate.

5.5.3 Simulated Lake Water Quality and Pollution Load Balance

The water quality and pollution load balance of the Lake are simulated in the parameters of COD, T-N and T-P under the following hydrological/hydraulic conditions.

Item	Value
Average Annual Inflow (million m^3/year)	183.6
Lake Water Volume (million m^3/year)	50.0
Lake Surface Area (km^2)	29.8

(1) Existing Water Quality and Pollution Load Balance

The existing average lake water quality is estimated as below, based on the sampling analyses conducted during the Study.

Parameter	Value
COD (mg/l)	31.40
T-N (mg/l)	1.83
T-P (mg/l)	0.07

The annual pollution load balance in the Lake is calculated by comparing the following production and reduction of pollution loads.

Production : (i) pollution load inflow to the lake and (ii) releasing pollution load from the lake bed

Reduction: (i) pollution load outflow from the lake, (ii) nutrient absorption by aquatic plants, (iii) primary sedimentation in the Ubate river mouth, (iv) secondary sedimentation in the lake and decomposition in the lake.

The existing annual pollution load balance in the Lake is summarized below.

Item		COD (ton/yr.)	T-N (ton/yr.)	T-P (ton/yr.)
Production	Pollution Load Inflow	4,187	378.5	47.9
	Releasing Pollution Load	9,789	652.6	6.0
	Total Production of Pollutants	13,976	1,031.0	53.9
Reduction	Pollution Load Outflow	5,765	336.0	12.9
	Nutrient Absorption by Aquatic Plants	-	25.6	1.8
	Primary Sedimentation in the Ubate River Mouth	619	179.3	36.0
	Secondary Sedimentation in the Lake	1,621	85.9	2.8
	Decomposition in the Lake	5,928	367.9	-
	Total Reduction of Pollutants	13,933	995.0	53.5

For the detailed calculation processes, see Appendix E Chapter III, Sub-section 3.4.3.

(2) Future Lake Water Quality and Pollution Load Balance

(a) Future Lake Water Quality

Future lake water quality is simulated based on the future total production of pollutants. The future total pollutants production are shown below. In this table, the future releasing pollution load is assumed to be equal to the existing one.

Item	Without Project			With Project		
	COD (ton/yr.)	T-N (ton/yr.)	T-P (ton/yr.)	COD (ton/yr.)	T-N (ton/yr.)	T-P (ton/yr.)
Pollution Load Inflow	5,081	488.0	62.6	4,328	360.2	47.1
Releasing Pollution Load	9,789	652.6	6.0	9,789	652.6	6.0
Total Production of Pollutants	14,870	1,141.0	68.6	14,117	1,013.0	53.1

The future average water quality of the Lake is calculated below.

Item	Unit	Existing Water Quality	Future Water Quality (Without Project)	Future Water Quality (With Project)
COD	mg/l	31.40	33.40	31.97
T-N	mg/l	1.83	2.02	1.79
T-P	mg/l	0.07	0.09	0.07

In this calculation, the future self-purification coefficients are assumed to be the same as the existing ones.

As shown above, the future lake water quality will still be highly eutrophic regardless of the wastewater treatment of point sources. It is due to the fact that a large pollution load of non-point sources is left untreated.

(b) Future Pollution Load Balance

Balance of the future annual pollution load in the Lake is summarized below. In this table, the future nutrient absorption by aquatic plants and secondary sedimentation in the lake are assumed to be the same as the existing ones.

Item		Without Project			With Project		
		COD (ton/y)	T-N (ton/y)	T-P (ton/y)	COD (ton/y)	T-N (ton/y)	T-P (ton/y)
Production	Pollution Load Inflow	5,081	488.0	62.6	4,328	360.2	47.1
	Releasing Pollution Load	9,789	652.6	6.0	9,789	652.6	6.0
	Total Production of Pollutants	14,870	1,141.0	68.6	14,117	1,013.0	53.1
Reduction	Pollution Load Outflow	6,132	370.9	16.5	5,820	328.6	12.9
	Nutrient Absorption by Aquatic Plants	-	25.6	1.8	-	25.6	1.8
	Primary Sedimentation in the Ubate River Mouth	762	236.7	47.7	649	174.7	35.9
	Secondary Sedimentation in the Lake	1,621	85.9	2.8	1,621	85.9	2.8
	Decomposition in the Lake	6,335	410.8	-	6,014	364.7	-
	Total Reduction of Pollutants	14,850	1,130.0	68.8	14,101	980.0	53.4

5.5.4 Target River Water Quality and Sewerage Treatment Level

In the previous Sub-section, the river water quality in the principal river stations at the time of standard river discharge (75% probable discharge) is simulated for the cases of existing, future without project and future with project as follows.

River	Location	Q (m^3/s)	BOD (mg/l)			CAR Standard	
			Existing	Future w/o	Future w/	Class	BOD (mg/l)
Ubate	After Suta R. Confluence	0.60	13.6	20.9	9.6	A	< 5.0
Ubate	Colorado	1.14	5.3	7.9	3.9	A	< 5.0
Suarez	Tolon	1.15	3.2	3.5	2.8	A	< 5.0
Suarez	After Chiquinquira	1.50	17.7	20.6	5.3	B	< 10.0

In the case of with project of the above table, it is assumed that the sewerage of all the urban areas will be treated to 40 mg/l in BOD. Further, it is assumed that all the industrial wastewater (including slaughterhouse and factory) will be treated to meet the CAR standard.

As shown in the table above, the future river water quality with project satisfies the existing CAR standard at all principal stations except After Suta River Confluence. However, no water is taken from the river section between After Suta River Confluence and Colorado. Hence, the water quality category of this river section can reasonably be changed from Class A to Class B, targeting 10 mg/l in BOD.

From the above discussions, all the sewerage should be treated to 40 mg/l in BOD. Further, all the industrial wastewater (including slaughterhouse and factory) should be treated to meet the CAR standard.

5.6 Improvement of Wastewater Treatment System

5.6.1 Existing Wastewater Treatment System

(1) Sewerage

At present, five (5) municipalities have one (1) treatment plant each. Their salient features are shown below.

Municipality	Treatment Process	Site Area (ha)	Facilities	Capacity	Completion Year
Ubate	Anaerobic Piston Reactor	1.76	2 Reactor 2 Sedimentation Tank	2,076 m^3	1995
Cucunuba	Stabilization Pond	0.19	3 Facultative Pond	1,657 m^2 x 2.0-2.5 m	1992
Lenguazaque	Activated Sludge	0.89	1 Aeration Tank 1 Sedimentation Tank	272 m^3	1998
S. M. de Sema	Stabilization Pond	3.84	1 Facultative Pond	857 m^2 x 1.4 m	1995
Saboya	Stabilization Pond	2.00	2 Facultative Pond	6,463 m^2 x 2.0 m	1992

The average treated wastewater quality of Ubate, San Miguel de Sema and Saboya analyzed by CAR in 1999 is shown below. Data of Cucunuba and Lenguazaque are not available.

Parameter	Ubate	S. M. de Sema	Saboya
PH	7.1	7.0	8.8
BOD (mg/l)	132.8	73.9	24.9
COD (mg/l)	410.5	319.2	103.4
SS (mg/l)	88.7	115.8	46.2
DO (mg/l)	0.0	4.4	5.7

(2) Slaughterhouse

All the slaughterhouses have treatment system. The existing typical treatment system consists of blood well, grease trap, screen and septic tank. For details, see Appendix E, Chapter II, Subsection 2.1.2.

The wastewater quantity and quality fluctuates very much, depending on slaughtering process. The wastewater includes a lot of organic matter of protein, blood and grease. They easily decompose, however, they emit a bad odor. Quick treatment is necessary.

(3) Factory

Among 50 dairy factories, only eight (8) factories of medium and large scale are provided with treatment process. The remaining 42 small factories discharge with no treatment into sewerage system (37), rivers (4) and irrigation system (1). The existing typical treatment system is composed of grit chamber, screen, grease trap and sedimentation tank.

The wastewater fluctuates very much in quantity and quality due to the irregular milk collection schedule.

5.6.2 Improvement of Sewerage Treatment

(1) Design Influent Quantity and Quality

The future influent wastewater quantity and pollution loads to each sewerage system in 2010 are estimated as shown in Appendix E, Table 2.14. However, the treatment plant should be designed including groundwater infiltration into the sewer networks in addition to the wastewater from domestic, slaughterhouse and dairy factory sources. In this Study, the groundwater infiltration is assumed to be 0.1 l/ha/s, referring to the design value of the existing Ubate treatment plant. The design influent wastewater quantity and quality of each sewerage treatment system are summarized below.

Municipality	Served Area (ha)	Served Pop. (person)	Wastewater Quantity (m^3/d)	BOD Content (mg/l)
C. de Carupa	37	2,192	515	224
Ubate	158	22,883	6,212	321
Tausa	11	1,074	192	314
Sutatausa	12	1,476	234	316
Cucunuba	21	2,048	363	288
Lenguazaque	33	2,800	670	223
Guacheta	41	4,602	983	242
S. M. de Sema	16	730	303	279
Fuquene (Fuquene)	15	615	184	167
Fuquene (Capellania)	12	517	149	173
Susa	37	1,765	478	202
Simijaca	75	5,048	1,551	236
Caldas	10	621	141	220
Chiquinquira	391	48,364	12,298	226
Saboya	40	1,616	488	166
Total	909	96,351	24,761	

(2) Design Treated Wastewater Quality

The wastewater of all the municipalities is treated to 40 mg/l in BOD, based on the proposal made in Subsection 5.5.4.

(3) Selection of Treatment Processes for Alternative Study

Many types of treatment process have been developed among which the following five (5) types are the most popular: (i) stabilization pond (SP), (ii) aerated lagoon (AL), (iii) piston flow anaerobic reactor (RAP), (iv) oxidation ditch (OD) and (v) activated sludge (AS).

The priority sequence of the above five (5) processes in technical, social and economical aspects are compared as follows in general.

Item	SP	AL	RAP	OD	AS
BOD Removal	B	B	C	A	A
SS Removal	C*	B	C	A	A
Construction Cost	A	B	B	B	C
Operation & Maintenance Cost	A	B	B	C	C
Design for Construction	A	B	B	B	C
Energy Demand	A	B	A	C	C
Sludge Removal	A	A	B	B	C
Required Land Space	C	B	A	A	A

Note: A: good, B: fair, C: poor, *: it is due to content of algae

Among the above five (5) processes, SP, AL and OD are quantitatively compared in terms of construction cost, operation & maintenance cost and required land acquisition in the following Section. RAP and AS are excluded from the comparison study from the following reasons.

(a) RAP usually requires aerobic post treatment process such as oxidation ditch or facultative pond. The actual data in the existing Ubate treatment plant show that this treatment efficiency is inferior to that of the other treatment processes. See, Appendix F, Table F.1.1 to Table F.1.4.

(b) AS is usually applied for urban areas with a high population density. It requires a large amount of energy in operation, and a high level of skill in installation and operation & maintenance.

(4) Alternative Study of Treatment Process

(a) Ubate

The treated wastewater of the existing Ubate treatment plant (RAP) is in an unsatisfactory level and some aerobic treatment process should be attached as mentioned before. However, the available land space is limited to the open space of 16,600 m^2 in the existing plant site which is insufficient for a stabilization pond system. Hence, aerated lagoon and oxidation ditch are compared as follows.

Item	Aerated Lagoon	Oxidation Ditch
Required Land Space (m^2)	15,000	11,000
Construction Cost (million Col$)	586.8	1,044.6
O & M Cost (million Col$/year)	89.4	144.8

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

As shown above, the aerated lagoon system is recommendable.

(b) Lenguazaque

In Lenguazaque municipality, an activated sludge treatment plant was constructed in October 1998. However, it does not have sufficient capacity to treat the wastewater to the required level (BOD = 40 mg/l). An additional treatment system should be attached to the existing one. However, only 9,300 m^2 is available in the existing plant site for installation of the additional plant. This space is not enough to apply the stabilization pond system. Then, the aerated lagoon system is proposed.

(c) Saboya

The existing Saboya treatment plant has enough capacity to treat the wastewater to 40 mg/l in BOD. In fact, the existing treated wastewater quality is in a satisfactory level. Then, no improvement of the existing plant is necessary.

(d) Chiquinquira

The treatment plant should treat a large quantity of wastewater, requiring a wide land space. The municipality has already acquired the land of 116,444 m^2 along the Suarez River. The treatment plant should be designed to be accommodated within this land space. Hence, three (3) treatment systems of stabilization pond (combination of anaerobic pond and facultative pond), aerated lagoon and oxidation ditch are compared. The results are as follows.

Item	Stabilization Pond	Aerated Lagoon	Oxidation Ditch
Required Land Space (m^2)	107,000	59,000	43,000
Construction Cost (million Col$)*	826.8	1,734.4	2,824.5
O & M Cost (million Col$/year)	71.0	272.4	452.7

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

As evident from the above table, stabilization pond is recommendable.

(e) Other Municipalities

The alternative study was made for a model project to treat the wastewater of 1,000 m^3/day with a BOD concentration of 250 mg/l, considering the project scale for the objective municipalities. Further, the study was made based on the following assumptions and considerations.

(i) For the stabilization pond system, the following two (2) types are compared: (i) facultative pond only, and (ii) combination of anaerobic pond and facultative pond, because the anaerobic pond can minimize retention time and land space requirement. A maturation pond is not attached in both cases in consideration of the required level of water quality in the rivers.

(ii) The project site is flat, therefore, pumping is considered to lift the influent wastewater to the pond/tank.

The results are summarized below.

Item	Stabilization Pond		Aerated	Oxidation
	FA	AN + FA	Lagoon	Ditch
Required Land Space (m^2)	22,700	16,000	6,800	5,000
Construction Cost (million Col$)	239.6	246.5	328.4	480.0
O & M Cost (million Col$/year)	14.4	14.4	44.2	57.9

Note: FA: Facultative Pond, AN: Anaerobic Pond, Exchange rate = 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

As shown in the above table, the stabilization pond system of FA is the most recommendable when sufficient land space is available, followed by the stabilization pond system of AN + FA. Hence, the stabilization system of FA or AN + FA is proposed, depending on the land space availability for each municipality.

(5) Proposed Treatment System

The total design served population of the proposed 14 treatment systems is assumed at approximately 95,000 in 2010. The proposed treatment system of each municipality is summarized below. For the five (5) municipalities having treatment system at present, only additional treatment system, facilities and required land are presented in the following table.

Municipality	System	Additional Facilities	Required Land (m^2)
C. de Carupa	SP	2 facultative pond	12,500
Ubate	AL	2 aerated pond, 2 facultative pond, 6 aerator (33 kW)	15,000
Tausa	SP	1 anaerobic pond, 2 facultative pond	3,600
Sutatausa	SP	1 anaerobic pond, 2 facultative pond	4,800
Cucunuba	SP	1 anaerobic pond, 1 facultative pond	4,700
Lenguazaque	AL	1 aerated pond, 1 facultative pond, 4 aerator (8.8 kW)	5,200
Guacheta	SP	3 pump (4.5 kW), 2 facultative pond	22,500
S. M. de Sema	SP	2 facultative pond	9,000
Fuquene (Fuquene)	SP	2 facultative pond	5,200
Fuquene (Capellania)	SP	1 anaerobic pond, 1 facultative pond	2,800
Susa	SP	2 pump (0.8 kW), 2 facultative pond	10,800
Simijaca	SP	4 pump (3 kW), 2 facultative pond	41,000
Caldas	SP	2 facultative pond	5,200
Chiquinquira	SP	4 pump (14.8 kW), 2 anaerobic pond, 4 facultative pond	107,000
Saboya	-	-	-

Note: SP: Stabilization pond, AL: Aerated lagoon

For details of the proposed treatment system, facilities and their layout, see Appendix F, Chapter II, Subsection 2.2.4.

5.6.3 Improvement of Industrial Wastewater Treatment

(1) Slaughterhouse

It is proposed to install a grease trap and a septic tank after the blood well and screen for treatment of the slaughterhouse wastewater. Most of the municipalities are already provided with such processes. However, Caldas and Fuquene municipalities have only the blood well and screen. Hence, a grease trap and a septic tank are proposed for the two (2) municipalities.

(2) Dairy Factory

As mentioned before, only eight (8) factories are provided with a treatment system among the 50 dairy factories. The existing typical treatment system is composed of grit chamber, screen, grease trap and sedimentation tank. These existing treatment systems meet the regulation of CAR (BOD removal rate: 20%, SS removal rate: 50%) according to the observation by the Study Team (see, Appendix F, Chapter II, Section 2.4).

Therefore, it is proposed to install a treatment plant consisting of grit chamber, screen, grease trap and sedimentation tank for the 42 factories having no treatment plant at present. Size of the treatment plant varies depending on the wastewater quantity and quality, however, the sedimentation tank is designed to maintain a retention time of 4-6 hours in this Study.

5.7 Project Cost for Improvement of Wastewater Treatment

5.7.1 Investment Cost

The investment cost for the proposed projects are estimated based on the same assumptions as given in Chapter III, Section 3.8 (Project Cost for Improvement of Water Resources and Use Management System).

The total investment cost for the sewerage improvement is estimated at 7,561 million Col$ (3.94 million US$) as of October, 1999 with the following breakdown.

Item	Sewerage (million Col$)
Direct Construction	5,518.2
Civil Works	3,748.5
Mechanical/Electrical Equipment	1,769.7
Land Acquisition	298.0
Engineering / Administration	1,163.2
Physical Contingency	581.6
Total	7,561.0
Total (million US$)	(3.94)

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

The required investment cost for the improvement of the industrial wastewater treatment (slaughterhouse and factory) is as small as 231 million Col$ (0.12 million US$).

The investment cost for the sewerage improvement by municipality are shown below.

Municipality	Investment Cost (million Col$)	O&M Cost (million Col$/year)	Municipality	Investment Cost (million Col$)	O&M Cost (million Col$/year)
Ubate	1,564.4	144.1	Fuquene	146.4	35.8
Cucunuba	190.0	43.8	Capellania	126.8	35.4
Lenguazaque	585.2	80.0	Susa	313.9	45.5
S. M. de Sema	188.1	43.4	Simijaca	939.9	56.7
C. de Carupa	265.2	44.6	Caldas	127.1	35.3
Tausa	444.0	35.9	Chiquinquira	1,887.1	101.8
Statausa	161.0	36.3	Saboya*	-	34.7
Guacheta	621.3	57.4	Total	7,561.0	831.0

*: No improvement of the existing treatment plant is required.

For details, see Appendix F, Chapter II, Subsection 2.2.5.

5.7.2 O&M Cost

The estimated annual O&M cost includes labor, fuel, electricity charge, repairing, management and other costs but excludes replacement cost of equipment.

The total annual O&M cost for all the sewerage treatment plants in the Study Area is estimated at 831.0 million Col$/year (0.43 million US$/year). The annual O&M cost by municipality is shown in the above table.

The total annual O&M cost for the improved industrial wastewater treatment plants (including slaughterhouse and factory) is estimated at 27 million Col$/year (0.014 million US$/year).

CHAPTER VI AQUATIC PLANT CONTROL OF THE LAKE

6.1 Historical Propagation of Aquatic Plants

6.1.1 Decrease of Water Surface Area

Aerial photos of the Lake have been taken 12 times since 1940 and They are available at the Geologic Institute "Agusti Codazzi". Among them, the latest is the one taken in 1993. The Study Team took a new aerial photo in May 1999 to analyze the aquatic plant propagation in the recent years.

Comparison of these aerial photos shows that the frontline of the aquatic plant areas (emergent, floating and floating leaf plants excluding submerged plants) has moved forward at a high speed. The frontlines of aquatic plants in the past were delineated by using the above mentioned aerial photos.

The historical reduction of water surface area or expansion of aquatic plant area are estimated as follows by adopting December 1940 as the base time. The historical propagation of the aquatic plants is shown in Fig. 6.1.

Date of Photos	Water Surface Area (ha)	Expanded Plant Area (ha)	Accumulated Plant Area (ha)
Dec.11, 1940	3,071	-	-
Jan. 27, 1955	2,806	265	265
Feb. 21, 1963	2,376	430	695
Jan. 04, 1978	2,211	165	860
Jan. 09, 1983	2,036	175	1,035
Feb.16, 1989	1,881	155	1,190
Dec.25, 1993	1,603	278	1,468
May 15, 1999	1,363	240	1,708

The water surface area of the Lake has decreased at a constant rate of 24.5 ha/year during 49 years of 1940-1989, while, the reduction speed has doubled to 50.4 ha/year after 1989. The historical reduction of the water surface area in the Lake is shown in Fig. 6.2.

6.1.2 Historical Propagation of Bulrush

An emergent plant, Bulrush (scientific name: *Scirpus Californicus*, local name: Junco) is considered to play a key role in the reduction of the lake area of Fuquene. Bulrush strikes roots into the lake bed in a permanent way and its stalks accelerate deposition of organic and non-organic materials, making the water depth shallower and finally, converting the littoral zone of the Lake to wetlands.

The existing Bulrush area in the Lake is estimated to be 842 ha, based on the interpretation analysis of the 1999 aerial photo. This area has expanded during 59 years of 1940-1999 at an average increasing rate of 14.4 ha/year. The increasing speed of Bulrush area can be roughly estimated by overlaying the existing Bulrush area on the historical propagation of aquatic plant areas as shown in Fig. 6.1. From this overlaid figure, the historical expansion of Bulrush area is calculated as below.

Period	Expanded Plant		Expanded Bulrush		(2)/(1)
	Area (ha) (1)	(%)	Area (ha) (2)	(%)	(%)
1940 – 1955	265	15.5	188	22.3	70.9
1955 – 1963	430	25.2	281	33.4	65.3
1963 – 1978	165	9.7	159	18.9	96.4
1978 – 1983	175	10.2	117	13.9	66.9
1983 – 1989	155	9.1	35	4.2	22.6
1989 – 1993	278	16.3	2	0.2	0.7
1993 – 1999	240	14.0	60	7.1	25.0
Total	1,708	100.0	842	100.0	49.3

As shown in the above table, the expanded aquatic plant area (165 ha) during 1963-1978 has been completely converted to Bulrush area (96.4%). The expanded aquatic plant areas during 1940-1955 and 1955-1963 are also considered to have been completely converted to Bulrush area. The aerial photo taken in 1999 did not identify Bulrush in some parts of the expanded plant areas during 1940-1955 and 1955-1963 because the Bulrush in such areas had already been replaced by pasture.

From the above discussions, it is concluded that the aquatic floating islands in 1978 has been completely converted to Bulrush growing areas in 20 years (1978 to 1999). Hence, the conversion time from the existing floating island to Bulrush is roughly estimated to be 20 years.

6.2 Existing Aquatic Plants

6.2.1 Species and Distribution of Aquatic Plants

(1) Species

The aquatic plants are classified in this Study into four (4) types: submerged, floating leaf, floating and emergent plants. Those in the Lake were surveyed in 1979, 1986, 1997 and 1999 (this Study). Number of the identified species in the above surveys are summarized below.

Type	1979	1986	1997	1999
Submerged	-	1	1	1
Floating Leaf	1	2	1	1
Floating	1	4	4	3
Emergent	6	10	7	12

The species of the existing aquatic plants in 1999 are listed below.

Type of Plants	Species
Submerged	*Egeria densa* (Brazilian Elodea),
Floating Leaf	*Potamogeton illionensis* (Pond Weed)
Floating	*Eichornia crassipes* (Water Hyacinth), *Lemna minor* (Duck Weed), *Azolla filliculoides* (Azolla)
Emergent	*Scirpus californicus* (Bulrush), *Typha angustifolia* (Cattail), *Bidens laevis*, *Cyperus rufus* (Bulrush), *Ludwigia peplides*, *Polygonum hydropiperoides*, *Myriophyllum acuaticum* (Parrot-feather), *Juncus bogotensis* (Bulrush), *Hydrocotyle ranunculoides*, *Pseudoraphis sp*., *Scripus sp*. (Bulrush), *Begonia cucullata* (Begonia)

Note: (   ): English Name

For the names of the species in the previous surveys, see Appendix G, Table G.2.3.

Among the above species, the most prevailing ones of each plant type are *Egeria densa* (English name: Brazilian Elodea) in submerged plant, *Potamogeton illionensis* (English name: Pond Weed) in floating leaf plant, *Eichornia crassipes* (English name: Water Hyacinth, Local name: Buchon) in floating plant and *Scirpus californicus* (English name: Bulrush, Local name: Junco) and *Typha angustifolia* (English name: Cattail) in emergent plant.

Brazilian Elodea has widely been noticed by the local people since the beginning of 1990's, however, it was already identified in the 1986 survey as *Ranunculus sp.* Pond Weed, Water Hyacinth, Bulrush and Cattail were already identified in the 1979 survey.

(2) Distribution

The existing aquatic plant areas by major species are estimated as follows, based on the interpretation of the aerial photo in 1999 and field survey.

Aquatic Plants	Area (ha)	(%)
Bulrush	842.2	52.8
Cattail	56.7	3.6
Water Hyacinth mixed with Other Floating Plants	545.7	34.2
Water Hyacinth mixed with Brazilian Elodea	151.2	9.5
Sub-total	1,595.8	100.0
Brazilian Elodea*	804.4	
Water Surface	558.8	
Sub-total	1,363.2	
Total	2,959.0	

In the above table, Brazilian Elodea* (804.4 ha) covers only the visible area on the water surface which was identified by the aerial photo. Further, an additional invisible area of 399.6 ha exists under the water.

The regional distribution of the above plants are shown in Fig. 6.3.

6.2.2 Characteristics of Aquatic Plants

The major aquatic plants in the Lake are Brazilian Elodea, Pond Weed, Water Hyacinth, Bulrush and Cattail. The characteristics of the above five (5) major plants are described below.

(1) Brazilian Elodea (submerged plant)

It is distributed over the lake area with a water depth of less than approximately 4.0 m. It hardly grows in the deeper area than 4.0 m due to the lack of photosynthesis effects. It covers approximately 90% (visible and invisible) of the total surface water area (about 1,400 ha) of the Lake. It does not exist in the inflow river, Ubate River; however, it is abundant in the outlet river, Suarez River. It reproduces by the spread of plant fragments or grows from the stems harvested by machine.

Branches sprout from "double nodes" located at intervals along the stems. Slender roots extend from the nodes located in the lower part of the stems to attach the bottom soils. Generally, it is about 1.0 m long, however in this Lake, it sometimes extends up to 3.0 m.

The stems are provided with dense bright green leaves. Length of the leaves is several centimeters. Small and white flowers bloom above the water surface.

(2) Pond Weed (floating leaf plant)

It takes roots into the bottom and grows up to the water surface in the shallower area than 4.0 m. It makes no large communities and coexists with Brazilian Elodea.

(3) Water Hyacinth (floating plant)

It floats in the water, forming islands and grows at a high speed. It propagates in the coastal and shallower lake area than 3.0 m, in the mouth of the Ubate River, and in the irrigation/drainage canals surrounding the Lake.

(4) Bulrush and Cattail (emergent plant)

They are perennial plants with a strong and cylindrical stalk. The stalk is erected and reaches a height of approximately 2.5-3.0 m. They are the most prevailing aquatic plants in the coastal or wetland areas of the Lake, coexisting with the other small emergent plants.

6.2.3 Biomass of Aquatic Plants

(1) Submerged Plant

The existing biomass of submerged plant (Brazilian Elodea) was estimated by a sampling measurement during late April to early May in 1999. The sampling measurement was done at 22 points with different water depths.

The biomass at each point was measured at two (2) portions: upper portion (water surface to 1.0 m depth) and lower portion (1.0 m depth to bottom). Density of the Brazilian Elodea decreases in inverse proportion to water depth as shown in Fig. 6.4. No significant quantity of Brazilian Elodea was identified in the water surface area with a water depth deeper than 4.0 m (below EL. 2,535.0 m). Further, there are no significant biomass under the emergent and floating plants. The average density of Brazilian Elodea by water depth is summarized below.

Water Depth (m)	Density (kg/m^2)		
	Upper 1.0 m	1.0m – Bed	Total
Less than 2.0	14.5	4.4	18.9
2.0 – 3.0 m	11.6	3.6	15.2
3.0 – 4.0 m	4.3	7.5	11.8
More than 4.0 m	0	0	0

The existing water surface area (including Elodea) is delineated as shown in Fig. 6.3. On the other hand, the water surface area by water depth is delineated by using the bathymetric map in 1984. The existing water surface area by water depth is calculated as follows by overlapping both figures. For the bathymetric map in 1984, see Appendix G, Fig. G.2.1.

Water Depth (m)*	Existing Water Surface Area (ha)
Less than 2.0	518
2.0 – 3.0	601
3.0 – 4.0	85
4.0 – 5.0	99
More than 5.0	60
Total	1,363

*: Water level is assumed at 2,539.0 m.

Then, the total quantity of Brazilian Elodea in the Lake is estimated to be 197,300 ton (wet weight) with the following breakdown.

Portion	Wet Weight (ton)
Upper 1.0 m	147,400
1.0 m - Bed	49,900
Total	197,300

(2) Floating Plant

The prevailing floating plant in the Lake is Water hyacinth. Most of Water hyacinth form floating islands together with various species of the other floating plants and emergent plants.

The sampling measurement for the biomass of floating plant was made at 20 plots of the floating islands. The biomass of Water hyacinth and other mixed plants were measured in wet weight.

The floating plants forming islands grow in the lake area with a water depth shallower than 3 m. The average biomass density of the total floating plants is estimated to be 109.11 kg/m^2.

On the other hand, the existing floating plant area is estimated to be 696.9 ha (see, Subsection 6.2.1). Accordingly, the total existing biomass of the floating plants is roughly estimated at 690,000 ton in wet weight as shown below.

Plant	Area (ha)	Density (kg/m^2)	Wet Weight (ton)
Water hyacinth with other floating/emergent plants	545.7	109.11	595,400
Water hyacinth with Elodea	151.2	62.75*	94,900
Total	696.9		690,300

*: Average density of Water hyacinth (109.11 kg/m^2) and Elodea (16.38 kg/m^2)

For details of the survey results, see Appendix G Table G.2.4.

(3) Emergent Plant

There are 12 species of emergent plant in the Lake of which two (2) tall emergent plants, Burlush and Cattail prevail. These two (2) tall emergent plants coexist with the other small emergent ones. Cattail usually grows offshore Burlush.

The sampling measurement of biomass was made at 20 plots for Burlush mixed with other small emergent plants and at 10 plots for Cattail mixed with other small emergent plants. The biomass was measured by dividing the following three (3) portions: (i) leafs/stems above water surface, (ii) leafs/stems under water, and (iii) roots.

Burlush mostly grows in the lake area shallower than 1.5 m, on the other hand, Cattail exists offshore Burlush with a water depth of 0.9 – 2.5 m.

The average biomass density of the two (2) emergent plants (mixed with other emergent plants) are shown below.

Plant	Biomass Density ((kg/m^2)			Total
	Leaf/Stem above Water Surface	Leaf/Stem under Water	Root	
Burlush	7.87	10.23	12.14	30.22
Cattail	8.46	8.60	90.65	107.70

The existing Burlush and Cattail areas are estimated to be 842.2 ha and 56.7 ha, respectively (see, Subsection 6.2.1). Accordingly, the total existing biomass of the emergent plants is roughly estimated at 315,600 ton in wet weight with the breakdown of Burlush (254,500 ton) and Cattail (61,600 ton).

For details of the survey results, see Appendix G, Table G.2.5.

6.2.4 Reproduction Test of Brazilian Elodea

Brazilian Elodea is reproduced by striking plant fragments into soil or by sprouting from the stems harvested by machine. Elodea of the Lake grows at a high speed. It is said to reproduce up to the original height in a short period when it is harvested, leaving roots and some portion of the stem on the lake bed.

A field experiment was tried for the purpose of analyzing the reproduction rates of Elodea after machine harvesting. The experiment started in mid-June, 1999 with the cooperation of CAR. The preliminary results are described below The experiment will be continued.

The reproduction experiment was done at the following five (5) locations: (A) northern fringe of Isla Santuario, (B) southern fringe of Isla Santuario, (C) near Isla Santuario, (D) near the mouth of Q. Monroy and (E) near the mouth of Naranjitos canal. The existing Elodea in each experimental location was harvested by machine at around 1.5 m in depth from the water surface, leaving roots and some portion of the stem on the lake bed. The experimental lots were not enclosed by protector and then, invasion of Elodea fragments from outside was allowed. The experiment started in June 7, 1999 for location (A), September 23, 1999 for location (B) and October 28, 1999 for locations (C), (D) and (E).

The interim results are summarized below.

Site	Water Depth (m)	Original Vol. (kg/m^2)	Initial Vol.* (kg/m^2)	Elapsed Time (day)	Measured Vol. (kg/m^2)	Reproduction Vol. (kg/m^2)
A	1.90	11.51	0.46	-	-	-
				78	0.53	0.07
				120	0.70	0.24
				199	2.36	1.90
B	2.55	14.29	0.81	-		
				97	5.44	4.63
C	2.50	(16.0)**	0.22	-	-	-
	1.90			63	0.22	0.00
D	2.54	(16.0)**	0.44	-	-	-
	1.91			63	4.00	3.56
E	3.10	(16.0)**	0.94	-	-	-
	2.60			63	4.44	3.50

*: Remained volume after harvesting, **: estimated

The reproduction rate varies from location to location. The average reproduction rates are roughly estimated to be 1.92 kg/m^2 (0.00 – 3.56 kg/m^2) during two (2) months and 2.38 kg/m^2 (0.12 – 4.63 kg/m^2) during three (3) months.

The experiments should be further continued to obtain the reproduction rate – time curve.

6.3 Existing Fish

There are four (4) species of fish in the Lake, among which two (2) are native and the others are exotic, as shown below.

Native	*Eremophilus mutisii, Grundulus bogotensis*
Exotic	*Cyprinus carpio, Carassius auratus* (Gold Fish)*

*: ( ): English Name

Salmo gairdneri (Trout) no longer exist in the Lake. They have shifted their habitats to the connecting rivers due to the water pollution/excessive aquatic plants in the Lake. In the Lake, Trout is only cultivated at the deepest part.

6.4 Control of Aquatic Plants

6.4.1 Necessity of Aquatic Plant Control

(1) Projection of Future Aquatic Plant Area

The future aquatic plant area of the Lake is projected as follows based on the analyses in Chapter II, Sub-section 6.1.1 and 6.1.2.

(a) The total aquatic plant area of the Lake (covering emergent and floating plant areas but excluding submerged plant area) has increased by 1,708 ha during 59 years of 1940 to 1999. The expansion speed during 1940-1989 was 24.5 ha/year on average, however, it has accelerated to 50.4 ha/year during the recent 10 years of 1989-1999.

(b) This expansion has always been initiated by formation of floating aquatic islands and thereafter, the floating islands have gradually been replaced by emergent plants. According to the interpretation of the historical aerial photographs, the expanded floating plants have completely been replaced by emergent plants after 20 years. Hence, all the existing floating plant areas are assumed to become the emergent ones after 20 years in the future.

(c) On the other hand, the habitat of emergent plants is limited to wet-lands or shallow water areas. They generally grow in the water areas of the Lake shallower than 1.5 m. According to the bathymetric map of the Lake in 1984, the lake area shallower than 1.5 m (measured from the elevation of 2,539.0 m) is estimated to be 1,603 ha. Hence, the emergent plant area in the water of the Lake will not exceed 1,603 ha in the future.

(d) The total emergent and floating plants area will reach 2,654.2 ha in 2020 if it continues expanding at a speed of 50.4 ha/year in the future. The emergent plants will cover 1,595.8 ha of the total area of 2,654.2 ha in 2020 if the existing floating plant area is completely replaced by emergent plants. Then, the remaining 1,058.4 ha will be floating plant area.

(e) The floating plants are assumed to increase at a constant growth rate every year, referring to a basic concept in the previous study report (see, Appendix G, Chapter III, Subsection 3.1.1). In the Lake, they increase at a high rate, but, some parts are replaced by the emergent plants every year. Then, they will increase from 696.9 ha in 1999 to 1,058.4 ha in 2020 at an apparent growth rate (net growth rate) of 2% per annum.

(f) The submerged plant area will decrease according to the propagation of the emergent and floating plants area.

Based on the above assumptions, the future aquatic plant distributions in 2010 and 2020 are estimated as below, compared with the existing one.

Classification	1999		2010		2020		Remarks
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	
Emergent Plant	898.9	30.4	1,284.0	43.4	1,595.8	53.9	Burlush, Cattail
Floating Plant	696.9	23.6	867.0	29.3	1,058.4	35.8	Water Hyacinth and others
Sub-total	1,595.8	54.0	2,151.0	72.7	2,654.2	89.7	Total aquatic plant area
Submerged Plant	1,204.0	40.7	649.0	21.9	145.6	4.9	Growing in water depth < 4.0 m
Pure Water Area	159.2	5.3	159.0	5.4	159.2	5.4	Water area deeper than 4.0 m
Sub-total	1,363.2	46.0	808.0	27.3	304.8	10.3	Total water surface area
Total	2,959.0	100.0	2,959.0	100.0	2,959.0	100.0	Total lake area

(2) Problems Caused by Excessive Aquatic Plants

The following major problems will be caused by the above-mentioned excessive growth of aquatic plants in the future.

(a) Reduction of Storage Capacity of the Lake

Aquatic plants remove water, resulting in reduction of storage capacity of the Lake and those in the shallow areas reduce the effective storage capacity. Reduction of the effective storage capacity of the Lake is estimated as follows, along with the existing area, average density and biomass of the aquatic plants in the Lake.

Plant	Area (ha)	Average Density (kg/m^2)	Total Biomass (ton)	Under Water Biomass (ton)	Reduced Effective Storage (m^3)*
Emergent	899	35.11	315,600	244,700	244,700
Floating	697	99.04	690,300	345,200	345,200
Submerged	1,204	16.38	197,300	197,300	147,400
Total	2,800		1,203,200	787,200	737,300

*: specific weight of aquatic plants is assumed to be nearly 1.0 ton/m^3.

In the above table, the underwater biomass of emergent plant is estimated by field observation. The underwater biomass of floating plant is assumed to be half of the total biomass since the lower portion of floating plants are submerged under water.

The underwater biomass of emergent plants is assumed to fully reduce the effective storage capacity since they grow in the shallow water areas. It is evident that the underwater biomass of floating plants fully reduces the effective storage capacity. With regard to submerged plants, the biomass in the upper layer of 1.0 m depth (75% of total biomass) is assumed to actually reduce the effective storage capacity. Reduction of the effective storage capacity at present is also shown in the above table.

Reduction of the effective storage capacity in the future (2020) is also estimated in the same way as the present. It is shown below.

Plant	Area (ha)	Average Density (kg/m^2)	Total Biomass (ton)	Biomass under Water (ton)	Reduced Effective Storage (m^3)*
Emergent	1,596	35.11	560,400	435,100	435,100
Floating	1,058	99.04	1,047,800	523,900	523,900
Submerged	146	16.38	23,900	23,900	17,900
Total	2,800		1,632,100	982,900	976,900

*: specific weight of aquatic plants is assumed to be nearly 1.0 ton/m^3.

As mentioned above, the effective storage capacity of the Lake will further decrease by 0.24 million m^3 by the year of 2020 due to the growing aquatic plants when no control measures are taken.

(b) Deterioration of Lake Water Quality

Excessive growth of aquatic plants makes the lake water anaerobic due to the following effects.

(i) Decomposition of withered aquatic plants consumes oxygen in the lake water.

(ii) Aquatic plants on the water surface block sunlight, resulting in the prevention of photosynthesis.

(iii) Aquatic plants on the water surface reduce natural aeration of the lake water (input of oxygen from the air to the lake water).

The lake water has already become anaerobic in the areas with densely growing aquatic plants, emitting a toxic substances of H_2S, especially under the floating islands. In such areas, the lake water is colored black and emits bad odor. Further, the entire lake deposits are under anaerobic condition. See, Chapter V, Subsection 5.1.3.

The water quality will further worsen in the future according to the growth of aquatic plants. It will cause fatal damages not only on the aquatic lives in the Lake but also on the water uses in the surrounding areas.

Such deteriorated lake water may not allow benthos, fishes and other aquatic lives at all. Treatment of such water for human use may not be difficult, however, groundwater recharged from the Lake may decay roots of the pastures in the surroundings of the Lake.

(c) Blocking of Water Flow

Excessive aquatic plants in the Lake block the outlet of the Lake and those in the Suarez River also block the water flow in the River. This blocking may result in flood damage to the low areas surrounding the Lake and damage to the water uses downstream of the Suarez River.

6.4.2 Possible Control Measures

The following five(5) control measures are enumerated as the possible ones: (i) Reduction of inflow nutrients, (ii) Dredging of the lake bed, (iii) Harvesting of submerged plants, (iv) Removal of floating plants, and (v) Aquatic plant control by grass carp.

(1) Reduction of Inflow Nutrients

Aquatic plants grow up by absorbing various kinds of nutrients from the bed soil and water through the roots, stems and leaves. Nitrogen (N) and phosphorus (P) are the most essential nutrients. The Lake is currently much eutrophicated and contains a large quantity of N and Col$ in the water and bed deposits as shown below.

Item	N	P
Average Water Quality (mg/l)	1.83	0.07
Average Bed Deposit Quality (mg/dry-kg)	4,600	150

However, reduction of the inflow nutrients (N, P) to the Lake is not considered effective as described below although the cut of nutrient sources may theoretically curb the growth of aquatic plants.

(a) Most of the inflow nutrients (N, P) to the Lake come from the non-point sources including livestock, lands (farmland, pasture and shrub/forest) and households in rural area. Those from the point sources of sewerage and industries are limited. Percentage of the existing annual inflow of nutrients by source are shown below (see, Chapter V, Table 5.9).

Pollutant Source	N (%)	P (%)
Sewerage	22.9	21.4
Industry	0.8	1.5
Livestock	60.5	75.5
Land	15.7	1.6
Household	0.1	0.0
Total	100.0	100.0

Currently, there is no practical way to control N and P of the livestock and lands. Treatment of N and P in the above sewerage and factories is technically possible. However, it requires a large cost and is considered economically infeasible.

(b) Highly concentrated nutrients (N, P) are accumulated in the deposits of the entire lake bed. The lake bed has a large nutrient potential sources which can supply nutrients to aquatic plants for a long time.

(c) Aquatic plants grow even in an oligotrophic lake.

(2) Dredging of the Lake Bed

Dredging of the lake bed will decrease the photosynthesis capacity of Elodea. The lake bed must be dredged to maintain the water depth of more than 4 m to completely control the growth of Elodea. The required dredging works covers 1,900 ha (lake area shallower than 4.0 m excluding emergent plant area) and an earth volume of 43 million m^3.

Hence, the possible dredging will be limited to such critical areas as the front zone of Bulrush.

Dredging of the front-zone of Bulrush may contribute to the control of the expansion of Bulrush area since its habitat is usually limited to the wetlands or shallower water areas than 1.5 m.

(3) Harvesting of Submerged Plants

CAR and Cundinamarca Prefecture are currently harvesting Elodea by machines every day. The machines harvest only the upper portion of Elodea (1.5 m from the water surface), leaving the lower part of stems and roots on the lake bed. As a result, Elodea is said to reproduce itself to the original conditions in a short period after the harvesting.

This harvesting is endless. Besides, CAR and Cundinamarca Prefecture are troubled with disposal of the harvested Elodea. Use of the harvested Elodea is considered to be the key for the successful implementation of this control measures.

According to the questionnaire survey, approximately 50% of the total number of farmers in the Study Area are interested in using Elodea as fertilizer. Then, use of the harvested Elodea as green fertilizer for the pasturelands surrounding the Lake or as compost for the farmlands is considered to be one of the most possible uses.

(4) Removal of Floating Plants

The total existing floating plants (mainly Water hyacinth) cover approximately 700 ha which mostly form compacted floating islands. The floating islands are extending at a high rate.

Removal of these floating plants is also urgent. However, an adequate disposal system of the removed floating plants should be developed since the required disposal quantity is large. Composting of the removed floating plants for agricultural use is considered to be the most possible disposal system.

(5) Aquatic Plant Control by Grass Carp

The Grass Carp (*Ctenopharyngodon idellus*) is indigenous to those rivers of North Vietnam, China and Russia that flow into the Pacific Ocean. It has been introduced into more than 50 countries throughout the world for aquatic plant control and fish cultivation.

The grass carp is polyphagous, however, it prefers aquatic plants. It can live in a wide range of water temperature (0-35 ℃). It grows faster and eats more grasses under warm water. An adult grass carp is said to usually consume the same weight of grasses as the body weight per day.

The aquatic plant control, especially the control of Elodea, in the Lake Fuquene by grass carp is considered effective. However, efficiency of the control is uncertain because the water temperature of the Lake is not warm enough. The growth rate and food consumption rate of a grass carp in the Lake Fuquene is estimated through a field experiment as described in the following Section.

6.4.3 Field Experiment of Aquatic Plant Use and Grass Carp

(1) Experiment for Use of Elodea as Green Fertilizer

(a) Experimental Methodology

A field experiment was conducted for approximately eight (8) months during late May, 1999 to mid-January, 2000 with the cooperation of CAR. The experiment was performed for the following two (2) experimental lots with different kinds of soils, located on the western coastal plain of the Lake nearby the port.

Lot	Condition
Block-1	High content of organic matter (higher than 9%)
Block-2	Low content of organic matter (less than 2%)

For each experimental lot, the following five (5) cases of experiments were conducted.

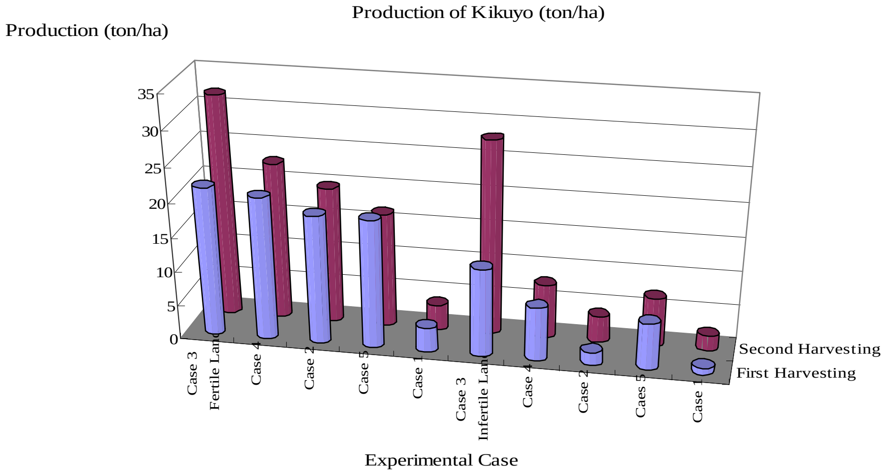
Case	Condition
1	Covered with 75 cm thick Elodea
2	Covered with 50 cm thick Elodea
3	Covered with 25 cm thick Elodea
4	Chemical fertilizer only
5	Neither Elodea nor chemical fertilizer

The results of the experiments were evaluated in terms of the production of pasture (species: Kikuyo) per unit land area.

Green fertilizer of Elodea decomposes, improving soil conditions slowly over a long period. Generation of the effects as fertilizer is slow, different from chemical fertilizer. Therefore, the effects of Elodea as green fertilizer were confirmed through two (2) stages of pasture harvesting.

(b) Results of the Experiment

The unit productions of pasture in the two (2) harvesting stages are shown below.



(c) Evaluation of the Experimental Results

(i) Case-3 was more efficient than Case-1 and Case-2. The pasture production of Case-1 and Case-2 were delayed probably due to blocking of sunlight from pasture since Elodea thickly covered the pasture.

(ii) In the fertile land, the pasture production of Case-3 was nearly the same as that of Case-5 in the first harvesting. However, it was two (2) times of Case-5 in the second harvesting. It means that the green fertilizer may display the effects slowly.

(iii) In the infertile land, the effects of the green fertilizer were much larger than those in the fertile land. The production of Case-3 was two (2) times of Case-5 in the first harvesting and four (4) times in the second harvesting.

(iv) The green fertilizer of Elodea increases the pasture production to a considerable extent. The production increase is larger in infertile land than in fertile land. However, the green fertilizer use of Elodea may be limited to the surrounding fertile pasturelands of the Lake since the infertile lands are mostly distant from the Lake.

(v) More experimental studies are considered necessary to conclude the effectiveness of the Elodea green fertilizer for the fertile lands around the Lake.

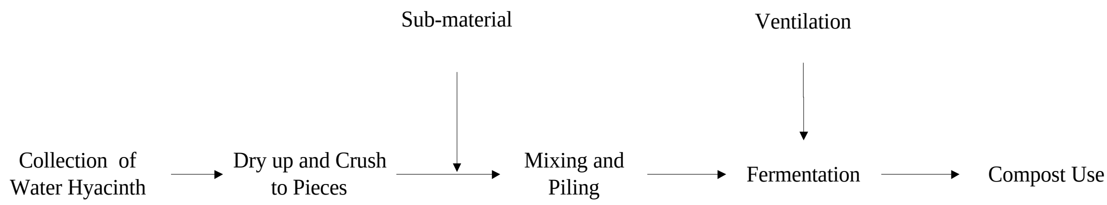
For details, see Appendix E, Chapter III, Subsection 3.3.1.

(2) Experiment for Composting Aquatic Plants

(a) Experimental Methodology

Compost of aquatic plants has been used in many countries as fertilizer and soil conditioner. It is generally said suitable for flower and green vegetables (spinach, lettuce, etc.) due to their requirement of comparatively little nutrients

(N, P). The compost is usually produced through the following processes.



The experiment was conducted for three-and-a-half (3.5) months, i.e., early September 1999 to mid December 1999 near the port of Lake Fuquene with the cooperation of CAR.

The experiment was performed for Elodea, Water hyacinth and Burlush with various quantities of sub-materials. Cow dung was used as sub-materials. The actual composting test started after the harvested aquatic plants had been naturally dried during 10 days.

(b) Results of the Experiment

(i) Chemical Characteristics of Aquatic Plants

Chemical characteristics of the aquatic plants are analyzed as follows.

(Dry Weight)

Item	Unit	Elodea	Water Hyacinth	Bulrush
Moisture Content	(%)	92.2	91.0	76.9
Ash Content	(%)	20.8	16.8	7.4
N	(%)	2.85	1.84	1.03
P	(%)	0.23	0.13	0.05
N/P Ratio	-	12.4	14.2	20.6
K	(%)	2.81	1.91	0.97

Heavy metal is negligible.

(ii) Reduction Rate of Volume and Weight

The volume and weight of the aquatic plants were reduced as shown below through the composting process.

Item	Aquatic Plant	At Initial Time of Composting (%)	At Completed Time of Composting (%)
Volume	Elodea	100	22
	Water hyacinth	100	45
	Bulrush	100	78
Weight	Elodea	100	32
	Water hyacinth	100	57
	Bulrush	100	46

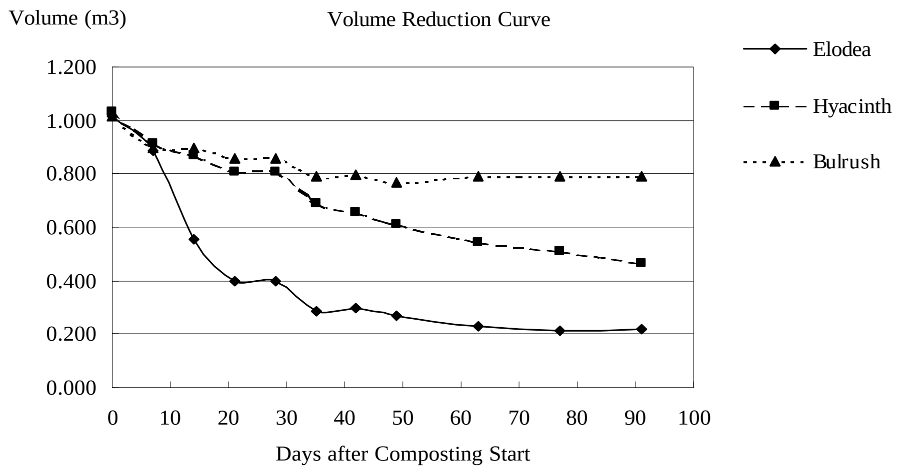
Note: Initial time: 10 days after harvested time.

(iii) Required Composting Period

Further, the volume reduction curves of the three (3) aquatic plants are shown in the following figure.

As shown in the figure bellow, reduction of the volume of Elodea finished in 70-80 days after the start of composting. It means that decomposition of Elodea was almost completed during this period. However, the volume of Water hyacinth was still under reduction even at the final stage of this composting experiment. It will require more time to attain a satisfactory decomposition.

On the other hand, reduction of the volume of Bulrush finished in 30 days after the start of composting. The reduction rate is small and no more decomposition is expected. It is considered due to its high fibrous characteristics.



(c) Conclusion

The following conclusions can be reached from the above field experiment and previous experiences in Japan and other countries.

(i) Compost of Elodea and Water hyacinth can be produced in the Study Area regardless of the low atmospheric temperature. However, composting of Bulrush is difficult.

(ii) Composting of Elodea and Water hyacinth can be completed within three (3) months and five (5) months, respectively.

(iii) Sufficient preparatory works of crushing/squeezing of aquatic plants before composting works will further reduce the initial compost weight/volume and required composting period. A large piling of compost raw materials will generate a higher inner temperature than the small scale experiment of this time, resulting in further reduction of the composting period.

(iv) Compost production of Elodea and Water hyacinth to satisfy the standard quality of the Colombian Agriculture and Livestock Institute (ICA) is possible. Only the concentration of phosphorus (P) is smaller than the standard, however, this shortage can be met by adding a little chemical fertilizer with a high concentration of P. The concentration of heavy metal is very small compared to the standards.

For details, see Appendix E, Chapter III, Subsection 3.3.2.

(3) Experiment for Aquatic Plant Control by Grass Carp

(a) Experimental Methodology

For the experiment, sterile triploid grass carps with a chromosome number (3N) were imported from USA with permission of the Ministry of Environment. After quarantine of the National Agricultural and Livestock Planning Institute (INPA), they were released into the experimental cage and yard in October 11, 1999. The experiment is being done for the following two (2) cases with cooperation of CAR.

(i) Experiment in Cage

One (1) floating cage made of nets was installed nearby the Isla del Santuario. The water area at the site is 6.0 m deep with no growing aquatic plants.

This experiment is being done to analyze the characteristics of grass carp such as sequence of food preference, growth rate, grass consumption rate, disease, etc. The above consumption rate and growth rate will increase with elapse of time. Therefore, the experiment is scheduled to be continued for more than two (2) or three (3) years.

(ii) Experiment in Yard

Four (4) experimental yards were set up on a shallow site (water depth: 2.0 m) nearby the Isla del Santuario where Brazilian Elodea densely grows. Each yard is enclosed by nets.

This experiment is being done to establish the growth rate of grass carp and consumption rate of Elodea under the existing natural conditions. The grass consumption rate is measured by harvesting the remaining Elodea in the yard. The experiment started with the first yard. The experiment will be continued by shifting the grass carps to the second yard and thereafter, to the third and fourth yards in every measurement time.

These experiments will be continued for more than two (2) or three (3) years since the growth rate and consumption rate will increase with the elapse of time.

(b) Records of the Experiment

(i) Experiment in Cage

Small 271 fingerlings with an average size of 10.0 cm (16.0 g) were released into the cage in October 11, 1999.

Thereafter, 49 fishes were dead during the period of November 8 to November 25. Therefore, the remaining fishes except one (1) fish were returned to the quarantine tank of the Lake Neusa. Further, 37 fishes were dead immediately after the transfer to the Lake Neusa. Soon after, the alive 184 fishes were returned to the experimental cage in the Lake Fuquene again. On the other hand, the one (1) fish left in the Lake Fuquene is still alive.

(ii) Experiment in Yard

Comparatively large 259 fingerlings with an average size of 15.0 cm (75.0 g) were released into the first yard in October 11, 1999. Out of 259 fishes, 62 fishes were dead until December 7, 1999.

The growth rate and Elodea consumption rate of grass carps were measured in January 11, 2000. Immediately after the measurement, 30 fishes were dead. Then, 167 fishes are alive at present in the experimental yards: 98 fishes in the second yard and 67 fishes in the first yard.

As mentioned above, a considerable number of grass carp fingerlings have been dead. The cause of death was checked in the quarantine tank of Lake Neusa. However, no serious disease has been recognized. Then, this may be attributable to the following reasons.

(i) Abnormally high turbidity of the lake water caused by the flood occurred during November. The flood is reportedly the biggest in the recent history.

(ii) Experimental measurements shocked and weakened them to death.

(c) Estimated Growth and Consumption Rate

In January 11, 2000, size and weight of the grass carps in the first yard were measured. The results are shown below, compared to those at the starting time of the experiment.

Date	Average Size (cm)	Average Weight (g)
Oct. 11, 1999	15.0	75.0
Jan. 11, 2000	20.5	95.3

In the same day, the consumed Elodea was estimated to be 1,248 kg by harvesting the remained Elodea in the experimental yard.

From the above data, the average unit consumption rate during three (3) months of October 11, 1999 to January 11, 2000 is estimated to be as follows.

Unit Consumption Rate = 1,248 kg / 90 days / 197 fishes = 70 g/day/fish

It is generally said that an adult grass carp eats as much grass as its body weight every day if sufficient favorite grass is available and young one eats more. The above consumption rate of the experiment is considered reasonable, taking into consideration the disadvantage of low water temperature in the Lake.

The experiment must be further continued to reach the final conclusion of unit consumption rate of Elodea. However, control of Elodea by grass carp is considered possible.

6.4.4 Selection of Optimum Use of Aquatic Plants

(1) Use of Harvested Submerged Plants (Elodea)

Three (3) alternative uses of Elodea, (i) green fertilizer use for pastureland, (ii) compost use for flower farming, and (iii) compost use for potato cultivation are compared as follows.

(a) Green Fertilizer Use for Pastureland

In this case, the harvested Elodea is used as green fertilizer for the pastureland in the surrounding areas of the Lake. The required works include harvesting by machine, transportation by boat and unloading at the shore. It is assumed that the farmers will transport the unloaded Elodea to their pasturelands from the nearest unloading site by themselves.

The required cost is estimated to be 15,300 Col$/ton in wet weight.

The green fertilizer of Elodea may produce a considerable effects on the growth of pasture. However, it is doubtful that the farmers are willing to share the harvesting cost of Elodea at this moment. Then, all the cost is assumed to be borne by CAR in this Study.

(b) Compost Use for Flower Farming

Compost is currently used for flower farming. The existing area of flower farming is approximately 4,000 ha in the metropolitan area of Bogota (mainly Zipaquira region). Therefore, the potential compost demand in those areas is roughly estimated at 260,000 ton/year. The present market price of this compost is 140,000 Col$/ton.

Feasibility on the use of composted Elodea for the flower farming is studied as follows.

The nutrient contents of the above-mentioned compost are shown below compared with those of Elodea.

Component	Compost being Used (%)	Elodea (%)	
	Compost Weight	Dry Weight	Compost Weight
Humidity	29.92	0.00	30.00
T-N	0.82	2.85	2.00
T-P	0.40	0.23	0.16
K	1.52	3.39	2.37

The compost made of Elodea is sufficient in T-N and K but short of T-P. Therefore, some additive is necessary to supplement T-P of Elodea compost. Twelve (12) kg of the chemical fertilizer (Di-ammonium Phosphate) need to be added to the Elodea compost per ton.

The unit production cost of Elodea compost including harvesting, composting, land transportation (Lake – Zipaquira: 60 km) and additive costs is estimated at 187,200 Col$/ton in compost weight. For the breakdown of the cost, see Appendix G, Chapter III, Subsection 3.4.1.

(c) Compost Use for Potato Cultivation

In this case, the composted Elodea is used for potato cultivation as an alternative of chemical fertilizer. Approximately 17,000 ha of potato is cultivated in the hilly areas of the Study Area. However, the farmers usually use chemical fertilizer for this potato cultivation at present.

The chemical fertilizer currently used for potato cultivation has very high nutrient contents compared to those of Elodea as shown below.

Component	Chemical Fertilizer (%)	Elodea (%)	
	Dry Weight	Dry Weight	Compost Weight
Humidity	0.00	0.00	30.00
T-N	15.00	2.85	2.00
T-P	6.54	0.23	0.16
K	12.45	3.39	2.37

As shown in the table above, 7.5 tons of Elodea compost is necessary to provide the same quantity of T-N as contained in one (1) ton of chemical fertilizer. Further, 267 kg of chemical fertilizer (Di-ammonium Phosphate) need to be added to supplement T-P.

The cost of Elodea compost (7.5 ton) required to substitute for chemical fertilizer of one (1) ton is estimated at 1,456,350 Col$. In this cost estimate, the transportation distance is assumed to be 40 km between Lake Fuquene and major potato cultivation area. For the breakdown of the cost, see Appendix G, Chapter III, Subsection 3.4.1.

On the other hand, the market price of one (1) ton of chemical fertilizer currently used for potato cultivation is estimated at 534,000 Col$/ton on farm gate.

As evident from the above cost comparison, the use of Elodea compost as an alternative of chemical fertilizer is economically infeasible. Further, farmers need 7.5 times labor force in fertilization works compared to chemical fertilizer.

(d) Conclusion

As discussed above, compost use for potato cultivation is definitely infeasible. Then, green fertilizer use and compost use for flower farming are compared so that CAR can select the optimum one from the viewpoint of cost.

The unit production cost of compost for flower farming at the market place (including transportation cost to Zipaquira) is estimated to be 187,200 Col$/ton (compost weight). Out of the above production cost, the compost production company can bear 112,000 Col$/ton (compost weight) if the company's profit is assumed at 20% of the market price at Zipaquira (140,000 Col$/ton compost weight). In this case, CAR must bear the remaining cost of 75,200 Col$/ton (compost weight), equivalent to 10,700 Col$/ton (wet weight).

On the other hand, CAR must bear 15,300 Col$/ton (wet weight) for the use of green fertilizer as mentioned before.

From the above comparison of cost to be borne by CAR, compost use for flower farming is cheaper than green fertilizer.

(2) Use of Removed Floating Plants (Water hyacinth)

It is considered difficult to use Water hyacinth as green fertilizer for the surrounding pasturelands of the Lake since Water hyacinth contains much cellulose which is not easily decomposed. Then, two (2) alternative uses, (i) compost use for flower farming and (ii) compost use for potato cultivation are compared as follows.

(a) Compost Use for Flower Farming

The nutrient components of Water hyacinth are compared with those of the compost currently used for flower farming as follows.

Component	Compost being Used (%)	Water hyacinth (%)	
	Compost Weight	Dry Weight	Compost Weight
Humidity	29.92	0.00	30.00
T-N	0.82	1.84	1.29
T-P	0.40	0.13	0.09
K	1.52	2.30	1.61

The compost of Water hyacinth is also sufficient in T-N and K but short of T-P. Then, 15.5 kg of chemical fertilizer (Di-ammonium Phosphate) needs to be added to supplement T-P.

The islands of Water hyacinth are removed in a different way from Elodea. They are cut into several pieces by cutting equipment and trawled by boat to the port.

The unit production cost of Water hyacinth compost including removal, composting, transportation (Lake – Zipaquira: 60 km) and additive costs is estimated at 110,100 Col$/ton in compost weight. For the breakdown of the cost, see Appendix G, Chapter III, Sub-section 3.4.2.

(b) Compost Use for Potato Cultivation

Studied below is the use of the composted Water hyacinth for potato cultivation as an alternative of chemical fertilizer.

The chemical fertilizer currently used for potato cultivation has very high nutrient contents compared to those of Water hyacinth as shown below.

Component	Chemical Fertilizer (%)	Water hyacinth (%)	
	Dry Weight	Dry Weight	Compost Weight
Humidity	0.00	0.00	30.00
T-N	15.00	1.84	1.29
T-P	6.54	0.13	0.09
K	12.45	2.30	1.61

As shown in the table above, 11.6 tons of Water hyacinth compost is necessary to provide the same quantity of T-N contained in one (1) ton of chemical fertilizer. Further, 275 kg of chemical fertilizer (Di-ammonium Phosphate) need to be added to supplement T-P. This case is definitely less economical than the case of Elodea.

From the above discussions, compost use for flower farming is recommended.

6.5 Proposed Aquatic Plant Control Plan

6.5.1 Dredging of the Lake Bed

Dredging of the front zone of Bulrush is proposed to stop the expansion of Bulrush. The following priority dredging zones are selected based on the analyses of the aforementioned historical expansion of Bulrush. For location of the dredging zones, see Fig. 6.5.

Dredging Zone	Dredging Distance (km)
(1) Eastern Coastal Area of Isla del Santuario	3
(2) East-north Bay Area	3
(3) Eastern and Western Coastal Areas of Suarez River Outlet	3
(4) Eastern and Western Coastal Areas of Ubate River Mouth	3

The proposed dredging works are summarized below.

Item	Quantity	Remarks
Dredging Zone Distance	12,000 m	
Dredging Width	20 m	
Dredging Depth	2.0 m	Water Depth: 3.0 m, Datum Water Level: 2,539 m
Dredging Volume	480,000 m^3	

In this Study, the excavated soil is assumed to be dumped on the neighboring pasturelands, especially the low-lying lands prone to habitual inundation. This land reclamation will release some places from flood problems. The land reclamation area is roughly estimated to be approximately 50 ha when the reclamation depth is assumed at 0.3-0.5 m.

However, a pilot project is considered necessary prior to the proposed full scale dredging project to confirm the effectiveness of the dredging. The pilot project will check the following subjects: (i) effectiveness to stop the expansion of Bulrush, (ii) refilling of the dredged site, (iii) topographic deformation of the surrounding lands, and (iv) recovery of land use of the soil dumping site.

The pilot project will be performed at some location in the neighboring areas of the Ubate River mouth. The dredging works of the pilot project are shown below.

Item	Quantity	Remarks
Dredging Zone Distance	300 m	
Dredging Width	20 m	
Dredging Depth	2.0 m	Water Depth: 3.0 m, Datum Water Level: 2,539 m
Dredging Volume	12,000 m^3	

6.5.2 Harvesting/Removal and Composting of Aquatic Plants

(1) General

The existing submerged plants (Elodea) and floating plants (Water hyacinth) are harvested or removed along with control by grass carp. The harvested Elodea and removed Water hyacinth are composted for the use of flower farming.

To complete the use of aquatic plants, the following four (4) stages of work are necessary: (i) harvesting/removal of aquatic plants, (ii) composting of harvested/removed aquatic plants, (iii) transportation of compost to farmland, (iv) spreading of compost on farmland including adding additives. The former two (2) stages of work, harvesting/removal and composting of aquatic plants are included in this aquatic plant control project. However, the latter two (2) stages of work are excluded from this project and they will be implemented by farmers themselves.

Technical viability on the use of Elodea and Water hyacinth composts for flower farming was confirmed based on the field experiment and previous studies. However, some pilot project may be necessary prior to the implementation of full scale project so that farmers can actually accept the Elodea and Water hyacinth composts for flower farming.

(2) Harvesting/Removal of Aquatic Plants

(a) Removal of Water hyacinth

Water hyacinth is extending at a high rate. On the other hand, it is being replaced by Bulrush in some parts. Then, Water hyacinth area is assumed to increase at 2% per year in case of without project. However, it is assumed to increase at 4.5% per annum after completion of the proposed dredging due to stop of the replacement by Bulrush. See, Appendix G, Chapter IV, Subsection 4.1.2.

Under these circumstances, the project aims to decrease Water hyacinth to approximately 50% of the existing one by 2010 (target year of this master plan study) and nearly zero in 2015. For this purpose, annually, 5 ha (5,000 ton in wet weight) and 75 ha (75,000 ton in wet weight) of Water hyacinth will be mechanically removed by the pilot project and full scale project, respectively. Control by grass carp is not considered since grass carp does not like Water hyacinth so much.

The removal works consists of cutting floating islands by equipment, trawling by boat to port and unloading at port.

(b) Harvesting of Elodea

According to the field experiments, the reproduction rate of Elodea after machine harvesting was still small during the experiment period (2-6 months). However, the reproduction rate is considered to make a rapid increase after the plant grows to a certain height where sufficient sunlight is available. In this Study, it is assumed to recover the original biomass one (1) year after machine harvesting.

Elodea is considered to immediately die when covered by Bulrush or Water hyacinth and to soon reproduce when Bulrush or Water hyacinth are removed. Then, Elodea area will increase or decrease according to the change of Bulrush/Water hyacinth covering area in the future.

It may be possible to control all the Elodea by only grass carp if the consumption rate of grass carp is large enough. However in this Study, a combination of machine harvesting and grass carp is proposed to control Elodea since the consumption rate in Lake Fuquene is not still clear.

Approximately 20% of the existing Elodea will be harvested by machine and the remaining Elodea will be controlled by grass carp. For this purpose, annually, 30 ha (5,000 ton in wet weight) and 240 ha (38,000 ton in wet weight) of Elodea will be harvested by machine by the pilot project and full scale project, respectively.

The harvesting works consist of harvesting by machine, transportation by boat to port and unloading at port.

(3) Compost Production of Aquatic Plants

The humidity of the produced compost is assumed at 30%. Then, one (1) ton of compost is produced from seven (7) tons of raw aquatic plants. Annually, 1,400 ton and 16,100 tons of compost will be produced from the harvested Elodea and removed Water hyacinth in the pilot project and full scale project, respectively, as shown below.

Project	Item	Harvested/Removed Plants (ton/year in wet weight)	Produced Compost (ton/year in compost weight)
Pilot	Elodea	5,000	700
	Water hyacinth	5,000	700
	Total	10,000	1,400
Full Scale	Elodea	38,000	5,400
	Water hyacinth	75,000	10,700
	Total	113,000	16,100

The required net compost yard area for Elodea and Water hyacinth is estimated at 31,700 m^2 based on the following assumptions.

(a) Piling height of raw materials: 3.0 m

(b) Composting period: three (3) months for Elodea and five (5) months for Water hyacinth

Then, 16 compost stock bins with each size of width (50 m) x length (40 m) x height (3 m) are proposed. The required gross compost yard is estimated to be 45,000 m^2.

For the assumed physical and chemical properties of compost, see Appendix G, Chapter IV, Subsection 4.1.2

6.5.3 Control by Grass Carp

(1) Elodea Consumption of Grass Carp

Grass carp is generally said to consume grass as much as its own body weight per day. On the other hand, the growth rate of grass carp varies depending on the water temperature. Dr. Yoshio Sakurai assumed the average growth rate of grass carp in Japan (see Appendix G, Chapter III, Subsection 3.2.5). In this Study, the growth rate of grass carp in Lake Fuquene is assumed to be half of that in Japan, taking into consideration the comparatively low water temperature of Lake Fuquene. The assumed growth rate is shown below.

Age (year)	1	2	3	4	5	6	7	8	10	20
Body Weight (kg)	0.3	1.5	3.0	4.5	6.0	7.5	9.0	10.0	10.0	10.0

The existing Elodea will be removed by grass carp together with machine harvesting. For this purpose, 44,000 fingerlings of grass carp will be released into the Lake.

(2) Construction of Fish Barrier

A fish barrier will be constructed in the upper reaches of the Suarez River to block the grass carps swimming downward from the Lake. Usually, the following two (2) kinds of fish barriers are employed: (i) Net with solid waste removal screen and (ii) Electrical fish barrier.

Net with solid waste removal screen is considered unpractical, taking into consideration the large quantity of floating aquatic plants in the river. An automatic solid waste removal equipment needs to be installed, resulting in a large cost requirement. Further, it may dam up the river water when lacking in proper maintenance.

Hence, electrical fish barrier is proposed in this Study. This system consists of two (2) or more metal electrodes (plus and minus) installed in water with a voltage applied between them. Electric current passing between the electrodes, via the water medium, produces an electric field in the river section. This electric field gives a shock to the fishes which try to pass through the electric field. Hence, fishes do not approach or enter the electric field.

This electrical fish barrier has been developed and applied in many countries: Japan, USA, France and others, to block or guide fish swimming direction.

6.5.4 Controlled Aquatic Plant Area

The aquatic plant area in the Lake will be controlled by the proposed projects to a large extent. The future aquatic plant area with project is shown below compared to the area without project

(unit: ha)

Case	Aquatic Plant	1999	2005	2010	2015	2020
Without Project	Bulrush	899	1,113	1,284	1,446	1,596
	Water hyacinth	697	785	867	957	1,058
	Elodea	1,204	902	649	398	146
	Total	2,800	2,800	2,800	2,800	2,800
With Project	Bulrush	899	1,113	1,284	1,284	1,284
	Water hyacinth	697	694	376	58	0
	Elodea	1,204	602	Negligible*	214	272
	Total	2,800	2,409	1,660	1,556	1,556

*: Elodea will increase according to the decrease of Water hyacinth. Elodea consumption of grass carp will increase year by year. The balance of Elodea will become the minimum in this year.

The aquatic plant area with project varies depending on the implementation schedule of each component project. Then, the above estimation is made based on the following assumed schedule.

(1) Dredging will be completed by 2010

(2) Harvesting/Removal and Composting of Aquatic Plants

Pilot project will be performed during 2001-2003 and actual operation of full scale project will start in 2005.

(3) Grass carps will be released in 2003.

Further, in the above estimation of area, the Elodea biomass consumed by grass carp is converted into the equivalent area by assuming the density of Elodea as 16 kg/ m^2.

For details, see Appendix G, Table G 4.1 and Table G 4.2.

6.6 Project Cost for Aquatic Plant Control

6.6.1 Investment Cost

The investment cost for the proposed projects is estimated based on the same assumptions as given in Chapter III, Section 3.8 (Project Cost for Improvement of Water Resources and Use Management System).

The total investment cost for the aquatic plant control is estimated to be 30,938.3 million Col$ (16.12 million US$) as of October, 1999 with the following breakdown.

(1) Dredging of Lake Bed

The investment costs of the pilot and full scale projects are estimated as follows.

(unit: million Col$)

Item	Pilot Project	Full Scale Project	Total
Direct Construction	320.4	12,816.0	13,136.4
Land Acquisition*	2.0	89.0	91.0
Engineering /Administration	64.5	2,581.0	2,645.5
Physical Contingency	32.2	1,291.0	1,323.2
Total	419.1	16,777.0	17,196.1
Total (million US$)	(0.22)	(8.74)	(8.96)

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (Oct. 1999), *: Land compensation for soil dumping

(2) Harvesting/Removal and Composting of Aquatic Plants

The investment costs of the pilot and full scale projects are estimated as follows.

(unit: million Col$)

Item	Pilot Project	Full Scale Project	Total
Direct Construction	1,102.0	8,221.3	9,323.3
Procurement of Equipment	603.0	5,472.3	6,075.3
Compost Yard Construction	499.0	2,749.0	3,248.0
Land Acquisition	24.0	111.0	135.0
Engineering /Administration	164.9	1,119.2	1,284.1
Physical Contingency	112.6	833.2	945.8
Total	1,403.5	10,284.7	11,688.2
Total (million US$)	(0.73)	(5.36)	(6.09)

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (Oct. 1999)

(3) Aquatic Plant Control by Grass Carp

The investment costs of the project are estimated as follows.

(unit: million Col$)

Item	Investment Cost
Direct Construction	1,580.0
Installation of Fish Barrier	730.0
Procurement of Grass Carp	850.0
Land Acquisition	-
Engineering /Administration	316.0
Physical Contingency	158.0
Total	2,054.0
Total (million US$)	(1.07)

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (Oct. 1999)

6.6.2 O&M Cost

The estimated annual O&M cost includes labor, fuel, electricity charge, repairing, management and other costs but excludes replacement cost of equipment.

The total annual O&M cost for the aquatic plant control is estimated to be 1,059.6 million Col$/year (0.56 million US$/year) at full operation time. It is broken down as follows.

(1) Dredging of Lake Bed

No O&M cost is necessary.

(2) Harvesting/Removal and Composting of Aquatic Plant

The annual O&M costs of the pilot and full scale projects are estimated as follows.

(unit: million Col$/year)

Item	Pilot Project	Full Scale Project
Harvesting/Removal	110.2	526.6
Composting	99.8	483.0
Total	210.0	1,009.6
Total (million US$/year)	(0.11)	(0.53)

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (Oct. 1999)

In the full scale project, the compost productions of Elodea and Water hyacinth are assumed to be 5,400 ton/year and 10,700 ton/year, respectively (see Subsection 6.5.2). Then, the unit O&M costs for the harvesting/removal and composting of Elodea and Water hyacinth in the full scale project are estimated as follows.

(unit: Col$/ton in compost weight)

Item	Elodea	Water hyacinth	Average
Harvesting/Removal	62,637	17,600	32,706
Composting	30,003	30,003	30,003
Total	92,640	47,603	62,709
Total (US$/ton)	(48.3)	(24.8)	(32.7)

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (Oct. 1999)

(3) Aquatic Plant Control by Grass Carp

O&M cost is required only for the electrical fish barrier and it is mainly electric charge. The annual O&M cost is estimated to be 50.0 million Col$/year (0.026 million US$/year).

CHAPTER VII MONITORING SYSTEM

7.1 Meteorological and Hydrological Monitoring

7.1.1 Improvement of Monitoring System

(1) Meteorological Monitoring

Meteorological observation is affected by shading of trees, bushes, etc. at some stations in the Study Area. The circumstances of such stations should be improved to obtain correct data.

There are defects of data at some stations in the Study Area, especially in the Lenguazaque river basin, due to malfunction of recording equipment. Periodical inspection is necessary for these stations.

(2) Hydrological Monitoring

The optimum operation of Hato Dam will be monitored/adjusted based on the river flow data of the Ubate and Suta rivers. At present, there already exist gauging stations along both rivers. These stations will be used for operation of Hato Dam.

On the other hand, the optimum operation of the Lake will be monitored/adjusted based on the inflow and outflow data of the Lake. In relation with this aspect, the following improvement of monitoring system is proposed.

There exist one (1) automatic gauging station at Colorado in the lower reaches of the Ubate River. This station will be used for obtaining the inflow data of the Lake. However, only water level has been observed at this station since 1989. Therefore, discharge measurement and establishment of the rating curve at this station is proposed.

At present, no gauging station exists near the outlet of the Lake in the Suarez River. Therefore, installation of a new gauging station is proposed to obtain the outflow data of the Lake.

7.1.2 Cost for Improvement of Monitoring System

The installation cost of one (1) new gauging station in the Suarez River is estimated at 3,600 thousand Col$ (1.9 thousand US$) as of October, 1999.

The annual O&M cost required for the said two (2) gauging stations is estimated at 440 thousand Col$/year (0.23 thousand US$/year) as of October, 1999.

7.2 Water Quality Monitoring

7.2.1 Improvement of Monitoring System

(1) General

The water quality of river/lake and wastewater in the Study Area are monitored by CAR on ad hoc basis at present. The current water quality monitoring system should be improved to enhance the environmental management of the Study Area. The monitoring will periodically be performed by CAR and municipalities.

The jurisdiction of CAR and municipalities for the water quality monitoring is demarcated as below.

CAR will monitor the surface water quality of river/lake as its own duty and further, sewerage effluent into river/lake to cross check the data observed by each municipality. On the other hand, each municipality will monitor the wastewater quality of sewerage inflow/outflow and factory outflow into sewerage.

(2) Sampling and Analysis

Surface water quality will be monitored by CAR every three (3) months at 17 points: four (4) points at the Lake and 13 points at the river. For location of the proposed monitoring points, see Appendix H, Table H.2.3.

Wastewater quality will be monitored by CAR twice a year at 15 sewerage treatment plants and three (3) major industrial effluent points. For location of the proposed monitoring points, see Appendix H, Table H.2.4.

The water quality parameters to be analyzed are selected to adapt National/CAR standards. For the selected parameters, see Appendix H, Table H.2.5.

(3) Improvement of Laboratory

The existing laboratory of CAR should be improved to meet the above periodical water quality monitoring. For procurement of the necessary laboratory equipment, see Appendix H, Table H.2.6.

7.2.2 Cost for Improvement of Monitoring System

(1) Investment Cost

The total procurement and construction costs related to the laboratory is estimated as follows.

Item	Cost (million Col$)	Remarks
Procurement Cost	544.4	Laboratory equipment
Construction Cost	875.0	Building and warehouse
Total	1,419.4	
Total (million US$)	(0.74)	

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

For details of the estimated cost, see Appendix H, Table H.2.6.

(2) O&M Cost

The O&M cost related to the laboratory is composed of manpower cost and consumable material cost. The annual O&M cost is estimated to be 142,760 thousand Col$/year (74 thousand US$/year).

7.3 Monitoring for Aquatic Plant Control

7.3.1 Monitoring Plan

The following changes should be monitored periodically to know the effects or impacts of the proposed aquatic plant control projects on the environments of the Lake.

(1) Change of Aquatic Plant Area

The floating and emergent aquatic plant areas of the Lake can be measured by aerial photograph on a macro-scale. Aerial photographs will be taken regularly, once in every three (3) years. They will be analyzed by GIS of CAR to prepare aquatic plant maps.

The submerged plant area will be surveyed visually on the field with the aid of aerial photograph once in every three (3) years.

(2) Change of Species of Fauna and Flora

Species of the fauna and flora in the Lake have been surveyed on ad hoc basis by CAR and other organizations. However, the species may possibly change according to the progress of the projects. Then, the species in the Lake will be confirmed regularly once in every three (3) years.

(3) Change of Bulrush Frontline and Refilling in the Dredged Lake Zone

The proposed lake bed dredging is expected to stop the expansion of Bulrush frontline. Then, the location of the Bulrush frontline will be surveyed once every three (3) years to confirm the effects of the project.

The lake bed of the dredged zone may possibly be buried by sediment deposition or topographic deformation in the future. Then, the lake bed level of the dredged zone will be surveyed once in every three (3) years.

(4) Growth and Consumption Rates of Grass Carp

Stocking of too many grass carps may over-consume the aquatic plants in the Lake. On the other hand, too few grass carp stocking may not attain a satisfactory control of the excessive aquatic plants. Then, the stocking number of grass carp must be controlled properly. For this purpose, the following monitoring will be made.

(a) Sampling measurement of the size and weight of grass carp once every year

(b) Sampling measurement of Elodea density to estimate the remaining biomass once every year

7.3.2 Monitoring Cost

The required cost of the above monitoring is estimated as follows.

Monitoring Item	Cost (1,000 Col$)	Remarks
1. Survey of Aquatic Plant Area	11,100	Once every 3 years
2. Survey of Fauna and Flora	4,000	Once every 3 years
3. Survey of Bulrush Frontline and Dredged Bed Level	2,200	Once every 3 years
4. Measurement of Grass Carp and Biomass	7,300	Once every year
Total (Equivalent Annual Cost: 1,000 Col$/year)	13,100	
Total (Equivalent Annual Cost: 1,000 US$/year)	(6.81)	

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

7.4 Geographic Information System (GIS)

7.4.1 Existing GIS of CAR

Computer based GIS is used in the Division of Information under the Sub-directorate of Planning and Development, and the Division of Technique Evaluation under the Sub-directorate Science mainly for presentation purpose. In the above organizations, three (3) personnel are involved in each division for GIS activities and one (1) staff is working as system technician in the Division of Information.

(1) Available Hardware and Software at CAR

The following hardware and software are currently available at CAR.

Hardware	PC Computer	4
	Unix Work Station	2
	Plotter HP 250 C/HP750C	3
	Digitizer	2
Software	Genasys Version 7.2	4
	CAD Map	1
	ER Mapper version 5.6	1
	Oracle	1
	Micro Station	1

(2) Available Data

(a) Digital Data

Digital data of approximately 220 are available at CAR. They include spatial data covering the whole CAR jurisdiction like river networks, reserved areas, meteorological stations, region wise like regional risks, municipal wise such as soil use, topography and data for particular basins. For the list of the available data, see Appendix H, Table H.4.1.

(b) Maps and Drawings

Maps and drawings of approximately 80 for the Study Area are available at CAR. They include those of cartography of basin, hydrological information, river/lake system, irrigation system, erosion zone, agricultural zone, soil classification, cadastral information, hydraulic structures, etc. These can be used for the establishment of GIS as required. For the list of the available maps and drawings, see Appendix H, Table H.4.2.

(c) Spatial Data Collected/Used by the Study Team

The following major spatial data were collected and used by the Study Team besides the above mentioned attribute data.

Basin	River basin, municipality area, road network
Land	Geology, soil erosion, land use, reserved area
Water Use	River network, irrigation block
Water Monitoring	Hydrological station, groundwater well, water quality station, isohyetal map
Lake Fuquene	Aquatic plant area, bathymetric map

7.4.2 GIS Data Input and Its Application

In order to uncover the capability of GIS for environmental monitoring, some examples of GIS application were performed by using the Genasys software available in CAR, giving due emphasis to methodology. For this, the necessary data were input to Genasys software.

The used data include land use, river/channel network, meteorological data, aquatic plants, topographic features, reserved area, cadastral map, groundwater data, bathymetric features, water use, etc.

The performed exercises include the followings.

(1) Display of spatial data and link with attribute tables

(2) Analysis of spatial data

(3) Prediction of spatial irrigation water requirement

(4) Slope stability analysis

(5) Extracting information of Lake Fuquene from aerial photo

For the methodologies of the above analyses, see Appendix H, Chapter IV, Section 4.3.

CHAPTER VIII ENVIRONMENTAL EDUCATION

8.1 Current Efforts in Environmental Education

8.1.1 Environmental Education at Municipal Level

The environmental laws in force in Colombia allow the municipalities to undertake programs of environmental education attached to the formal education. However, the development of these activities has been a problem for many municipalities due to the lack of preparation of teachers and the shortage of teaching materials that would make the teacher's job easier.

The present efforts on environmental education made by the municipalities in the Study Area are similar to those presented in others municipalities of the country. Some have not developed any program, others have developed some activities through the UMATA (Municipal Unit for Technical Assistance on Livestock and Agriculture).

In the Study Area, some schools and universities have developed some academic programs related to the environment that contribute to increasing public awareness on environmental matters.

8.1.2 Environmental Education at CAR Level

In the CAR Regional Ubate, there is no regular program on environmental education and only punctual activities are performed only when requested by the municipalities or communities. Some workshops and seminars are performed from time to time by CAR, addressed to the communities with the aim of creating the necessary awareness and changes of attitudes of the people on the environment. In some cases, there is a cooperation between CAR and the municipalities for a specific program of reforestation that includes seminars on how to plant trees and the norms of conservation and protection of the natural resources.

Additionally, CAR through the Checua Project also has introduced environmental education into the region by teaching students, officers of UMATAS and the people in general on water management, multiplicity of crops, cultivation methods and field observations. Also the Checua Project has trained teachers on the management of eroded zones.

8.1.3 Environmental Education at Prefecture Level

The formal education in the region basically depends on the Secretary of Education of the Prefectures of Cundinamarca and Boyaca although the municipalities also support economically in some cases the function of many schools in the region.

The Prefecture of Cundinamarca has enforced Decree No. 1743 of 1994, that obligates school teachers to prepare the scholar environmental projects which must be implemented by them in their respective communities. For the preparation of such projects, both Secretaries of the Prefecture (Environment and Education) conjointly with CAR, give the necessary training and advice.

The Prefecture of Cundinamarca through its Secretary of Environment plans to establish within this year (1999), the Environmental Network for the Fuquene Lake Basin whose headquarter will be in Ubate City. This network will be coordinated by the Prefecture and integrated by CAR, municipalities and other related institutions, and the main objectives of this network will be the implementation of environmental education programs and the promotion of public awareness on the environment.

8.1.4 Environmental Education at Non- Governmental Organization Level

In the Study Area, there is only one (1) non-governmental organization, “the Fuquene Lake Foundation”. It was founded in 1998 by the citizens mainly of Chiquinquira City in view of the many environmental problems that are affecting the Fuquene Lake.

The main objective of this organization is the promotion of environmental campaign or environmental projects directed to the lake recovery. Besides, this foundation established branches in some municipalities of the region in order to expand its activities.

According to the interview with the director and members of this foundation, the source of their technical information is basically CAR, and they would like to cooperate with CAR in implementation of the projects tending to the conservation of the lake environment.

8.2 Public Awareness on the Environment in the Study Area

8.2.1 General

A questionnaire survey was conducted to evaluate the present level of public awareness on the environment in the Study Area. The questionnaire was addressed to the following three (3) groups of people in the Study Area.

(1) Farmers: 145 farmers were randomly selected from the 10 representative municipalities of the Study Area. Among them, some farmers are users of the irrigation system, the others are not user and some farmers living on the highlands are also included.

(2) Factory Managers: the questionnaire was addressed to the managers of 14 milk processing factories and 11 coal mining selected from the Study Area. The selection was made to cover various sizes of factories and mining, taking into consideration the existing size distribution of the factories and mining. The selected milk processing factories are mainly located in the municipalities of Ubate, Simijaca and San Miguel de Sema. The selected coal mining are situated in the municipalities of Cucunuba, Lenguazaque, Guacheta and Tausa.

(3) Representative Citizens: the questionnaire was conducted on 112 citizens distributed over all the 14 urban areas of the Study Area.. They were selected from the leading people with professional roles serving the communities and older people engaged in commercial and industrial activities in each locality.

8.2.2 Evaluation of Present Public Awareness on the Environment

(1) Public Awareness on the Common Environmental Issues

(a) Environment of Lake Fuquene

The people living in the Study Area have a high awareness on the deterioration of the environments of Lake Fuquene. Almost 100% of the respondents to the questionnaire (farmers: 97%, factory managers: 100% and citizens: 96%) know that the Lake has suffered from a rapid reduction of the surface water area in the recent years. They are all worried that the Lake might become extinct in the future.

Further, they have a great concern on the environmental damages to be caused when the Lake decreases its size or becomes extinct. They say that the damages will be fatal to the economy and environments of the region. On the other hand, a few respondents (3% of farmers and 5% of citizens) mentioned that this reduction of the Lake will produce a beneficial effect of land use enlargement.

Most of the respondents attribute this reduction of the Lake to the following causes: lack of proper maintenance, poor dredging, improper water level control, propagation of aquatic plants, sedimentation, land invasion, poor control of water use, poor watershed management, decrease of rainfall, etc.

(b) Watershed Management

The people in the Study Area are highly concerned about the watershed management. A significant percentage of the respondents know that CAR is performing a soil erosion control project in the mountain areas of the Study Area (farmers: 40%, milk processing factory managers: 36%, coal mining managers: 73% and citizens: 54%).

Seventy six percent (76%) of the farmers answered that they would be willing to change the current cultivation method to prevent soil erosion if necessary although few of them had received technical assistance from governmental entities. Almost all the factory managers showed their interest in participation or cooperation with CAR in the erosion control project if necessary.

(c) Participation in Environmental Education Programs

People living in the urban areas have participated in environmental education programs more than those in the rural areas. The percentage of the respondents who have participated in environmental education programs are shown below.

Farmers: 17%, Milk Process Factory Managers: 50%, Coal Mining Managers: 18%, Citizens: 53%

Among the above citizens, 51% have also experienced participating in campaign activities organized by governmental entities or NGOs.

The people in the Study Area are very eager to get more knowledge and information on environment. Almost all the respondents replied that they are willing to participate in environmental education programs or campaigns.

Radio and television are considered as the most effective ways to educate the people about environmental subjects. According to the questionnaire survey, the people in the Study Area mostly receive environmental information through radio and television.

(2) Public Awareness of Farmers

(a) Approximately 30% of the respondents listed the following water related problems as the serious ones: water level lowering in the lake (28%), sediment deposition in the river/channel (32%), excessive aquatic plants in the river/channel (34%). They are also worrying about the contamination of the public water body (32%). However, 34% of the respondents answered that there are no serious water related problems.

(b) The farmers are also affected by droughts, floods and soil erosion. The 28% manifested that they have had problems in coordination of the water use with other people due to the lack of river water in dry season. The 39% answered that they are affected by floods more than once a year.

The 21% recognizes that their field is affected by soil erosion and the remaining 79% has no erosion problems. The 57% of the respondents having the soil erosion problems are taking steps to protect their field.

(c) The government has decided to transfer the operation and maintenance works of the irrigation system from CAR to the Users Association in the near future. Only 26% know this decision and the remaining 74% have not heard about it. With regard to the capability of the Users Association, 33% believe that it will be able to perform the operation and maintenance works, however, 37% doubt its capability due to financial and technical constraints and the others do not know about this subject or gave no answer to it.

(d) The 86% consider that soil erosion in the mountainous fields causes significant sedimentation problems in the downstream. The 84% are aware that agricultural and livestock activities cause water pollution problems in the downstream rivers and lakes.

(e) The 48% are interested in using Elodea of the Fuquene Lake as fertilizer, 32% answered negative and 20% do not know anything about this subject.

(3) Public Awareness of Factory Managers

(a) A high percentage of the factory managers (milk processing factory: 100%, coal mining: 82%) are worried about the river/lake water pollution caused by untreated industrial wastewater.

(b) The 93% of the milk processing factory managers are aware of the adverse effects of their wastewater containing sodium hydroxide (NaOH) and sodium chlorate ($NaClO_3$) which are used in the cleaning process of bottles and tanks.

(c) The 91% of the coal mining managers are aware of the fact that the mining activities cause soil erosion and discharge water containing iron into the rivers. The 64% consider that the mining activities cause significant sedimentation problems in the downstream rivers and lakes. However, 27% think that this sedimentation problem is not significant and 9% do not respond to it.

(4) Public Awareness of Citizens

(a) More than 50% of the respondents listed the following environmental problems as the major ones: insufficient water supply system (66%), insufficient sewerage system (65%), insufficient garbage disposal system (73%), pollution of rivers/channels (71%), soil erosion (63%) and sedimentation in the rivers/channels (57%).

(b) The major deficiencies of water supply, sewerage and garbage disposal indicated by the respondents are as follows.

Water Supply	: Poor water quality (74%), old facilities (52%), etc.
Sewerage	: No or deficient treatment system (54%), old facilities (52%), etc.
Garbage Disposal	: Deficient final disposal system and others (45%), etc.

(c) The respondents identified the following as the major pollution sources in the rivers: domestic wastewater (74%), garbage (69%), industrial wastewater (46%) and residues from slaughterhouses (44%).

(d) According to the governmental decision, each municipality must solve the above environmental problems for itself from now on. The 69% know this decision, however, the others do not know about it. Only 28% believe that their municipalities have the capability to assume this responsibility, 65% doubt the capability due to the lack of financial and technical resources, and the remaining people gave no answer.

(e) The 82% of the respondents know that the factories must treat their wastewater before discharging it into the municipal sewerage system according to the law and the remaining people do not know this regulation. However, only 8% believe that the factories comply with the law and 64% think that this law is not enforced.

8.3 Promotion of Environmental Education

8.3.1 Necessary Program

An education program to promote public awareness on environmental issues should be undertaken for effective implementation of the proposed projects. The education program will have the following four (4) objective levels: (1) Schools, (2) Farmers and Users of the Water District, (3) Dairy Factory Owners, and (3) General Public.

(1) Schools

CAR will promote the environmental education in all educational institutions of the region and provide constant guidance on main environmental issues. This activity will be coordinated with the Cundinamarca and Boyaca prefectures, related municipalities and NGOs.

The main environmental issues to be developed will include the control of water pollution, excessive aquatic plants, soil erosion, etc. and ecological conservation of the region.

(2) Farmers and Users of the Water District

Before, during and after the implementation of the proposed projects, periodic seminar addressed to farmers and users of the water district will be conducted by

CAR in coordination with the related municipalities through the UMATA (Municipal Unit for Technical Assistance on Agriculture and Livestock). The materials for the seminars will include overall explanation on the proposed projects and their relations with the water resources management of the basin.

(3) Dairy Factory Owners

Periodic seminar addressed to dairy factory owners will be conducted by CAR in coordination with the related municipalities. This will promote the awareness of owners about the significance of complying with the water quality standard and thus, in turn promote the installation of treatment plants.

(4) General Public

The following programs will be performed for educating the general public:

(a) Environmental education through radio and television is highly recommended to widely promote public awareness on the environmental issues of Lake Fuquene and its significance on the overall socio-economy of the region.

(b) It is necessary to always inform the people of what CAR is performing in the basin to get the understanding and cooperation of the citizens for any program or project of environmental conservation. In this sense, the publication of newspaper articles related to the environmental protection of Lake Fuquene is recommended. In addition, the publication of "Informative Bulletin of CAR" is also recommended to make the public know about CAR activities in the region and the main environmental issues.

(c) CAR is considered as the source of information on environmental subjects, therefore, seminars or conferences on how to reduce the pollutants coming from sewerage, industries, etc. should be carried out and addressed to the professional people interested in the subject.

8.3.2 Required Cost

The above educational activities will mainly be performed by the Regional Office of Ubate, CAR. However, the equipment is not sufficient in this office. Procurement of new equipment will be necessary to implement the environmental education programs effectively.

The required procurement cost of educational equipment is estimated as follows.

Procurement of Equipment	Quantity	Cost (1,000 Col$)
Vehicle	1	38,400
Equipment for Education Program	l.s.	27,264
Total		65,664
Total (1,000 US$)		(34.2)

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October,1999)

For the breakdown of the above cost, see Appendix I, Chapter III, Section 3.2.

The annual operation cost of the above-mentioned educational program is estimated at 48,000 thousand Col$/year (25 thousand US$/year) as of October, 1999.

CHAPTER IX INSTITUTIONAL ASPECTS

9.1 Related Law and Regulations

The laws relevant to environment in Colombia are listed in Table 9.1. Among them, Law 3, 1961, Decree 1594, 1984, Agreement 58, 1987 of CAR, Agreement 10, 1989 of CAR and Agreement 031, 1991 of CAR, are directly related to this Study.

(1) Law 3, 1961

By means of this law, the irrigation system of Fuquene-Cucunuba was given up to CAR for its administration and management.

(2) Decree 1594, 1984

The water quality criteria to classify surface water body on national level are established by this decree. This decree also make provisions for wastewater discharge into surface water.

For the national standards of surface water quality and permissible quality of wastewater discharging into river and municipal sewerage, see Appendix E, Table E.1.19.

(3) Agreement 58, 1987 of CAR

Norms for the management and control of the water resources quality in the administration area of CAR are given in this agreement.

Article 26 of this agreement state that the water bodies under the jurisdiction of CAR are classified according to the current and potential water uses as follows.

(a) Class A: suitable for human and domestic uses with conventional treatment, preservation of flora and fauna, agriculture use and livestock use.

(b) Class B: suitable for preservation of flora and fauna, agriculture use and livestock use

(c) Class C: suitable for agriculture use and livestock use

(d) Class D: suitable for restricted agriculture use, energy generation and restricted industrial use

This agreement also makes provisions for wastewater discharge into surface water.

For the CAR standards of surface water quality, see Appendix E Table E.1.20.

(4) Agreement 10, 1989 of CAR

This agreement dictates norms for the management of water of public use under the jurisdiction of CAR.

Article 8 states that all natural or juridical person, public or private needs concession or permission from CAR to use public water. Concessions are given for surface and groundwater uses.

Article 119 states that persons interested in the execution of activities that imply the use, occupation or modification of watercourses located in the territory of CAR, must have permission of CAR.

(5) Agreement 031, 1991 of CAR

By this Agreement is adopted the general regulation for the functioning of the irrigation and drainage district composed of the hydraulic system of Fuquene-Cucunuba.

9.2 Existing Organization of Related Agencies

(1) CAR Headquarters

The implementing agency of this Study is the Regional Autonomous Corporation of Cundinamarca, which is a public corporate entity, autonomous both administratively and financially.

(a) Functions

The main functions of CAR are as follows:

(i) To execute national policies, plans and programs concerning the environment, which are defined by the approval law of the National Development Plan and the National Investment Plan or by the Ministry of the Environment. To execute those duties related to regional level that have been delegated according to law, within the corresponding jurisdiction;

(ii) To act as the maximum environmental authority within the area of its jurisdiction according to the rules of superior hierarchy and complying the criteria and guidelines set forth by the Ministry of the Environment;

(iii) To advise the different territorial authorities in setting environmental education plans and to carry out informal environmental education programs, according to the national policy guidelines.

(iv) To grant concessions, permits, authorizations and environmental licenses required by law for the use, development or mobilization of the renewable natural resources or for the development of activities that affect or could affect the environment. To grant permits and concessions for forestry developments, and concessions for the use of superficial and underground water and to establish closed season for sport hunting and fishing.

(v) To promote and execute irrigation works, draining, protection against flooding, correction of riverbeds and water streams, and the necessary land recovery works in order to defend, protect and manage adequately the hydrographic basins within the territory of its jurisdiction, in coordination with the directing and executive entities of the National System for Land Adapting, according to the legal framework and to the corresponding technical foresights.

(vi) To execute, manage, operate and maintain in coordination with the territorial authorities, the necessary projects, sustainable development programs and infrastructure works to defend and protect or to decontaminate or recover the environment and the renewable natural resources.

(vii) To impose, distribute and collect the valorization contributions referred to the charges on the property, because of the execution of public works by the "Corporation"; to set other rights that can be charged according to the law.

(b) Organizational Structure

CAR's headquarter flowchart is shown Fig. 9.1. The structure of CAR may be divided into the following components:

(i) Corporate Assembly: is the main organ of direction of the agency.

(ii) Directive Council: is the administration organ of the agency

(iii) General Director: is the legal representative of the Corporation and its first executive authority.

(iv) Internal Structure: the current internal structure is composed by Sub-Directorates and Regional Directorates

(c) Financial Aspects

The financial system of CAR is centralized and the budget allocated in 1998 is as follows.

Items	1998 (million Col$)
1.Expenditures of Functioning	23,891.0
1.1 Personal	16,690.9
1.2 General Services	4,268.3
1.3 Transference	2,931.8
2. Investment	17,126.1
3. Debt	2,699.4
Total	43,716.4
Total (million US$)	(30.66)

Exchange rate: 1 US$ = 1,426 Col$ (1998)

(2) CAR Related Branch Offices

This Study falls under the jurisdiction of the Regional Directorates of Ubate and Zipaquira whose functions, structure and financial situation is presented as follows.

(a) Functions

Main functions of the Regional Directorates are:

(i) To execute the objectives established for the regional level according to the programs, projects, products, services and activities of the Corporation, and the competencies delegated by the General Director by mean of a regulation.

(ii) To coordinate, to supervise and to execute the activities related to the planning, analysis and the projections of the activities of the Regional Directorate.

(iii) To coordinate, to supervise and to execute the activities related to the environmental education, communications, coordination and community and inter-institutional participation, in its jurisdiction.

(iv) To coordinate, to supervise and to execute the activities related to the enforcement of regulation that must be fulfilled in its jurisdiction.

(v) To coordinate, to supervise and to execute the activities related to the environmental quality control in its jurisdiction.

(b) Organizational Structure

The organizational structures of the Regional Directorates of Ubate and Zipaquira are basically the same and composed of the following levels:

(i) Directive Level: is managed by the Regional Director

(ii) Advisement Level: involves mainly juridical aspects.

(iii) Operative Level: is composed of coordinators or groups in charge of the execution of programs and control on the environment and the natural resources.

In the case of Ubate, there are 2 different groups of staffs assigned to other activities; the first one is assigned to the management of the irrigation and drainage district and the other group is assigned to implement the Checua Project. These groups, although using the offices of the Regional Office of Ubate, have their own Director or Chief.

(c) Financial Aspects

(i) Regional Directorates of Ubate and Zipaquira

Items	1998 (million Col$)	
	Ubate	Zipaquira
1.Expenditures of Functioning	1,107.7	1,567.3
1.1 Personal	956.5	1,500.7
1.2 General Services	151.2	66.5
2. Investment	623.0	769.9
Total	1,730.6	2,337.1
Total (million US$)	(1.21)	(1.64)

Exchange rate: 1 US$ = 1,426 Col$ (1998)

(ii) Irrigation and Drainage District and Checua Project

Items	1998 (million Col$)	
	District	Checua Project
1.Expenditures of Functioning	974.5	484.5
1.1 Personal	578.1	477.1
1.2 General Services	396.4	7.4
2. Investment	-	1,343.6
Total	974.5	1,828.1
Total (million US$)	(0.68)	(1.28)

Exchange rate: 1 US$ = 1,426 Col$ (1998)

(3) Environmental Secretariat of Cundinamarca Prefecture

(a) Functions

The main functions are presented hereunder:

(i) To participate in the elaboration of the Prefecture Development Plan and to assure that the environmental component is duly incorporated into the Plan, both in the environmental chapter as well as in the other sectors.

(ii) To promote the execution of programs and the implementation of national, regional and sectoral policies related to the environment and the natural resources that must be developed in the Prefecture of Cundinamarca.

(iii) To collaborate with the Regional Autonomous Corporations of its jurisdiction, with the Capital District and with the Municipalities of Cundinamarca, in the execution of programs and environmental projects that are identified as priorities, according to the agreement and alliances subscribed for this purpose.

(iv) To promote, to co-finance or to execute in coordination with the Regional Autonomous Corporations and other competent entities, the works and soils recovery projects, the regulation of water flow or water currents, as well as programs for the adequate management of the water basins.

(v) To implement environmental education and dissemination programs that contribute to the creation of a better public awareness on the necessity of conservation and to realize a sustainable use of the renewal natural resources and environment.

(b) Organizational Structure

The internal structure is composed of the followings:

(i) Office of the Secretary

(ii) Office of Environmental Policy and Information

(iii) Environmental Protection Directorate

(iv) Environmental Promotion Directorate

(c) Financial Aspects

The amount of money budgeted for the Environmental Secretariat for the year 1999 is shown below:

Concepts	Year 1999 (million Col$)
1.Expenditures of Functioning	60.0
2. Investment	5,910.0
2.1 Protection of Ecosystems for Natural Resources Conservation	4,100.0
2.2 Management, Disposal of Solid Waste	800.0
2.3 Education and Environmental Awareness	180.0
2.4 Planning and Environmental Ordering of the Territory	100.0
2.5 Instrumental Programs	730.0
Total	5,970.0
Total (million US$)	(3.11)

Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October,1999)

(4) Public Services Department of Representative Related Municipalities

(a) General

Generally, the basic services in the urban centers of the Study Area, are provided by the municipalities through their Department of Public Services. On the other hand, since most of the municipalities in the Study Area have no environmental department, some problems of environmental concerns are managed also by the Department of Public Services or are delivered to CAR.

(b) Functions

The main functions are presented hereunder:

(i) To perform the operation and maintenance of the services of municipal water supply, sewerage, solid waste management, public toilets, public market and slaughterhouses.

(ii) To supervise the construction of water supply system and sewerage in the urban and rural sectors.

(iii) To address, coordinate and control the cleaning service of streets, parks, etc.

(c) Organizational Structure

Fig. 9.2 presents the organizational structure of the Public Service Department of Ubate Municipality, which can be taken as the representative of the related municipalities.

(d) Financial Aspects

Table 9.2 presents the total budget, and the budgets appropriated for investment in public services and environmental projects in the municipalities of the Study Area in 1999.

CHAPTER X IMPLEMENTATION PROGRAM AND PROJECT EVALUATION

10.1 Implementation and Cost Disbursement Schedules

10.1.1 Implementation Schedule

(1) General

The proposed major project components for the environmental improvement of the Study Area are (i) water resources and use management, (ii) wastewater treatment, and (iii) aquatic plant control of the Lake. These consist of the following sub-project components, respectively.

Project Component	Sub-project Component
Water Resources and Use Management	Irrigation, Drainage and Municipal Water Supply
Wastewater Treatment	Sewerage Treatment
Aquatic Plant Control	Dredging of Lake Bed, Harvesting/Removal and Composting of Aquatic Plant, and Aquatic Plant Control by Grass Carp

The construction works and procurement of equipment for the above sub-projects will be implemented during the period 2001 – 2010 in accordance with the priority sequence. Their implementation schedules are described below.

(2) Improvement of Water Resources and Use Management System

(a) Irrigation

The proposed future irrigation area (24,849 ha) is divided into 17 irrigation blocks of which 11 irrigation blocks will be improved. These are Suta, Cap-1, Cap-2, Lenguazaque, Marino/Marino-Ubate, Susa, Simijaca, Old-Suarez, Merchan, Upper Honda and Upper Susa.

Among these, Suta, Cap-1 and Cap-2 will be given priority. These three (3) blocks are to be irrigated by Hato Dam. However, the dam is not fully utilized due to lack of irrigation facilities in these blocks at present.

Detailed design will be completed within 2002. The construction works of the three (3) priority blocks will be done during 2003 – 2006. The remaining nine (9) blocks will be implemented during 2007 – 2010.

(b) Drainage

This is the improvement of the Suarez River channel. No construction works are proposed. O&M works of river channel clearance will be implemented every year after 2002.

(c) Water Supply

This is the improvement of the existing intake (pump) and purification plant of Chiquinquira water supply system. The project will be started at the earliest time considering that the existing treated water quality does not satisfactorily meet the standards.

Detailed design will be completed within 2002. The construction period is scheduled during 2003-2006.

(3) Wastewater Treatment (Sewerage Treatment)

In this Study, the implementation program of only sewerage treatment system is proposed since the industrial wastewater treatment project is small. The proposed project includes improvement of four (4) existing treatment plants in the municipalities of Ubate, Cucunuba, Lenguazaque and San Miguel de Sema, and installation of 10 new plants in the other municipalities including Chiquinquira.

Chiquinquira will be given top priority followed by Ubate in due consideration that the served population of both cities shares 74% of the total served population in the Study Area, the respective receiving waters are much polluted and land acquisition has already been completed in both cities.

Detailed design and construction works of the treatment plants for both cities will be done during 2001 – 2005. Projects for the other municipalities will be implemented during 2006 – 2010 in accordance with the priority sequence based on the size of served population.

(4) Aquatic Plant Control

(a) Dredging of Lake Bed

The pilot project will be implemented in 2002. Detailed design of the full scale project will be completed within 2006. The dredging works of the full scale project will be executed during 2007-2010.

(b) Harvesting/Removal and Composting of Aquatic Plants

The pilot project will be performed for three (3) years during 2001 – 2003. Procurement of the equipment and construction of the compost yard for the pilot project will be implemented in early 2001. The operation of the pilot project will start immediately after completion of the procurement and construction.

The full scale project will start in 2004. Procurement of the equipment and construction of the compost yard for the full scale project will be completed within 2004. The operation of the full scale project will start in 2005 and be completed by 2016.

(c) Aquatic Plant Control by Grass Carp

The project will start in 2003 immediately after completion of the ongoing experiment. The procurement of grass carp and installation of the electrical fish barrier will be completed within 2003. Fingerlings of grass carp will be released immediately after completion of the fish barrier.

The implementation schedules of the above projects are shown in Table 10.1.

10.1.2 Cost Disbursement Schedule

The estimated investment cost (including costs for construction and procurement) and annual O&M cost (at the time of full operation) of the proposed projects are summarized below.

Project Component	Investment Cost (million Col$)	Annual O&M Cost (million Col$/year)
Water Resources and Use Management		
Irrigation	15,049.0	162.3
Drainage	-	38.5
Municipal Water Supply	780.1	Negligible
Total	15,829.1 (8.25 million US$)	200.8 (0.10 million US$/year)
Wastewater Treatment		
Sewerage Treatment	7,561.0 (3.94 million US$)	831.0 (0.43 million US$/year)
Aquatic Plant Control		
Dredging of Lake Bed	17,196.1	-
Harvesting/Removal and Composting	11,688.2	1,009.6
Grass Carp	2,054.0	50.0
Total	30,938.3 (16.12 million US$)	1,059.6 (0.026 million US$/year)

Exchange rate: 1US$ = 106 ¥ = 1,920 Col$

The disbursement schedules of the investment and O&M costs of the above projects are shown in Table 10.1.

10.2 Economic Analysis

10.2.1 General

The project cost is converted to economic cost by applying a conversion factor which is assumed to be 0.9. The project life is assumed as 30 years. The average interval of the replacement of equipment is assumed at 15 years.

The economic efficiency of the project is evaluated in terms of economic internal rate of return (EIRR), benefit - cost ratio (B/C) and net present value (NPV).

10.2.2 Water Resources and Use Management

(1) Economic Benefits

(a) Irrigation

The proposed irrigation project will increase milk production of livestock on the beneficial pasturelands with a total gross area of 6,971 ha (net area: 6,274 ha). The beneficial area is classified into the following five (5) types.

Type	Irrigation Improvement	Net Area (ha)	Milk Production (l/ha/d)	
			W/o Project	w/ Project
A	From rainfed to low level irrigation	1,758	5.0	16.1
B	From rainfed to optimum irrigation	2,176	5.0	22.4
C	From low level irrigation to optimum irrigation	2,058	16.1	22.4
D	From low level irrigation to medium level irrigation	282	16.1	16.8

From the above, the increase of milk production by the project is estimated to be 70,538 l/day. Then, the project is expected to produce annual benefit of 3,965 million Col$/year (2.07 million US$/year) by assuming the unit benefit (net selling price) at farm gate as 154 Col$/l.

(b) Drainage

Annually, 170 ha of pastureland in the surrounding area of the Lake will be relieved from inundation, resulting in increase of the milk production of livestock. However, this beneficial effect will not occur throughout the year. It is assumed to appear during 25% period of the year.

The produced annual benefit of the project is estimated to be 38.1 million Col$/year (0.02 million US$/year) by assuming the unit milk production of the area as 16 l/ha/d and unit benefit at farm gate as 154 Col$/l.

(c) Municipal Water Supply

The proposed project will improve the public health of 45,500 water users in Chiquinquira City in 2010. The cost (including construction and replacement costs of facilities) of the project during project life is estimated at 758 million Col$ (0.39 million US$). It is assumed equivalent to the economic benefit on the water users.

(2) Economic Evaluation

The economic efficiency of the water resources and use management project is estimated as follows.

Index	Economic Efficiency	Remarks
EIRR	26%	
B/C	2.2	For a discount rate of 10%
NPV	10,899 million Col$ (5.68 million US$)	For a discount rate of 10%

10.2.3 Wastewater Treatment (Sewerage Treatment)

The proposed project will treat the wastewater of approximately 95,000 people and industries, improving the environments of the public water body and conserving the water resources in the Study Area. Most of the benefits by the project are intangible, however, the monetary benefit is estimated from the viewpoint of cost saving. This cost saving accrues from the saving of additional treatment cost of Chiquinquira water supply. The benefit is estimated at 1.7 million Col$/year (0.001 million US$/year).

10.2.4 Aquatic Plant Control

(1) Economic Benefit

(a) Dredging of Lake Bed

The project will dispose dredged soils on the low pasturelands in the surroundings of the Lake. This will create a flood free pastureland of 50 ha, resulting in increase of the milk production of livestock. The annual project benefit is estimated to be 45 million Col$/year (0.02 million US$) by assuming the unit milk production increase as 16 l/ha/d and unit benefit at farm gate as 154 Col$/l.

Further, the project will contribute to the mitigation of the anaerobic condition in the Lake by controlling the expansion of Bulrush area.

(b) Harvesting/Removal and Composting of Aquatic Plants

The following benefits are expected from the project together with aquatic plant control by grass carp: (i) compost production, (ii) reduction of water pollution damage on the pasturelands around the Lake, (iii) reduction of water pollution damage on the municipal water supply of Chiquinquira, (iv) conservation of lake storage capacity, (v) improvement of landscape, and (vi) improvement of aquatic life habitat.

The benefits of (i) to (v) are tangible, while (vi) is intangible. The tangible benefits are analyzed below.

(i) Compost Production

The current market price of compost is 140,000 Col$/ton in Zipaquira (largest consumption area). Then, the selling price at the compost production site near Lake Fuquene is estimated at 122,000 Col$/ton by deducting the transportation cost between Zipaquira and production site. On the other hand, the project will produce 16,100 ton of compost per year. Therefore, the annual benefit of the project is estimated at 1,964.2 million Col$/year (1.02 million US$/year).

(ii) Reduction of Water Pollution Damage on the Pasturelands around the Lake

The pasturelands around the Lake are irrigated by the lake water. Without project, the lake water in the future will be much polluted with H_2S. This substance will be generated under anaerobic condition caused by excessive aquatic plants. This polluted water containing a toxic substance will damage the growth of pasture in the land of 500 ha, resulting in reduction of the milk production of livestock (8,000 l/d). The project will recover the reduction of milk production. The annual benefit of the project is estimated at 449.7 million Col$/year (0.23 million US$/year), by assuming the unit benefit at farm gate as 154 Col$/l.

(iii) Reduction of Water Pollution Damage on the Municipal Water Supply of Chiquinquira

Similarly, the above-mentioned water pollution will damage on the municipal water supply of Chiquinquira. To recover this damage, additional water purification facilities with a construction cost of 235 million Col$ (0.12 million US$) will be necessary. This cost will be saved by the project.

(iv) Conservation of Lake Storage Capacity

The project will conserve 594,400 m^3 of the lake storage capacity in 2020. This economic value is estimated to be 105 million Col$ (0.05 million US$), referring to the unit storage cost of Hato Dam (176 Col$/$m^3$).

(v) Improvement of Landscape

The project will improve the landscape of the Lake by clearing off the excessive aquatic plants. It will enhance the tourism development around the Lake. Approximately, 100,000 tourists visit this region per year. It is assumed that 40,000 or 40% of them will visit the Lake in the future. Then, the project is expected to produce annual benefit of 800 million Col$/year (0.42 million US$/year), by assuming that one (1) tourist will spend 20,000 Col$ around the Lake on average.

(c) Aquatic Plant Control by Grass Carp

The project will produce the following benefits along with the harvesting/removal and composting of aquatic plants: (i) reduction of water pollution damage on the pasturelands around the Lake, (ii) reduction of water pollution damage on the municipal water supply of Chiquinquira, (iii) conservation of lake storage capacity, (iv) improvement of landscape and (v) improvement of aquatic life habitat.

(2) Economic Evaluation

The economic efficiency of the aquatic plant control project is estimated as follows.

Index	Economic Efficiency	Remarks
EIRR	5%	
B/C	0.8	For a discount rate of 10%
NPV	- 4,553 million Col$ (- 2.37 million US$)	For a discount rate of 10%

10.2.5 Master Plan (Total Project)

The proposed master plan is evaluated as follows.

(1) Economic Benefits

The above-mentioned economic benefits are summarized below.

Project	Annual Benefit (million Col$/year)	One Time Benefit (million Col$)
Water Resources and Use Management	4,003.1	758.0
Irrigation	3,965.0	-
Drainage	38.1	-
Municipal Water Supply	-	758.0
Wastewater Treatment	1.7	-
Aquatic Plant Control	3,258.9	340.0
Dredging of Lake Bed	45.0	-
Harvesting/Removal and Composting, and Grass Carp	3,213.9	340.0
Total	7,263.7	1,098.0
Total (million US$/year or million US$)	(3.78)	(0.57)

(2) Economic Evaluation

The economic efficiency of the master plan is estimated as follows.

Index	Economic Efficiency	Remarks
EIRR	10%	
B/C	1.0	For a discount rate of 10%
NPV	0.0	For a discount rate of 10%

For the flow of economic cost and benefit, see Appendix K, Chapter I, Table K 1.1 to Table K 1.4.

10.3 Financial Analysis

Financial analysis is made for the following three (3) sub-project components: (i) irrigation, (ii) sewerage treatment, and (iii) compost production.

10.3.1 Irrigation

The financial analysis is made collectively for all the irrigation blocks of the Study Area.

(1) Water Charge

The existing average unit water charge of the Study Area is estimated at 39,537 Col$/ha/year (5.5% of present annual farm household income) in 1999. The future unit water charge is assumed to increase in proportion to the increase of affordability of the users, namely the growth of per capita GDP. The growth rate of per capita GDP is projected as follows: 0% until 2000, 2.9% for 2001 to 2011 and thereafter constant.

(2) Revenue and Cost Disbursement

Disbursement of the expected revenue, and required investment cost and O&M cost (including replacement cost) are shown below.

Revenue			Cost		
Year	Irrigation Area (ha)	Annual Revenue (million Col$/year)	Year	Total Investment Cost (million Col$)	Ave. Annual O&M Cost (million Col$/year)
- 2000	20,337	804	- 2000	-	-
2005	21,068	961	2001 - 2005	5,415	1,024
2010	23,945	1,260	2006 - 2010	9,634	1,137
2011-	24,849	1,345	2011-	-	1,242

(3) Financial Evaluation

The existing water charge system can cover all O&M cost but can never cover the construction cost.

However, some portion of the investment cost should be borne by farmers since the farm land is private property. As an alternative, 10% of the investment cost is borne by the farmers and the remaining 90% is shouldered by the government. In this case, the water charge should be raised up from 39,537 Col$/ha/year to 43,670 Col$/ha/year (6.0% of present annual farm household income) for the base year 2000 to keep the balance between revenue and cost under the condition of 10% discount rate. This increase of 0.5% is deemed to be affordable, considering the increase of farm household income by the proposed irrigation project.

10.3.2 Sewerage Treatment

The financial analysis is made collectively for all the sewerage treatment systems of the Study Area.

(1) Sewerage Charge

The sewerage charge of Ubate City is considered as the representative one of the Study Area. The existing unit sewerage charge of the city for domestic wastewater is 1,865 Col$/month/house in 1999. This charge is for all the sewerage system including pipelines and treatment plant. This is equivalent to 0.26% of the average monthly household income (700,000 Col$/month/house) in the Study Area. On the other, the willingness to pay of the people was obtained at 0.32% of the household income through interview surveys.

Then, the existing affordable sewerage charge is determined to be 0.29% of the household income or 2,030 Col$/month/house. From this value, the existing affordable sewerage treatment charge is estimated to be 812 Col$/month/house or 0.12% of the household income by assuming the share of the treatment charge as 40% of the total charge.

On the other hand, the existing sewerage charge of the city for industrial wastewater is 13,039 Col$/month/factory. Then, the existing affordable sewerage treatment charge for industrial wastewater is determined to be 5,677 Col$/month/factory by adopting the ratio between the actual domestic and industrial charges in Ubate City.

The future unit sewerage treatment charge is assumed to increase in proportion to the increase of affordability of the beneficiaries, namely the growth of per capita GDP. The growth rate of per capita GDP is projected as follows: 0% until 2000, 2.9% for 2001 – 2011 and thereafter constant.

(2) Revenue and Cost Disbursement

Disbursement of the expected revenue, and required investment cost and O&M cost (including replacement cost) are shown below.

Revenue				Cost		
Year	Served Household (nos.)	Served Industry (nos.)	Ave. Annual Revenue (million Col$/year)	Year	Total Investment Cost (million Col$)	Ave. Annual O&M Cost (million Col$/year)
- 2000	22,305	49	221	- 2000	-	-
2005	24,784	49	282	2001 – 2005	3,565	274
2010	27,539	49	362	2006 – 2010	3,996	491
2011 -	28,125	49	380	2011 -	-	831

(3) Financial Evaluation

The above sewerage treatment charge can not cover even the O&M cost. The sewerage treatment charge for domestic wastewater should be raised up from 0.12% (812 Col$/month/house in 2000) to 0.25% (1,776 Col$/month/house in 2000) of the household income (700,000 Col$/month/house in 2000) to cover the O&M cost at least. The sewerage treatment charge for industrial water should be raised up in proportion to the domestic wastewater charge.

10.3.3 Compost Production

(1) Market Price of Compost

The existing market price of compost is 140,000 Col$/ton in Zipaquira (largest consumption region). It can be converted to the selling price at production site (122,000 Col$/ton) by deducting the transportation cost.

The future selling price is assumed to increase in proportion to the increase of affordability of the users, namely the growth of per capita GDP. The growth rate of per capita GDP is projected as follows: 0% until 2000, 2.9% for 2001 to 2011 and thereafter constant.

(2) Revenue and Cost Disbursement

The pilot project will be implemented during 2001 - 2004. The full scale project will start in 2004 and terminate in 2016. All costs of the pilot project will be borne by the government. The products will be given to the farmers free of charge since the project will be conducted for experimental farming.

Disbursement of the expected revenue, and required investment cost and O&M cost (including replacement cost) for the full scale project are shown below. The following cost covers all the costs for harvesting/removal and composting of aquatic plants.

Revenue			Cost		
Year	Annual Compost Production (ton/year)	Annual Revenue (million Col$/year)	Year	Total Investment Cost (million Col$)	Ave. Annual O&M Cost (million Col$/year)
2004	-	-	2004	10,285	-
2005	16,100	2,266	2005-2010	-	1,267
2010	16,100	2,614	2011-2016	-	1,010
2011 - 2016	16,100	2,690			

(3) Financial Evaluation

Financial viability of the compost production by private sector is evaluated in terms of financial internal rate of return (FIRR) for the three (3) cases as shown below.

Case	Cost Shearing		FIRR (%)
	Government	Private	
Case-1	No cost	Investment cost (100%), O&M cost (100%)	8
Case-2	Investment cost (50%)	Investment cost (50%), O&M cost (100%)	23
Case-3	Investment cost (70%)	Investment cost (30%), O&M cost (100%)	39

This project will contribute to not only compost production but also the environmental improvement of the Lake. The required cost should be borne by both government and private sector in a proper allocation. This project may be attractive for the participation of private sector when the government shoulders a considerable portion of the investment cost.

For the flow of cost and revenue, see Appendix K, Table K 2.1 to Table K 2.3.

10.4 Environmental Impact Assessment

Potential environmental impacts of the proposed projects, both positive and negative are described below along with recommended mitigation measures as required.

10.4.1 Impacts on Soil and Land

(1) Reserved Area/Paramos

The proposed projects do not include any land reformation in the reserved areas/paramos. No impact is expected.

(2) Lake Side Area

Dredging of the lake bed is proposed for the front zone of Bulrush to control the expansion of Bulrush toward the lake center. The dredged soils will reclaim approximately 50 ha of low pasture lands around the Lake in a height of 0.3–0.5 m, relieving the lands from floods. No adverse impacts are expected since the dredged soils are fertile and reclamation scale is not large.

10.4.2 Impacts on Water

(1) Hydrology and Hydraulics of the Lake

(a) Water Level

The drainage project will decrease the high water level of the Lake, resulting in reduction of the inundation area of 170 ha around the Lake.

(b) Outlet Water Flow

The aquatic plant control project will improve the discharge capacity of the lake outlet, resulting in reduction of the flood damages around the Lake and damages on the water use of the Suarez River.

(c) Storage Capacity

The aquatic plant control project will save 590,000 m^3 of storage capacity of the Lake by reducing the aquatic plant biomass.

(2) Surface Water Quality

(a) River Water

All the sewerage in the Study Area will be treated to 40 mg/l in BOD. This project will mitigate the river water quality from 8 mg/l to 4 mg/l in BOD at Colorado of the Ubate River and from 21 mg/l to 5 mg/l in BOD after the effluent of the Chiquiquira sewerage in the Suarez River.

(b) Lake Water

Further, the proposed sewerage treatment will improve the lake water quality; COD from 33 mg/l to 32 mg/l; T-N from 2.0 mg/l to 1.8 mg/l; T-P from 0.09 mg/l to 0.07 mg/l.

The excessive aquatic plants of the Lake will make the lake water seriously anaerobic, containing a toxic substance of H_2S. This will cause fatal damages on the aquatic lives and water uses in and around the Lake. The proposed aquatic plant control project will settle these problems.

The proposed dredging may make the lake water turbid during the construction phase. However, selection of a proper dredging method (e.g., pneumatic soil transportation dredging method with water pollution control curtain) could minimize negative impacts on the water quality in the Lake.

10.4.3 Impacts on Flora

(1) Potential Endangered Species

All the project sites will be on agricultural lands or in the lake area. There are no endangered species in this sphere. No impact is expected.

(2) Impact of Aquatic Plant Control

The aquatic plant control project will completely remove Water hyacinth of which existence was firstly recorded in 1979. The project will also decrease the Elodea biomass to 20% of the existing one by a combination of mechanical harvesting and grass carp feeding. The existence of Elodea was recorded in 1986 at first. The current high speed expansion of Bulrush toward the lake center will be controlled by the dredging of the lake bed. Thus, the existing excessive aquatic plants of the Lake will be removed to a desirable level.

There will be no meaningful biological impact with the proposed aquatic plant control project.

10.4.4 Impacts on Fauna

(1) Potential Endangered Species

There are no endangered species in or around the project sites. No impact is expected.

(2) Impact of Aquatic Plant Control

(a) Ecosystem of the Lake

There are no life forms in the deposits of the lake bed since the entire deposits are under anaerobic condition. Only worms and leeches are identified in the roots of Water hyacinth.

There are only four (4) species of fish of which exotic species are a kind of carp and gold fish. The proposed aquatic plant control will not damage their habitat.

There will be no meaningful biological impact with the proposed aquatic plant control projects.

(b) Grass Carp

Approximately 44,000 fingerlings of sterile triploid grass carp will be released in the Lake. Over-consumption of aquatic plants by the grass carps may cause damage to the ecosystem in the Lake. The damage could be prevented by controlling the number of grass carps through the proposed periodical monitoring of the ecology in the Lake.

The escape of grass carps from the Lake may cause unexpected ecological changes in the downstream. To prevent these ecological changes, sterile triploid grass carps will be released and an electrical fish barrier will be constructed at the outlet of the Lake.

10.4.5 Impacts on Social Environment

(1) Agriculture

The irrigation and drainage projects will improve water conditions of the pasture lands of 7,140 ha, resulting in additional milk production of livestock of 73,300 l/day.

(2) Public Health

The improvement of municipal water supply intake and purification plant of Chiquinquira will supply stable and clean water to the users, improving the public health of the city. Further, the proposed sewerage treatment will make the public water body clean, improving the amenity of the region.

(3) Sludge Disposal

Sludge from the sewerage treatment plant will be dried in the sun, and thereafter, it will be disposed on farmlands. However, this sludge disposal will not be frequent, only once in two (2) years. Odor of the treatment plant will not worsen the living environment of the people since all the plants are located far from residential areas.

(4) Resettlement

There will be no resettlement due to the projects.

(5) Water Right

At present, the irrigation water charge is determined based on the conditions of groundwater table, irrigation area, distance from canal, etc. Water right will be given to the new water users following this water charge system. The proposed optimum operation of Hato Dam/Lake and proposed additional irrigation facilities will increase available water in the future. Then, no adverse impacts will be caused on the existing water users.

(6) Compost Production

The composting of aquatic plants and marketing of the compost will save the cost for aquatic plant control of the government. This cost saving will enhance the environmental management of the government financially.

(7) Impact during Construction Phase

During construction phase, the construction sites will be subject to atmospheric pollution due to dust, noise and odor. However, it would be a temporary phenomenon and its affects will disappear when the construction works are completed.

10.4.6 Conclusion

In the overall assessment, the positive impacts of the projects will overweigh the negative ones. The most important positive impact is the recovery of the Lake. The Lake is a natural endowment of the Study Area from the viewpoints of physical, socio-cultural and biological resources.

Other major positive impacts include the increase of irrigation water availability, reduction of flood damage, improvement of public health, improvement of river/lake water quality, compost production, improvement of landscape, improvement of aquatic life habitat, etc.

The possible negative impacts are (i) temporary water turbidity in the Lake due to the dredging works, (ii) damage to the lake ecosystem due to the over-consumption of aquatic plants by grass carps, and (iii) unexpected ecological changes in the downstream of the Lake due to the escape of grass carps.

The first negative impact will be minimized by employing a proper dredging method (e.g., pneumatic soil transportation dredging method with water pollution control curtain). The second one will be prevented by controlling the number of grass carps through the proposed periodical monitoring of the ecology in the Lake. The third one will be prevented by the release of sterile triploid grass carps and construction of an electrical fish barrier at the outlet of the Lake.

As mentioned above, the proposed projects could be implemented with no significant adverse impacts on the environment.

CHAPTER XI RECOMMENDATIONS

11.1 Water Resources and Use Management

(1) The three (3) irrigation blocks of Suta, Cap-1 and Cap-2 are originally planned to receive water from Hato Dam. However, Hato Dam has not been fully used due to the lack of irrigation intake and distribution facilities. These irrigation systems should be implemented at the earliest time.

(2) Clearance of the Suarez River channel (removal of aquatic plants) will contribute to the lowering of flood water level of Lake Fuquene. However, the aquatic plants soon recover. Then, the channel clearance should be implemented periodically.

(3) The water purification plant of Chiquinquira should be improved immediately to meet the standard of drinking water quality along with the improvement of pump station.

(4) Hato Dam and Lake Fuquene should be operated in accordance with the proposed optimum operation rules. Aquatic plants in the Lake outlet and Suarez River should be well controlled to obtain the expected results of the proposed operation rule of the Lake.

(5) Rational irrigation water use is necessary along with the proposed improvement of irrigation system to mitigate the drought problems in the irrigation service areas. For this purpose, investigation on yield response to water consumption by underground and surface irrigation methods should be conducted in order to obtain the most efficient way of water use for crop cultivation in the drought irrigation areas.

11.2 Sewerage Treatment

Wastewater of the urban areas in the Study Area are mostly originated from Ubate and Chiquinquira cities. Improvement of the sewerage treatment system of both cities is important. Land for construction of the treatment plants are already available, then, construction should be started at the earliest time.

11.3 Aquatic Plant Control

(1) The excessive aquatic plants should be controlled by an integral method of dredging, harvesting/composting and grass carp.

(2) The harvested aquatic plants should be reused to the maximum extent to sustain a satisfactory environment of the Lake. Then, the harvesting, compost production and marketing should be implemented as a package under joint operation of both public and private sectors.

(3) Effectiveness of the dredging and applicability of the produced compost should be confirmed through a pilot project prior to the full scale implementation. The pilot project should be commenced at the earliest time.

(4) Compost of aquatic plants can effectively be used not only as fertilizer but also as soil conditioner since it contains much cellulose. Further studies are recommended to confirm the improvement of soil condition by the compost of aquatic plants.

(5) The ongoing experiment of grass carp should be continued to confirm the effectiveness of the aquatic plant control by grass carp. The ongoing experiment for the growth rate of Elodea should also be continued to reach a final conclusion of the required number of equipment for the mechanical harvesting.

11.4 Monitoring

For successful implementation of the proposed projects, the existing monitoring system of hydrology and water quality should be improved. Further, during and after implementation of the proposed aquatic plant control project, area of the aquatic plants (including biomass/species) and growth of the grass carp should be monitored periodically to confirm their effectiveness and to check adverse effects on the lake environments.

11.5 Environmental Education

For smooth implementation of the proposed projects, significance of the environmental conservation of the Study Area must be well understood by the people: water users, sewerage beneficiaries, factory managers and citizens. For this purpose, CAR should promote environmental education through frequent performance of seminar, campaign, publication, etc. by making the most use of the advantages that CAR is the largest information source of the environments of the Study Area.

Table 3.1 Yearly Water Balance at Each Irrigation Block (Present Condition)

(unit: 10^3 m^3/year)

Block	Irrigation Area (ha)	Ave. Water Resources	Average Water Use	Average Deficit	Average Surplus	5-year Probable Deficit
1. Suta	832	11,552	5,088	2,049	8,513	2,442
2. Cap-1	634	39,755	6,704	0	33,051	0
3. Cucunuba	1,892	11,795	9,265	0	2,530	0
4. Lenguazaque	1,751	40,979	10,707	1,219	31,490	2,464
5. Cap-2	316	40,529	2,177	0	38,351	0
6. Marino	700	1,344	4,280	3,652	716	3,826
7. Marino-Ubate	387	95,937	2,366	0	93,570	0
8. Fuquene	2,537	27,294	15,514	0	11,780	0
9. Honda	509	20,594	3,113	0	17,482	0
10. Susa	563	12,023	2,692	641	9,972	972
11. Suarez	8,309	182,149	36,760	0	145,390	0
13. Old-Suarez	228	278	988	877	168	928
14. Madron	1,359	11,907	5,888	2,893	8,912	4,520
15. Merchan	320	9,273	1,387	259	8,145	693
Total	20,337		106,929	11,590		15,845

Note: 1) Block No. 12 dose not exist at present.
2) Average deficit is calculated by averaging the yearly deficits during 20 years.
3) 5-year probable deficit is the 4 th largest yearly deficit during 20 years.

Table 3.2 Yearly Water Balance at Each Irrigatión Block (Future Condition)

(unit: 10^3 m^3/year)

Block	Irrigation Area (ha)	Ave. Water Resources	Average Water Use	Average Deficit	Average Surplus	5-year Probable Deficit
1. Suta	1,277	16,318	8,677	88	7,728	218
2. Cap-1	1,365	39,649	12,431	37	27,254	0
3. Cucunuba	1,892	11,793	9,271	6	2,528	0
4. Lenguazaque	2,309	39,572	14,127	2,673	28,118	4,610
5. Cap-2	1,582	38,506	10,750	97	27,853	62
6.Marino+7.Marino-Ubate*	1,087	70,958	6,651	2,353	68,078	3,580
8. Fuquene	2,537	27,299	15,522	0	11,776	0
9. Honda	509	18,710	3,114	0	15,597	0
10. Susa	563	11,790	2,694	0	9,096	0
11. Suarez	8,309	274,835	36,778	0	238,058	0
12. Simijaca	417	24,392	2,007	121	22,505	168
13. Old-Suarez	228	272,033	988	0	271,045	0
14. Madron	1,359	11,907	5,892	2,896	8,910	4,522
15. Merchan	640	294,558	2,775	0	291,782	0
16. Upper Honda	349	17,705	2,135	207	15,777	321
17. Upper Susa	426	11,500	2,038	351	9,813	588
Total	24,849		135,850	8,829		14,069

Note: 1) Average deficit is calculated by averaging the yearly deficits during 20 years.
2) 5-year probable deficit is the 4 th largest yearly deficit during 20 years.
3) *: Block No.6 Marino and block No.7 Marino-Ubate are integrated to maximize the water use efficiency in both blocks.

Table 3.3 Proposed Irrigatión Facilities and Beneficial Area

Irrigation Block	Future Irrigation Area (ha)	Irrigation Facilities				Beneficial Area (ha)
		Ditch (km)	Gate (nos.)	Pump (nos.)	Turnout (nos.)	
1. Suta	1,277	10.5	3	-	-	1,277
2. Cap-1	1,365	28.0	-	-	-	731
3. Cucunuba	1,892	-	-	-	-	-
4. Lenguazaque	2,309	21.4	3	-	-	761
5. Cap-2	1,582	31.8	-	-	-	1,266
6.Marino+7.Marino-Ubate*	1,087	7.6	1	-	1	313
8. Fuquene	2,537	-	-	-	-	-
9. Honda	509	-	-	-	-	-
10. Susa	563	11.9	1	1	-	563
11. Suarez	8,309	-	-	-	-	-
12. Simijaca	417	9.0	2	-	-	417
13. Old-Suarez	228	6.2	-	-	1	228
14. Madron	1,359	-	-	-	-	-
15. Merchan	640	7.6	1	-	-	640
16. Upper Honda	349	9.1	1	-	-	349
17. Upper Susa	426	8.9	2	-	-	426
Total	24,849	152.0	14	1	2	6,971

Note: 1) Block No.6 Marino and No.7 Marino-Ubate are integrated to maximize the water use efficiency

Table 5.1 Existing Point Pollution Load Effluent Flowing into Rivers

No.	Name of Municipality	Sewerage System					Factory				
		Q (m^3/d)	BOD (kg/d)	COD (kg/d)	T-N (kg/d)	T-P (kg/d)	Q (m^3/d)	BOD (kg/d)	COD (kg/d)	T-N (kg/d)	T-P (kg/d)
1	Carmen de Carupa	116.5	70.4	90.2	13.42	1.321					
2	Ubate	3,710.6	357.5	800.3	140.84	17.801					
3	Tausa	86.6	54.1	70.1	10.34	0.980	2.7	7.3	8.9	1.89	0.911
4	Sutatausa	51.2	29.1	36.5	5.53	0.582					
5	Cucunuba	102.2	9.5	21.3	3.74	0.473					
6	Lenguazaque	248.2	98.6	94.4	18.81	1.834					
7	Guacheta	460.8	175.8	223.2	33.48	3.396	2.7	7.3	8.9	1.89	0.911
8	San Miguel de Sema	140.3	10.5	23.6	4.14	0.524					
9	Fuquene	70.4	40.0	50.2	7.60	0.800	2.7	7.3	8.9	1.89	0.911
10	Susa	171.9	103.8	132.9	19.79	1.949					
11	Simijaca	820.1	342.9	426.7	73.28	19.234	92.5	74.0	90.6	19.17	9.250
12	Caldas	7.6	4.3	5.4	0.82	0.086					
13	Chiquinquira	7,587.0	2,167.8	2,718.8	416.55	50.471					
14	Saboya	96.6	1.2	2.6	0.46	0.058					
	Total	13,670.0	3,465.3	4,696.2	748.81	99.511	100.6	95.9	117.4	24.83	11.98

No.	Name of Municipality	Slaughterhouse					Total				
		Q (m^3/d)	BOD (kg/d)	COD (kg/d)	T-N (kg/d)	T-P (kg/d)	Q (m^3/d)	BOD (kg/d)	COD (kg/d)	T-N (kg/d)	T-P (kg/d)
1	Carmen de Carupa						116.5	70.4	90.2	13.42	1.321
2	Ubate						3,710.6	357.5	800.3	140.84	17.801
3	Tausa						89.3	61.4	79.0	12.23	1.892
4	Sutatausa	1.6	4.1	6.5	0.81	0.016	52.8	33.2	43.0	6.34	0.598
5	Cucunuba						102.2	9.5	21.3	3.74	0.473
6	Lenguazaque						248.2	98.6	94.4	18.81	1.834
7	Guacheta						463.5	183.1	232.2	35.37	4.307
8	San Miguel de Sema	0.3	0.7	1.1	0.14	0.003	140.5	11.2	24.7	4.29	0.527
9	Fuquene	3.0	7.5	12.0	1.50	0.030	76.1	54.8	71.1	10.99	1.741
10	Susa						171.9	103.8	132.9	19.79	1.949
11	Simijaca	5.9	14.8	23.7	2.96	0.059	918.5	431.7	541.0	95.40	28.543
12	Caldas	4.0	10.0	16.0	2.00	0.040	11.6	14.3	21.4	2.82	0.126
13	Chiquinquira	16.4	41.1	65.7	8.21	0.164	7,603.4	2208.8	2784.5	424.77	50.636
14	Saboya	3.0	7.5	12.0	1.50	0.030	99.6	8.7	14.6	1.96	0.088
	Total	34.3	85.6	137.0	17.13	0.343	13,804.9	3,646.8	4,950.6	790.77	111.837

Table 5.2 Future Point Pollution Load Effluent Flowing into Rivers without Project

No.	Name of Municipality	Sewerage System Q (m^3/d)	Sewerage System BOD (kg/d)	Sewerage System COD (kg/d)	Sewerage System T-N (kg/d)	Sewerage System T-P (kg/d)	Factory Q (m^3/d)	Factory BOD (kg/d)	Factory COD (kg/d)	Factory T-N (kg/d)	Factory T-P (kg/d)
1	Carmen de Carupa	195.3	115.5	147.0	22.00	2.216					
2	Ubate	4,846.9	676.4	1,514.4	266.50	33.684					
3	Tausa	97.2	60.4	78.2	11.55	1.101	2.8	7.6	9.3	1.96	0.948
4	Sutatausa	129.9	73.8	92.6	14.02	1.476					
5	Cucunuba	181.1	52.8	118.2	20.80	2.629					
6	Lenguazaque	384.5	132.9	297.5	52.35	6.617					
7	Guacheta	629.2	238.4	302.2	45.39	4.635	2.8	7.6	9.3	1.96	0.948
8	San Miguel de Sema	164.3	25.5	57.1	10.04	1.269					
9	Fuquene	99.6	56.6	71.0	10.75	1.132	2.8	7.6	9.3	1.96	0.948
10	Susa	158.7	96.6	124.2	18.44	1.798					
11	Simijaca	903.0	375.0	466.9	79.71	20.371	96.2	77.0	94.2	19.93	9.620
12	Caldas	54.6	31.1	39.0	5.90	0.621					
13	Chiquinquira	8,751.2	2,535.1	3,196.2	486.93	57.230					
14	Saboya	142.2	2.5	5.6	0.98	0.124					
	Total	16,737.7	4,472.6	6,509.9	1,045.37	134.904	104.6	99.7	122.0	25.82	12.463

No.	Name of Municipality	Slaughterhouse Q (m^3/d)	Slaughterhouse BOD (kg/d)	Slaughterhouse COD (kg/d)	Slaughterhouse T-N (kg/d)	Slaughterhouse T-P (kg/d)	Total Q (m^3/d)	Total BOD (kg/d)	Total COD (kg/d)	Total T-N (kg/d)	Total T-P (kg/d)
1	Carmen de Carupa						195.3	115.5	147.0	22.00	2.216
2	Ubate						4,846.9	676.4	1,514.4	266.50	33.684
3	Tausa						100.0	68.0	87.5	13.51	2.049
4	Sutatausa	1.8	4.6	7.3	0.92	0.018	131.7	78.4	100.0	14.94	1.494
5	Cucunuba						181.1	52.8	118.2	20.80	2.629
6	Lenguazaque						384.5	132.9	297.5	52.35	6.617
7	Guacheta						632.0	246.0	311.4	47.35	5.583
8	San Miguel de Sema	0.3	0.7	1.2	0.15	0.003	164.6	26.2	58.2	10.19	1.272
9	Fuquene	3.3	8.2	13.2	1.65	0.033	105.7	72.4	93.5	14.37	2.113
10	Susa						158.7	96.6	124.2	18.44	1.798
11	Simijaca	5.9	14.8	23.7	2.96	0.059	1,005.1	466.7	584.7	102.60	30.050
12	Caldas	4.1	10.3	16.5	2.07	0.041	58.8	41.4	55.5	7.97	0.662
13	Chiquinquira	19.0	47.5	76.0	9.50	0.190	8,770.2	2,582.6	3,272.2	496.43	57.420
14	Saboya	2.8	6.9	11.0	1.38	0.028	145.0	9.4	16.6	2.36	0.151
	Total	37.2	93.1	149.0	18.62	0.372	16,879.6	4,665.4	6,780.9	1,089.81	147.739

Table 5.3 Future Point Pollution Load Effluent Flowing into Rivers with Project

No.	Name of Municipality	Sewerage System Q (m^3/d)	Sewerage System BOD (kg/d)	Sewerage System COD (kg/d)	Sewerage System T-N (kg/d)	Sewerage System T-P (kg/d)	Factory Q (m^3/d)	Factory BOD (kg/d)	Factory COD (kg/d)	Factory T-N (kg/d)	Factory T-P (kg/d)
1	Carmen de Carupa	195.3	7.8	17.5	3.08	0.389					
2	Ubate	4,846.9	193.9	434.1	76.39	9.655					
3	Tausa	97.2	3.9	8.7	1.53	0.194	2.8	4.5	5.6	1.18	0.569
4	Sutatausa	129.9	5.2	11.6	2.05	0.259					
5	Cucunuba	181.1	7.2	16.2	2.85	0.361					
6	Lenguazaque	384.5	15.4	34.4	6.06	0.766					
7	Guacheta	629.2	25.2	56.3	9.92	1.253	2.8	4.5	5.6	1.18	0.569
8	San Miguel de Sema	164.3	6.6	14.7	2.59	0.327					
9	Fuquene	99.6	4.0	8.9	1.57	0.198	2.8	4.5	5.6	1.18	0.569
10	Susa	158.7	6.3	14.2	2.50	0.316					
11	Simijaca	903.0	36.1	80.9	14.23	1.799	96.2	46.2	56.5	11.96	5.772
12	Caldas	54.6	2.2	4.9	0.86	0.109					
13	Chiquinquira	8,751.2	350.0	783.7	137.92	17.432					
14	Saboya	142.2	2.5	5.6	0.98	0.124					
	Total	16,737.7	666.3	1,491.8	262.52	33.182	104.6	59.8	73.2	15.49	7.48

No.	Name of Municipality	Slaughterhouse Q (m^3/d)	Slaughterhouse BOD (kg/d)	Slaughterhouse COD (kg/d)	Slaughterhouse T-N (kg/d)	Slaughterhouse T-P (kg/d)	Total Q (m^3/d)	Total BOD (kg/d)	Total COD (kg/d)	Total T-N (kg/d)	Total T-P (kg/d)
1	Carmen de Carupa						195.3	7.8	17.5	3.08	0.389
2	Ubate						4,846.9	193.9	434.1	76.39	9.655
3	Tausa						100.0	8.4	14.3	2.71	0.762
4	Sutatausa	1.8	4.6	7.3	0.92	0.018	131.7	9.8	19.0	2.96	0.277
5	Cucunuba						181.1	7.2	16.2	2.85	0.361
6	Lenguazaque						384.5	15.4	34.4	6.06	0.766
7	Guacheta						632.0	29.7	61.9	11.09	1.822
8	San Miguel de Sema	0.3	0.7	1.2	0.15	0.003	164.6	7.3	15.9	2.74	0.330
9	Fuquene	3.3	8.2	13.2	1.65	0.033	105.7	16.8	27.7	4.40	0.800
10	Susa						158.7	6.3	14.2	2.50	0.316
11	Simijaca	5.9	14.8	23.7	2.96	0.059	1,005.1	97.1	161.1	29.15	7.630
12	Caldas	4.1	10.3	16.5	2.07	0.041	58.8	12.5	21.4	2.93	0.150
13	Chiquinquira	19.0	47.5	76.0	9.50	0.190	8,770.2	397.5	859.7	147.42	17.622
14	Saboya	2.8	6.9	11.0	1.38	0.028	145.0	9.4	16.6	2.36	0.151
	Total	37.2	93.1	149.0	18.62	0.372	16,879.6	819.2	1,714.0	296.64	41.032

Table 5.4 Existing Non-point Pollutant Sources by Sub-basin

Sub-basin	Sub-basin	Livestock			Land Area (km^2)			Rural
	Area (km^2)	Bovine	Pig	Sheet	Farmland	Pasture	Shrub/Forest	Population
Ubate River	225.19	16,792	7,594	11,774	132.75	56.93	33.44	18,481
Suta River	112.00	11,963	2,458	6,284	71.05	28.43	12.51	8,958
Cucunuba Lake	92.00	4,858	2,051	6,119	35.97	42.22	11.58	9,277
Lenguazaque River	293.00	28,128	4,150	16,617	154.09	115.84	22.96	15,107
Fuquene Lake	269.82	31,537	1,668	10,859	81.76	142.99	21.18	14,612
Sub-total	992.01	93,278	17,921	51,653	475.62	386.41	101.67	66,435
Susa River	64.00	9,094	1,398	3,144	28.42	26.54	8.97	3,078
Simijaca River	153.00	17,423	2,233	4,629	85.37	47.55	19.90	6,949
Suarez Residual*	123.27	23,924	1,267	1,832	38.17	76.72	8.29	7,342
Chiquinquira River	130.00	10,286	3,092	1,883	105.06	6.49	16.44	7,677
Sub-total	470.27	60,727	7,990	11,488	257.02	157.3	53.6	25,046
Total	1,462.28	154,005	25,911	63,141	732.64	543.71	155.27	91,481.00

*: Surez River Sub-basin between Lake outlet and Tolon

Table 5.5 Unit Pollution Load Generation by Each Source Category

Pollutant Source	Unit	BOD	COD	T-N	T-P
Livestock					
Bovine	g/head/day	600	1,484	378	56
Pig	g/head/day	200	364	40	25
Sheep	g/head/day	64	132	38	6
Land					
Farmland	$kg/m^2/day$	8.57	20.6	18.8	0.202
Pasture	$kg/m^2/day$	1.00	2.4	2.19	0.11
Shrub/Forest	$kg/m^2/day$	0.75	13.9	1.04	0.082
Household*	g/person/day	4.0	6.5	0.67	0.108

*:After septic tank treatment

Table 5.6 Existing Pollution Load Generation by Each Source

Basin	Source	BOD		COD		T-N		T-P	
		(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
Upper Basin of the Lake	Point (sewerage)	846	1.23	1,410	0.85	238	0.49	28	0.45
	Point (industry)	34	0.05	46	0.03	8	0.02	2	0.03
	Sub-total	880	1.28	1,456	0.87	246	0.51	30	0.49
	Non-point (livestock)	62,857	91.71	152,592	91.49	37,939	78.84	5,982	97.01
	Non-point (land)	4,539	6.62	12,311	7.38	9,894	20.56	147	2.38
	Non-point (household)	266	0.39	432	0.26	45	0.09	7	0.12
	Sub-total	67,661	98.72	165,334	99.13	47,877	99.49	6,136	99.51
	Total	68,541	100.00	166,790	100.00	48,123	100.00	6,166	100.00
Suarez River Basin	Point (sewerage)	2,619	5.95	3,284	3.43	511	1.73	72	1.86
	Point (industry)	140	0.32	196	0.20	32	0.11	9	0.23
	Sub-total	2,759	6.27	3,480	3.64	543	1.84	82	2.13
	Non-point (livestock)	38,767	88.05	85,841	89.69	23,711	80.37	3,700	95.90
	Non-point (land)	2,400	5.45	6,224	6.50	5,232	17.73	73	1.90
	Non-point (household)	100	0.23	160	0.17	17	0.06	3	0.07
	Sub-total	41,267	93.73	92,225	96.36	28,959	98.16	3,776	97.87
	Total	44,026	100.00	95,705	100.00	29,502	100.00	3,858	100.00
Study Area*	Point (sewerage)	3,464	3.08	4,694	1.79	748	0.96	100	1.00
	Point (industry)	174	0.15	242	0.09	40	0.05	11	0.11
	Sub-total	3,638	3.23	4,936	1.88	788	1.02	111	1.11
	Non-point (livestock)	101,624	90.28	238,433	90.83	61,650	79.42	9,682	96.60
	Non-point (land)	6,939	6.16	18,535	7.06	15,125	19.49	220	2.20
	Non-point (household)	366	0.33	592	0.23	61	0.08	10	0.10
	Sub-total	108,929	96.77	257,560	98.12	76,836	98.98	9,912	98.89
	Total	112,567	100.00	262,496	100.00	77,624	100.00	10,023	100.00

*: Simulation objective area (upstream of the confluence of Chiquinquira River: 1,462 km^2)

Table 5.7 Future Pollution Load Generation by Each Source (Without Project)

Basin	Source	BOD		COD		T-N		T-P	
		(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
Upper Basin of the Lake	Point (sewerage)	1,432	1.85	2,646	1.41	453	0.85	55	0.79
	Point (industry)	36	0.05	50	0.03	9	0.02	3	0.04
	Sub-total	1,469	1.90	2,696	1.43	462	0.86	58	0.83
	Non-point (livestock)	70,924	91.85	172,505	91.77	43,012	80.52	6,735	96.95
	Non-point (land)	4,539	5.88	12,311	6.55	9,894	18.52	147	2.11
	Non-point (household)	282	0.37	459	0.24	47	0.09	8	0.12
	Sub-total	75,745	98.10	185,274	98.57	52,953	99.14	6,889	99.17
	Total	77,214	100.00	187,970	100.00	53,415	100.00	6,947	100.00
Suarez River Basin	Point (sewerage)	3,038	6.12	3,836	3.25	591	1.80	80	1.85
	Point (industry)	150	0.30	210	0.18	34	0.10	10	0.22
	Sub-total	3,187	6.43	4,037	3.42	625	1.90	90	2.09
	Non-point (livestock)	43,910	88.52	107,435	91.15	26,948	82.10	4,149	96.16
	Non-point (land)	2,400	4.84	6,224	5.28	5,232	15.94	73	1.69
	Non-point (household)	106	0.21	173	0.15	18	0.05	3	0.06
	Sub-total	46,416	93.57	113,832	96.58	32,198	98.10	4,225	97.91
	Total	49,603	100.00	117,869	100.00	32,823	100.00	4,315	100.00
Study Area*	Point (sewerage)	4,470	3.52	6,472	2.12	1,044	1.21	135	1.20
	Point (industry)	186	0.15	260	0.09	43	0.05	13	0.12
	Sub-total	4,656	3.67	6,732	2.20	1,087	1.26	148	1.31
	Non-point (livestock)	114,834	90.55	279,939	91.53	69,960	81.13	10,883	96.63
	Non-point (land)	6,939	5.47	18,535	6.06	15,125	17.54	220	1.96
	Non-point (household)	389	0.31	632	0.21	65	0.08	11	0.10
	Sub-total	122,162	96.33	299,106	97.80	85,150	98.74	11,114	98.69
	Total	126,818	100.00	305,838	100.00	86,237	100.00	11,262	100.00

*: Simulation objective area (upstream of the confluence of Chiquinquira River: 1,462 km^2)

Table 5.8 Future Pollution Load Generation by Each Source (With Project)

Basin	Source	BOD		COD		T-N		T-P	
		(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
Upper Basin of the Lake	Point (sewerage)	269	0.35	596	0.32	106	0.20	13	0.19
	Point (industry)	27	0.04	37	0.02	6	0.01	2	0.03
	Sub-total	297	0.39	633	0.34	112	0.21	15	0.22
	Non-point (livestock)	70,924	93.27	172,505	92.79	43,012	81.06	6,735	97.55
	Non-point (land)	4,539	5.97	12,311	6.62	9,894	18.64	147	2.13
	Non-point (household)	282	0.37	459	0.25	47	0.09	8	0.12
	Sub-total	75,745	99.61	185,274	99.66	52,953	99.79	6,889	99.78
	Total	76,041	100.00	185,907	100.00	53,065	100.00	6,904	100.00
Suarez River Basin	Point (sewerage)	395	0.86	884	0.77	156	0.48	20	0.47
	Point (industry)	147	0.32	173	0.15	26	0.08	6	0.14
	Sub-total	541	1.17	1,056	0.92	162	0.50	26	0.61
	Non-point (livestock)	43,010	93.38	107,435	93.51	26,948	83.28	4,148	97.60
	Non-point (land)	2,400	5.21	6,224	5.42	5,232	16.17	73	1.73
	Non-point (household)	106	0.23	173	0.15	18	0.06	3	0.06
	Sub-total	45,516	98.83	113,832	99.08	32,198	99.50	4,224	99.39
	Total	46,057	100.00	114,888	100.00	32,360	100.00	4,250	100.00
Study Area*	Point (sewerage)	664	0.54	1,480	0.49	262	0.31	33	0.30
	Point (industry)	174	0.14	210	0.07	31	0.04	8	0.07
	Sub-total	837	0.68	1,690	0.56	294	0.34	41	0.37
	Non-point (livestock)	114,834	93.36	279,939	93.07	69,960	81.88	10,883	97.56
	Non-point (land)	6,939	5.64	18,535	6.16	15,125	17.70	220	1.98
	Non-point (household)	389	0.32	632	0.21	65	0.08	11	0.10
	Sub-total	122,162	99.32	299,106	99.44	85,150	99.66	11,114	99.63
	Total	122,999	100.00	300,796	100.00	85,444	100.00	11,155	100.00

*: Simulation objective area (upstream of the confluence of Chiquinquira River: 1,462 km^2)

Table 5.9 Existing Pollution Load Runoff by Each Source

Basin	Source	BOD		COD		T-N		T-P	
		(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
Upper Basin of the Lake	Point (sewerage)	846	29.19	1,410	12.29	238	22.97	28	21.36
	Point (industry)	34	1.17	46	0.40	8	0.77	2	1.53
	Sub-total	880	30.36	1,456	12.69	246	23.74	30	22.88
	Non-point (livestock)	1,890	65.20	9,244	80.58	627	60.50	99	75.51
	Non-point (land)	122	4.21	746	6.50	163	15.73	2	1.53
	Non-point (household)	8	0.28	26	0.23	1	0.10	0	0.00
	Sub-total	2,019	69.64	10,016	87.31	790	76.26	101	77.12
	Total	2,899	100.00	11,472	100.00	1,036	100.00	131	100.00
Suarez River Basin	Point (sewerage)	2,619	62.82	3,284	34.33	510	50.55	72	50.00
	Point (industry)	140	3.36	196	2.05	32	3.17	9	6.25
	Sub-total	2,759	66.18	3,480	36.38	542	53.72	81	56.25
	Non-point (livestock)	1,312	31.47	5,738	59.98	381	37.76	61	42.36
	Non-point (land)	94	2.25	339	3.54	86	8.52	2	1.39
	Non-point (household)	4	0.10	10	0.10	0	0.00	0	0.00
	Sub-total	1,410	33.82	6,087	63.62	467	46.28	63	43.75
	Total	4,169	100.00	9,567	100.00	1,009	100.00	144	100.00
Study Area*	Point (sewerage)	3,465	49.02	4,527	21.69	748	36.56	98	35.64
	Point (industry)	174	2.46	242	1.16	40	1.96	12	4.36
	Sub-total	3,639	51.49	4,770	22.85	788	38.51	110	40.00
	Non-point (livestock)	3,202	45.30	14,982	71.78	1,008	49.27	161	58.55
	Non-point (land)	216	3.06	1,085	5.20	249	12.17	4	1.45
	Non-point (household)	11	0.16	36	0.17	1	0.05	0	0.00
	Sub-total	3,429	48.51	16,103	77.15	1,258	61.49	165	60.00
	Total	7,068	100.00	20,873	100.00	2,046	100.00	275	100.00

*: Simulation objective area (upstream of the confluence of Chiquinquira River: 1,462 km^2)

Table 5.10 Future Pollution Load Runoff by Each Source (Without Project)

Basin	Source	BOD		COD		T-N		T-P	
		(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
Upper Basin of the Lake	Point (sewerage)	1,432	38.31	2,646	19.01	453	33.88	55	32.05
	Point (industry)	36	0.96	50	0.36	9	0.67	3	1.75
	Sub-total	1,469	39.30	2,696	19.37	462	34.56	58	33.80
	Non-point (livestock)	2,135	57.12	10,450	75.07	710	53.11	111	64.68
	Non-point (land)	126	3.37	746	5.36	164	12.27	2	1.17
	Non-point (household)	8	0.21	28	0.20	1	0.07	0	0.00
	Sub-total	2,269	60.70	11,224	80.64	875	65.44	114	66.20
	Total	3,738	100.00	13,919	100.00	1,337	100.00	172	100.00
Suarez River Basin	Point (sewerage)	3,038	63.70	3,826	34.99	591	51.12	80	50.00
	Point (industry)	150	3.15	210	1.92	34	2.94	10	6.25
	Sub-total	3,187	66.83	4,037	36.92	625	54.07	90	56.25
	Non-point (livestock)	1,484	31.12	6,508	59.53	445	38.49	68	42.50
	Non-point (land)	94	1.97	377	3.45	86	7.44	2	1.25
	Non-point (household)	4	0.08	11	0.10	0	0.00	0	0.00
	Sub-total	1,582	33.17	6,896	63.08	531	45.93	70	43.75
	Total	4,769	100.00	10,933	100.00	1,156	100.00	160	100.00
Study Area*	Point (sewerage)	4,470	52.54	6,472	26.04	1,044	41.88	135	40.79
	Point (industry)	186	2.19	260	1.05	43	1.72	13	3.93
	Sub-total	4,656	54.73	6,733	27.09	1,087	43.60	148	44.71
	Non-point (livestock)	3,619	42.54	16,959	68.24	1,155	46.33	179	54.08
	Non-point (land)	220	2.59	1,123	4.52	250	10.03	4	1.21
	Non-point (household)	12	0.14	38	0.15	1	0.04	0	0.00
	Sub-total	3,851	45.27	18,120	72.91	1,406	56.40	183	55.29
	Total	8,507	100.00	24,853	100.00	2,493	100.00	331	100.00

*: Simulation objective area (upstream of the confluence of Chiquinquira River: 1,462 km^2)

Table 5.11 Future Pollution Load Runoff by Each Source (With Project)

Basin	Source	BOD		COD		T-N		T-P	
		(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
Upper Basin of the Lake	Point (sewerage)	269	10.49	596	5.03	106	10.74	13	10.07
	Point (industry)	27	1.05	37	0.31	6	0.61	2	1.55
	Sub-total	296	11.54	633	5.34	112	11.35	15	11.62
	Non-point (livestock)	2,135	83.23	10,450	88.13	710	71.94	111	85.96
	Non-point (land)	126	4.91	746	6.29	164	16.62	2	1.55
	Non-point (household)	8	0.31	28	0.24	1	0.10	0	0.00
	Sub-total	2,269	88.46	11,224	94.66	875	88.65	114	87.99
	Total	2,565	100.00	11,857	100.00	987	100.00	129	100.00
Suarez River Basin	Point (sewerage)	395	18.60	884	11.12	156	21.88	20	20.83
	Point (industry)	147	6.92	173	2.18	26	3.65	6	6.25
	Sub-total	541	25.47	1,056	13.28	182	25.53	26	27.08
	Non-point (livestock)	1,485	69.92	6,508	81.84	445	62.41	68	70.83
	Non-point (land)	94	4.43	377	4.74	86	12.06	2	2.08
	Non-point (household)	4	0.19	11	0.14	0	0.00	0	0.00
	Sub-total	1,583	74.53	6,896	86.72	531	74.47	70	72.92
	Total	2,124	100.00	7,952	100.00	713	100.00	96	100.00
Study Area*	Point (sewerage)	664	14.16	1,480	7.47	262	15.41	33	14.73
	Point (industry)	174	3.71	210	1.06	32	1.88	8	3.57
	Sub-total	837	17.85	1,689	8.53	294	17.29	41	18.30
	Non-point (livestock)	3,620	77.20	16,959	85.61	1,155	67.94	179	79.91
	Non-point (land)	220	4.69	1,123	5.67	250	14.71	4	1.79
	Non-point (household)	12	0.26	38	0.19	1	0.06	0	0.00
	Sub-total	3,852	82.15	18,120	91.47	1,406	82.71	183	81.70
	Total	4,689	100.00	19,809	100.00	1,700	100.00	224	100.00

*: Simulation objective area (upstream of the confluence of Chiquinquira River: 1,462 km^2)

Table 9.1 Relevant Laws to Environment in Colombia

Subject	Norms	Contents
	National Constitution	Right and duties of the citizens, duties of the state
	Decree-Law 2811, 1974	Renewal Natural Resources
General	Law 99, 1993 and its regulations	Creation of the Ministry of Environment and the National Environemtal System (SINA)
	Law 9, 1979	National Sanitary Code
	Law 11, 1986 and Law 12, 1986	Municipal Administration
	Decree 1333, 1986	Municipal Regimen Code
	Law 33, 1986 and Decree 1344, 1974	National Code of Transport and Transit
	Decree 285, 1986	Storing and Distribution of Combustibles
	Law 9, 1989	Urban Reform
	Law 135, 1994	Mechanism of citizens participation
	Decree 1855, 1994	Regional Plans of Corporations
	Decree 1753, 1994; Decree 2150,1995; Resulution 655, 1996; Decree 883,1997	Environmental Licenses
	Decree 2278, 1982	Sacrifice and Commercialization of animals
	Law 115, 1993 and Decree 1753, 1994	Environmental Education Projects
	Decree 1865, 1994	Technical assistance of CAR to Municipalities for Municipal Environmental Plan elaboration
	Law 142, 1994	Regimen of the Public Services for households
	Law 388	Territorial Development
	Law 491, 1999	Ecological Insurance and Environmental Offense
Air	Decree 2, 1982	Atmospheric emissions of points sources
	Decree 948, 1995	Atmospheric Pollution
	Decree 2857, 1981 and Decree 2024, 1982	Hydrographic Basins
	Decree 1449, 1977	Resources conservation in rural lands
Water	Law 475, 1998	Potable Water Quality
	Decree 1594, 1984	Water use and wastewater
	Decree 2314, 1986	Water concession
	Agreement 58, 1987 of CAR	Water and discharging
	Agreement 10, 1989 of CAR	Water of Public Use
	Agreement 031, 1991 of CAR	General Regulation for the Functioning of Fuquene-Cucunuba Irrigation and Drainage District
	Law 373, 1997	Efficiente use and water saving
	Agreement 23, 1993 of CAR	Reforestation of Hydrics banks
	Agreement 53, 1981 of CAR	Flora & Fauna
	Decree 1449, 1977	Forests Areas of Protection
Fauna	Decree 1014, 1981	Concession and permission for forest resource
&	Decree 1608, 1978	Wild Life
Fauna	Decree 2143, 1997	Prohibition of burning
	Decree 919, 1989	Evaluation of erosive zones
Soil	Decree 1946, 1989; Decree 2379, 1991 Decree 1929, 1924	Technical Assistance for Agriculture- livestock (Umatas)
	Agreement 33, 1979 of CAR	Statute for Zoning
	Decree 919, 1989	National System for disasters
	Decree 2104, 1983	Solid Waste Management
	Decrees 2655, 2656, 2657, 1988	Mining Code
	Resolution N.222, 1994 of Ministry of Environment and Agreement N.246, 1994 of CAR	Compatible Areas with quarries
	Law 41, 1993	Land Adaptation

Table 9.2 Municipal Budget and Amount Assigned to Environmental Projects and Public Services in the Study Area

		Budget 1999 (thousands Col$)							
Municipalities	Total Municipal		Public Services (1)			Environmental Projects (2)		Total (1+2)	% *
		Water Supply	Sewerage	Slaughterhouse	Solid Waste	Env.Education	Reforestatión		
1. Carmen de Carupa	1,427,107	196,825	-	4,553	-	-	-	201,378	14.11
2. Ubaté	4,583,993	113,744	210,000	132,083	10,000	-	55,000	520,827	11.36
3. Tausa	1,187,467							135,133	11.38
4. Sutatausa	1,018,265	86,000	31,000	1,000	7,800	-	14,000	139,800	11.77
5. Cucunuba	1,547,957	110,718	58,900	11,600	500	-	3,000	184,718	18.14
6. Lenguazaque	2,170,296	158,346	15,000	-	5,350	-	-	178,696	8.23
7. Guachetá	1,639,136	166	25,000	-	-	-	11,623	36,789	2.24
8. San Miguel de Sema	1,190,185	145,510	5,500	-	-	-	16,466	167,476	14.07
9. Ráquira	2,001,150	119,311	26,400	-	15,000	-	15,000	175,711	8.78
10. Fúquene	939,755	103,937	10,000	-	10,000	-	-	123,937	13.18
11. Susa	1,189,933	80,200	25,104	-	2,000	-	32,000	139,304	11.70
12. Simijaca	1,370,175	109,615	34,000		48,040		4,500	196,155	14.31
13. Caldas	1,017,657	98,100	16,000	-	-	3,500	32,406	150,006	14.74
14. Chiquinquirá	7,289,903	166,630	-	-	-	-	259,046	425,676	5.83
15. Saboyá	550,654	119,863	-	-	-	-	74,939	194,802	35.37
Total	29,123,633	1,608,965	456,904	149,236	98,690	3,500	517,980	2,970,408	13.01
Total (US$)	15,169	838	238	78	51	2	270	1,547	

* = percentage of total budget assigned to environmental projects and public services

Exchange rate : 1US$=106¥=1,920 Col$ (October 1999)

Table 10.1 Implementation and Cost Disbursement Schedule of Proposed Projects

Classification	Project	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Implementation Shedule	1. Water Resources and Use Management												
	(1) Irrigation												
	(2) Drainage*												
	(3) Municipal Water Supply												
	2. Wastewater Treatment (Sewerage Treatment)												
	3. Aquatic Plant Control												
	(1) Dredging of Lake Bed		Pilot	Pilot									
	(2) Harvesting/Removal and Composting												
	(3) Control by Grass Carp												
Investment Cost Disbuersement Schedule	1. Water Resources and Use Management	-	-	2,095.0	1,033.1	1,682.0	1,205.0	1,185.0	1,967.0	2,013.0	2,338.0	2,311.0	15,829.1
	(1) Irrigation	-	-	2,035.0	877.0	1,496.0	1,007.0	1,005.0	1,967.0	2,013.0	2,338.0	2,311.0	15,049.0
	(2) Drainage	-	-	-	-	-	-	-	-	-	-	-	-
	(3) Municipal Water Supply	-	-	60.0	156.1	186.0	198.0	180.0	-	-	-	-	780.1
	2. Wastewater Treatment (Sewerage Treatment)	-	614.0	697.0	697.0	722.0	835.4	637.2	999.5	824.3	925.0	609.8	7,561.2
	3. Aquatic Plant Control	-	1,403.5	419.1	2,054.0	10,284.7	-	1,290.0	3,872.0	3,872.0	3,872.0	3,871.0	30,938.3
	(1) Dredging of Lake Bed	-	-	419.1	-	-	-	1,290.0	3,872.0	3,872.0	3,872.0	3,871.0	17,196.1
	(2) Harvesting/Removal and Composting	-	1,403.5	-	-	10,284.7	-	-	-	-	-	-	11,688.2
	(3) Control by Grass Carp	-	-	-	2,054.0	-	-	-	-	-	-	-	2,054.0
	4. Total Project (million Col$)	-	2,017.5	3,211.1	3,784.1	12,688.7	2,040.4	3,112.2	6,838.5	6,709.3	7,135.0	6,791.8	54,328.6
	4. Total Project (million US$)	-	1.05	1.67	1.97	6.61	1.06	1.62	3.56	3.49	3.72	3.54	28.30
O&M Cost Disbuersement Schedule	1. Water Resources and Use Management	-	-	-	-	-	-	-	-	-	-	-	-
	(1) Irrigation	-	-	-	-	-	95.4	124.7	163.7	184.6	256.1	293.1	-
	(2) Drainage **	-	-	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	-
	(3) Municipal Water Supply	-	-	-	-	-	-	-	-	-	-	-	-
	2. Wastewater Treatment (Sewerage Treatment)		233.6	233.6	233.6	335.4	335.4	391.0	391.0	468.6	525.3	681.0	-
	3. Aquatic Plant Control	-	-	-	-	-	-	-	-	-	-	-	-
	(1) Dredging of Lake Bed	-	-	-	-	-	-	-	-	-	-	-	-
	(2) Harvesting/Removal and Composting	-	105.0	210.0	210.0	105.0	1009.6	1009.6	1009.6	2529.6	1009.6	1029.0	-
	(3) Control by Grass Carp	-	-	-	25.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	-
	4. Total Project (million Col$)	-	338.6	482.1	507.1	528.9	1528.9	1613.8	1652.8	3271.3	1879.5	2091.6	-
	4. Total Project (million US$)	-	0.18	0.25	0.26	0.28	0.80	0.84	0.86	1.70	0.98	1.09	-

Note: 1) Implementation schedule includes the periods for D/D and land acquisition. 2) *: Drainage project does not include construction works. 3)**: O&M cost of Drainage is negligible.
4) ——— Investment Schedule, – – – O&M Schedule 5) Exchange rate: 1US$=106￥=1,920 Col$ (October 1999)