EXECUTIVE SUMMARY

1. INTRODUCTION

The Study Area covers the Ubate - Chiquinquira valley located 100 km northeast of Bogota City, the capital of Colombia. Lake Fuquene is situated in the center of the valley.

The water resources in the valley is not used effectively due to insufficient water intake and distribution system. Livestock, domestic and industrial wastewater cause pollution of the surface water. 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. Alleviation of these environmental problems is essentially necessary to sustain the economic development of the valley.

In response to the request of the Government of Colombia, the Japan International Cooperation Agency conducted the “Study on Regional Environmental Improvement Plan for the Basin of Lake Fuquene” from February 1999 to May 2000. The objectives of the Study are:

(1) To formulate a master plan for regional environmental improvement for the Basin of the Lake, targeting the year 2010; and,

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

2. STUDY AREA

2.1 River System

The Study Area covers the drainage basin of the Ubate-Fuquene-Suarez river system with an area of 1,752 km^2. The main river originating on the southern mountains, runs from south to north through the Ubate-Chiquinquira valley with an average elevation of 2,500 m. The upper reaches of the main river is called the Ubate River and lower reaches is called the Suarez River.

In the middle reaches of the main river, Lake Fuquene, with a surface area of 30 km^2, is located. The Lake collects water from the drainage basins of the Ubate River and its tributaries covering 992 km^2. The Lake is drained by only one (1) river, the Suarez River. The river system is shown in Fig. 1.

2.2 Socio-economy

2.2.1 Existing Socio-economy

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

*: Covers only rural area within the Study Area

Among them, 14 municipalities include their urban centers, while the remaining three (3) municipalities cover only rural areas within the Study Area.

The total population of the 17 municipalities was 229,011 in 1998, of which 180,941 or 79% live in the Study Area. The urban and rural populations in the Study Area are shown below compared to those in the related municipalities.

	Municipality	Study Area
Urban Population	86,245	75,844
Rural Population	142,766	105,097
Total Population	229,011	180,941

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

The land in the Study Area. is mostly used for pasture and agricultural purposes, while the coverage of such natural lands as forest, shrub and water area is small as shown below.

Category	Area (km^2)	(%)
Forest/ Shrub	169	9.7
Pasture	615	35.1
Pasture/Agricultural Rotation	929	53.0
Lake	30	1.7
Urban Area	9	0.5
Total	1,752	100.0

Major economic activities in the Study Area are livestock raising, agriculture and dairy production. Approximately 171,000 of cattle were raised for meat and milk production in 1998. The major crops are potato, wheat, pea and maize. There are 50 dairy factories that produce milk, yogurt and cheese.

Per capita GDP in the Study Area in 1997 is estimated at 2,801,200 Col$ (= 2,455 US$) by assuming the average value of Cundinamarca Prefecture.

2.2.2 Projection of Future Socio-economy

The total population of the Study Area in 2010 is estimated at 208,483 based on the projection of the National Administrative Department of Statistics (DANE). The urban and rural populations are shown below, compared with the existing ones.

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

The number of total cattle and cows for milk production in the Study Area has decreased during the recent years. However, they are assumed to recover to the maximum ones in the past respectively by 2010 as shown below, considering the economic importance of livestock and milk production industries in the Study Area.

Number	1998 (1)	2010 (2)	(2)/(1)
Total Cattle	171,402	195,324	1.14
Cow for Milk Production	69,240	72,315	1.04

Then, the milk industry is estimated to increase from 1998 to 2010 by 4% in proportion to the increase of number of cows for milk production.

The annual growth rate of national GDP in the future is assumed to be 0.0% during 1998 - 2000 and 4.0% during 2001 - 2010, based on the economic growth in the past. These growth rates are also applied for the Study Area.

3. WATER RESOURCES AND USE MANAGEMENT

3.1 Climate and Hydrological Features

3.1.1 Climate of the Study Area

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 City. The Study Area is characterized by two (2) dry and two (2) rainy seasons which alternately occur as shown below.

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 area to 1,500 mm in the northern end of the valley. Among them, approximately two-thirds occur during rainy season.

Neither significant increasing nor decreasing trend is recognized in the annual rainfall depth during the past 54 years, i.e., 1945 - 1998.

3.1.2 Water Level of Lake Fuquene

The average water level of Lake Fuquene during 33 years in the past was 2,538.97 m above sea level. 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 2,540.50 m and minimum level of 2,537.99 m during the same period. Historically, the maximum water level has lowered, while the minimum water level has risen gradually, decreasing the fluctuation range.

The rise of water level in the Lake cause flooding the surrounding areas. Small dikes are provided along the perimeter of the Lake to protect the low-lying areas from the 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). The water level - flood prone area curve is estimated 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

3.2 Water Use

3.2.1 Water Demand

(1) Irrigation Water

The irrigated areas covering 20,337 ha extend on the flat plane of the Ubate-Chiquinquira valley along the river system of Cucunuba Lake-Ubate River-Fuquene Lake-Suarez River. It is divided into 14 irrigation blocks depending on available water sources.

The irrigated area is mostly covered by pasture. The pasture is irrigated by subterranean irrigation method. Namely, the irrigation water is first taken from a river into the irrigation canal networks in the pastureland. Then, water in the canals is infiltrated into the underground of the pastureland. The pasture absorbs this groundwater by capillary action.

The flat lands neighboring the existing irrigation systems are further irrigable. The total irrigation area will be extended, from 20,337 ha in 1999 to 24,849 ha in 2010. For this purpose, three new (3) irrigation blocks will be developed.

The existing and future irrigation areas by each block are shown in Fig. 2, along with location of the irrigation blocks.

The irrigation water requirement is met by rainfall on farm and surface water. The total annual surface water demand at present and in the future are estimated as follows.

Item	Present (1999)	Future (2010)
Nos. of Irrigation Blocks	14	17
Total Irrigation Area (ha)	20,337	24,849
Surface Water Requirement (million m^3/year)	97.76 (3.10 m^3/s)	125.77 (3.99 m^3/s)

(2) Other Water

The other water uses in the Study Area are municipal water including domestic, institutional and industrial uses, and livestock water.

The existing municipal water supply system serves almost all the urban and some rural population with mostly conventional treatment. The remaining rural population who are not served by the above municipal water supply system are all served by individual small scale piped water supply system (called “vereda” water supply system).

The existing and future demands of municipal and livestock water are estimated as follows.

Item	Present (1999)	Future (2010)
Municipal Water (m^3/day)	32,147 (0.37 m^3/s)	37,342 (0.43 m^3/s)
Livestock Water (m^3/day))	5,547 (0.06 m^3/s)	6,219 (0.07 m^3/s)

3.2.2 Existing Water Storage and Intake System

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. However, Palacio Lake is almost dead due to sediment deposition. Their locations are shown in Fig. 3, along with the longitudinal profile of the related river system. Salient features of the reservoir and lakes are summarized below.

Name	Major Purpose	Dimension
Hato Reservoir	Irrigation, Municipal Water, Flood Control	Dam Height: 33 m, Total Storage: 14.4 x 10^6 m^3
Palacio Lake	Irrigation	Surface Area: 0.4 km^2, Total Storage: 290 x 10^3 m^3
Cucunuba Lake	Irrigation	Surface Area: 2.5 km^2, Total Storage: 6.8 x 10^6 m^3
Fuquene Lake	Irrigation, Municipal Water	Surface Area: 29.8 km^2, Total Storage: 50.0 x 10^6 m^3

3.2.3 Water Demand and Supply Balance

At present, 20,337 ha is irrigated by water taken from the dam, rivers and lakes. However, the total annual water demand of 97.76 million m^3/year (3.10 m^3/s) is not fully met and water deficit of 15.85 million m^3/year (0.50 m^3/s) occurs in a 5-year drought. This water deficit is attributable not only to the shortage of water resources but also to the lack of irrigation facilities. In fact, the Hato Dam is not fully used due to the lack of irrigation facilities in the downstream areas.

In the future, the irrigation area will extend to 24,849 ha, generating a total annual water demand of 125.77 million m^3/year (3.99 m^3/s). Full operation of Hato Dam and construction of additional irrigation facilities at proper locations will maximize the available surface water and mitigate water deficit of irrigation. Under the above mentioned improved conditions, the total water deficit in a 5-year drought will be controlled below 14.07 million m^3/year (0.45 m^3/s).

The existing and future water demand and supply balances are compared as follows.

Item	Present	Future
Irrigation Area (ha)	20,337	24,849
Annual Water Demand (million m^3/year)	97.76	125.77
Annual Water Deficit (million m^3/year)	15.85	14.07
Deficit Ratio (%)	16.2	11.2

Even in the future, severe deficit will occur in the following seven (7) irrigation blocks:

Lenguazaque, Mariño, Mariño-Ubate, Simijaca, Madron, Upper Honda and Upper Susa. This deficit is due to the shortage of water source. Then, it can not be solved without construction of new reservoirs or promotion of water use saving.

3.3 Optimum Operation of Hato Dam and Lake Fuquene

3.3.1 Hato Dam

The optimum operation rule for irrigation water supply is determined to meet the water requirement in the downstream without any deficiency or any excess in a 5-year drought. The monthly releasing water of the dam under the conditions of the existing and future water uses is shown below.

(unit: m^3/s)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Existing Release	0.10	0.10	0.10	0.00	0.05	0.05	0.10	0.10	0.00	0.00	0.00	0.10
Future Release	1.50	0.95	0.50	0.00	0.05	0.05	0.50	0.80	0.35	0.00	0.00	0.60

The optimum operation rule for flood control is determined to minimize the flood water release to the downstream by using the allocated storage capacity for flood control. Further, it is also determined to secure a sufficient safety of the dam against abnormally large floods. The proposed flood release - water level curve under the existing and future optimum operation rules for irrigation water supply 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
Existing Release (m^3/s)	0.0	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00
Future Release (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.

3.3.2 Lake Fuquene

The optimum operation rule of the Lake is determined to maintain the water level as high as possible to protect the lake environments during the dry season and to control flood peak water level below a certain level during the rainy season.

Operation water level is determined for dry and rainy seasons respectively. 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.

The target water level and operation water level under the conditions of the existing and future water uses with the optimum Hato Dam operation are proposed as shown below.

Water Level	Existing Condition (m)	Future Condition (m)
High Water Level (2-year Return Period)	2,539.46	2,539.41
Low Water Level (2-year Return Period)	2,538.52	2,538.56
Most Frequent Water Level	2,539.0 – 2,539.1	2,539.0 – 2,539.1
Operation Water Level (Dry Season)	2,539.1	2,539.1
Operation Water Level (Rainy Season)	2,538.9	2,538.9

3.4 Improvement of Water Resources and Use Management

3.4.1 Irrigation

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 are as follows.

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

For location of the proposed irrigation facilities, see Fig. 2.

3.4.2 Drainage

The low pasturelands around 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. An average annual inundation area of 170 ha will be reduced by the proposed project.

3.4.3 Municipal Water Supply

Improvement of the intake facilities and water purification plant of the Chiquinquira water supply system are necessary.

The pump has suffered from cavitation when the intake water level drew down below a critical level in dry season. Replacement of the existing pumps is proposed.

The existing water purification plant does not satisfactorily treat the raw water to meet the national standard. The treated water meets the standard in only 10 days per month in the parameters of turbidity and Fe. Hence, the following improvement works are proposed to supply stable and clean water to 45,500 people in Chiquinquira City.

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

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

3.5 Project Cost

The investment and annual O&M costs for the proposed projects are estimated as shown below at the prices of October, 1999.

Item	Investment Cost (million Col$)	Annual O&M Cost* (million Col$/year)
Irrigation	15,049.0	162.3
Drainage	-	38.5
Municipal Water Supply	780.1	Negligible
Total	15,829.1	200.8
Total (million US$ or million US$/year)	(8.25)	(0.10)

*: At the full operation time, Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

4. WATERSHED MANAGEMENT

The lands in the Study Area (1,752 km^2) are mostly cultivated for pastures and agricultural crops. Forest and shrub lands occupy only 169 km^2 or 9.7%. In these natural lands, four (4) reserved areas covering 53 km^2 are selected.

CAR completed the soil erosion control for the watersheds of the Suta River, Ubate River and Cucunuba Lake in 1995. The erosion control is being implemented for the remaining watersheds of the Study Area and will be completed by 2004.

The average annual sediment runoff to Lake Fuquene is estimated to be about 16,000 m^3/year. It is assumed to cause an annual sediment deposition of 1.6 mm/year on the lake bed. It will decrease to a significant extent in the future by the ongoing erosion control project of CAR.

5. WATER QUALITY AND POLLUTION CONTROL

5.1 Existing River and Lake Water Quality

The existing water quality, deposits quality and biological quality in the main river (Ubate and Suarez rivers) and Lake Fuquene are evaluated as follows.

5.1.1. River and Lake Water Quality

(1) The water quality in the upper reaches of the Ubate River is generally good.

(2) The water temperature of the Lake is moderate (around 17 ^{o}C) and little varies throughout the year.

(3) Lake Fuquene is considered highly eutrophic, judging from the T-N (1.83 mg/l) and T-P (0.07 mg/l) that much exceed the ordinary criteria of lake eutrophication (T-N>0.2 mg/l, T-P>0.02 mg/l).

(4) DO in the Lake and Suarez River is low due to decomposition of the withered aquatic plants that consume a lot of DO. Further, a wide lake area where aquatic plants densely grow is colored black, emitting a highly concentrated toxic substance of sulfide (H_2S).

(5) BOD in the river water is comparatively low. However, COD in both river and lake water is very high, which is considered due to a high content of humic acid in the water

(6) T-Fe is considerably high in both river and lake water, which is considered due to the

fact that soils in the Study Area contain a high degree of iron. A highly concentrated T-Fe is observed in the Suarez River where DO content is low and as a result, iron is in more dissolved state.

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

(8) 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.

(9) The wastewater from the sewerage systems of Ubate and Chiquinquira cities much affects the river water quality in the downstream at a drought time.

5.1.2 Deposit Quality in the River/Lake Bed

(1) The deposit quality in the river and Lake are highly polluted by organic matter and nutrients.

(2) The lake deposits are under a high anaerobic condition. The deposits contain much sulfide (H_2S) and are colored black or dark gray.

(3) No pesticides and heavy metals are detected in both river and lake deposits.

5.1.3 Plankton and Benthos

(1) The existing phytoplankton in the Lake is small in number throughout the year because of the comparatively low water temperature. Population of the existing zooplankton is also small.

(2) No benthos are identified in the deposits of the Lake due to the anaerobic condition of the deposits. This anaerobic condition is mainly caused by decomposition of the deposited aquatic plants and detritus on the lake bed.

5.2 Pollution Load Runoff

5.2.1 Pollutant Sources

(1) Sewerage

There are 15 sewerage systems in 14 municipalities of the Study Area. These sewerage systems collect the domestic wastewater of almost all the urban population of 75,800 in the Study Area, wastewater of seven (7) slaughterhouses and wastewater of 41 dairy factories.

However, only five (5) sewerage systems are provided with treatment plants. The wastewater of the remaining 10 sewerage systems is discharged into the rivers with no treatment.

(2) Slaughterhouse

Each of the 14 municipalities including their urban centers within the Study Area have one (1) livestock slaughterhouse. Among them, seven (7) slaughterhouses discharge into the respective sewerage systems and the remaining seven (7) discharge into the rivers directly. All the slaughterhouses are provided with treatment plants.

(3) Factory

There are 50 dairy factories in the Study Area among which 41 factories discharge wastewater into sewerage system and the remaining nine (9) factories discharge into the rivers directly. Among the 50 factories, only eight (8) factories have treatment plants.

(4) Non-point Source

The non-point pollution loads are generated from livestock, lands and rural households among which the load from livestock is extremely large. The existing livestock counts 171,000 heads of cattle, 30,000 of pig and 64,000 of sheep.

5.2.2 Pollution Load Runoff

The pollution loads generated from the above point and non-point sources runoff through the rivers to Lake Fuquene. The pollution load runoff to the Lake is estimated for the existing condition, and future conditions without and with project in 2010 as shown below. In this estimation, the pollution load runoff for future with-project is calculated based on the following assumptions.

(1) All the sewerage are treated to 40 mg/l in BOD.

(2) All the industrial wastewater (slaughterhouse, dairy factory) are treated to meet the CAR standards.

(unit: kg/day)

Load Parameter	Pollutant Source	Existing	(%)	Future without Project	(%)	Future with Project	(%)
BOD	Point	880	30.4	1,469	39.3	296	11.5
	Non-point	2,019	69.6	2,269	60.7	2,269	88.5
	Total	2,899	100.0	3,738	100.0	2,565	100.0
COD	Point	1,456	12.7	2,696	19.4	633	5.3
	Non-point	10,016	87.3	11,224	80.6	11,224	94.7
	Total	11,472	100.0	13,919	100.0	11,857	100.0
T-N	Point	246	23.7	462	34.6	112	11.4
	Non-point	790	76.3	875	65.4	875	88.6
	Total	1,036	100.0	1,337	100.0	987	100.0
T-P	Point	30	22.9	58	33.8	15	11.6
	Non-point	101	77.1	114	66.2	114	88.4
	Total	131	100.0	172	100.0	129	100.0

Livestock is the largest source of pollution load runoff followed by sewerage. Ratio of the pollution load runoff to the Lake by each source under the existing condition is shown below.

Pollutant Source	BOD (%)	COD (%)	T-N (%)	T-P (%)
Point (sewerage)	29.2	12.3	22.9	21.4
Point (industry*)	1.1	0.4	0.8	1.5
Non-point (livestock)	65.2	80.6	60.5	75.5
Non-point (land)	4.2	6.5	15.7	1.6
Non-point (household)	0.3	0.2	0.1	0.0
Total	100.0	100.0	100.0	100.0

*: Slaughterhouse and dairy factory

5.3 Water Quality Simulation

5.3.1 Simulated River Water Quality

(1) Standard River Discharge for River Water Quality Evaluation

River water quality fluctuates throughout the year, depending on the variation of river discharge. It is due to the dilution effects of river water. Hence, the river water quality should be evaluated with a proper standard river discharge.

In this Study, the river discharge with a probability of 75% is proposed as the standard one for evaluation of the river water quality, based on the analysis of the flow regime of Ubate River.

(2) Simulated River Water Quality

The river water quality at the principal river stations was simulated for the existing condition, and future conditions without and with project in 2010. The simulated BOD concentration in the river discharge of 75% probability is shown below.

River	Location	Discharge (m^3/s)	BOD (mg/l)		
			Present	Future without Project	Future with Project
Ubate	Colorado	1.14	5.3	7.9	3.9
Suarez	Tolon	1.15	3.2	3.5	2.8
Suarez	After Chiquinquira City	1.50	17.7	20.6	5.3

5.3.2 Simulated Lake Water Quality

The future lake water quality is simulated based on the future pollution load balance in the Lake. The simulated future lake water quality under the conditions of without and with project in 2010 are shown below, compared with the existing one.

Item	Existing	Future without Project	Future 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

5.3.3 Target Treatment Level of Wastewater

In Subsection 5.3.1, the future river water quality with project is simulated under the following conditions: (i) all the sewerage are treated to 40 mg/l in BOD and (ii) all the industrial wastewater (slaughterhouse and dairy factory) are treated in compliance with CAR standards.

On the other hand, CAR stipulated the target river water quality in the Study Area by categorizing the river section into four (4) classes. The simulated future river water quality with project are compared with the target river water quality of CAR as shown below.

River	Location	Future with Project	CAR Standard	
		BOD (mg/l)	Class	BOD (mg/l)
Ubate	Colorado	3.9	A	< 5.0
Suarez	Tolon	2.8	A	< 5.0
Suarez	After Chiquinquira City	5.3	B	< 10.0

Then, all the sewerage and industrial wastewater (slaughterhouse and factory) should be treated as assumed in the simulation to meet the target river water quality of CAR.

5.4 Improvement of Wastewater Treatment System

5.4.1 Sewerage Treatment

In this Study, only the improvement of sewerage treatment is proposed since almost all the urban areas are already covered by the existing sewer networks.

Among the existing 15 sewerage systems, only five (5) systems are provided with treatment plant. These are Ubate, Cucunuba, Lenguazaque, San Miguel de Sema and Saboya. However, the capacity of all the existing treatment plants are insufficient except Saboya. Hence, the existing four (4) treatment plants will be improved and further, new treatment plants will be installed for the remaining 10 sewerage systems to treat the wastewater of approximately 95,000 people.

The proposed treatment system, required additional facilities and required additional land space are summarized below.

Municipality	System	Additional Facilities	Required Land (ha)	Remarks
C. de Carupa	SP	2 facultative pond	1.3	New
Ubate	AL	2 aerated pond with aerator, 2 facultative pond	1.5	Improvement
Tausa	SP	1 anaerobic pond, 2 facultative pond	0.4	New
Sutatausa	SP	1 anaerobic pond, 2 facultative pond	0.5	New
Cucunuba	SP	1 anaerobic pond, 1 facultative pond	0.5	Improvement
Lenguazaque	AL	1 aerated pond with aerator, 1 facultative pond	0.5	Improvement
Guacheta	SP	3 pump, 2 facultative pond	2.3	New
S. M. de Sema	SP	2 facultative pond	0.9	Improvement
Fuquene (Fuquene)	SP	2 facultative pond	0.5	New
Fuquene (Capellania)	SP	1 anaerobic pond, 1 facultative pond	0.3	New
Susa	SP	2 pump, 2 facultative pond	1.1	New
Simijaca	SP	4 pump, 2 facultative pond	4.1	New
Caldas	SP	2 facultative pond	0.5	New
Chiquinquira	SP	4 pump, 2 anaerobic pond, 4 facultative pond	10.7	New
Saboya	-	-	-	Sufficient

Note: SP: Stabilization Pond, AL: Aerated Lagoon

5.4.2 Industrial Wastewater Treatment

(1) Slaughterhouse

Among the existing 14 treatment plants, two (2) plants of Caldas and Fuquene municipalities have insufficient treatment process. These two (2) treatment processes will be improved.

(2) Dairy Factory

All of the existing treatment plants installed at the eight (8) factories have sufficient capacity. New treatment plants will be constructed for the remaining 42 factories.

5.5 Project Cost

The investment and annual O&M costs for the proposed projects are estimated as shown below at the prices of October, 1999.

Item	Investment Cost (million Col$)	Annual O&M Cost* (million Col$/year)
Sewerage Treatment	7,561.0	831.0
Industrial Wastewater Treatment	231.0	27.0
Total	7,792.0	858.0
Total (million US$ or million US$/year)	(4.06)	(0.45)

*: At the full operation time, Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

6. AQUATIC PLANT CONTROL OF THE LAKE

6.1 Existing Aquatic Plants

6.1.1 Species and Characteristics

(1) Species

There are four (4) types of aquatic plants consisting of 17 species in Lake Fuquene at present as shown below.

Type	Submerged	Floating Leaf	Floating	Emergent
Number of Species	1	1	3	12

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

Brazilian Elodea was firstly identified by the 1986 survey. Water Hyacinth, Bulrush and Cattail were found in the 1979 survey.

(2) Characteristics

(a) Brazilian Elodea (submerged plant)

This is distributed over the shallower lake area than approximately 4.0 m. It hardly grows in the deeper area than 4.0 m due to the lack of photosynthesis effects. It easily reproduces after being harvested. Generally, it is about 1.0 m long, however, it sometimes extends up to 3.0 m in the Lake.

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.

(b) Water Hyacinth (floating plant)

This 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.

(c) 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. In the lake water, they mostly grow in the shallower area than 1.5 m.

(3) Reproduction Rate of Brazilian Elodea

Brazilian Elodea reproduces by striking plant fragments into soil or by sprouting from the harvested stems. Elodea of the Lake grows at a high speed. It is said to reproduce up to the original height in a short period after machine harvesting.

A field experiment was conducted to estimate the reproduction rates of Elodea after machine harvesting. The interim results are described below

The reproduction rate varies from location to location. The average reproduction rates are roughly estimated as follows.

	After Two (2) Months	After Three (3) Months
Reproduction Volume (kg/m^2)	1.92 (0.00 – 3.56)	2.38 (0.12 – 4.63)
Percentage to Original Volume (%)	12	15

Note: Original volume is assumed at 16 kg/m^2.

The experiment will further be continued to obtain the reproduction rate - time curve.

6.1.2 Distribution and Biomass

(1) 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	52.8
Cattail	57	3.6
Water Hyacinth mixed with Other Floating Plants	546	34.2
Water Hyacinth mixed with Brazilian Elodea	151	9.5
Sub-total	1,596	100.0
Brazilian Elodea*	804	
Water Surface	559	
Sub-total	1,363	
Total	2,959	

*: Visible area identified by aerial photo only. Additional invisible 400 ha exist under water.

The regional distribution of the aquatic plants are shown in Fig. 4.

(2) Biomass

The existing aquatic plant biomass is estimated as follows.

Type	Growing Area (ha)	Density (kg/m^2)	Biomass (wet ton)
Emergent	899	35.11	315,600
Floating	697	99.04	690,300
Submerged	1,204	16.38	197,300
Total	2,800		1,203,200

6.2 Projection of Future Aquatic Plant Area

6.2.1 Historical Expansion of Aquatic Plant Area

The aquatic plant area (emergent and floating plants excluding submerged plants) has propagated at a high speed, resulting in reduction of water surface area. The estimated historical propagation of aquatic plants or reduction of water surface area is summarized below, by adopting December, 1940 as the base time.

Date of Photos	Water Surface Area (ha)	Aquatic Plant Area (ha)*
Dec.11, 1940	3,071	-
Feb.16, 1989	1,881	1,190
May 15, 1999	1,363	1,708

*: Emergent and floating plants area only

The water surface area of the Lake has decreased at an average 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.

6.2.2 Replacement of Floating Plant by Emergent Plant

The above mentioned expansion of aquatic plants area (emergent and floating plants) has always been initiated by formation of floating plant 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.

6.2.3 Projected Future Aquatic Plant Area

The total emergent and floating plants area will reach 2,654 ha in 2020 if it continues expanding at a speed of 50.4 ha/year in the future. The emergent plants will cover 1,596 ha of the total area of 2,654 ha in 2020 if the existing floating plant area is completely replaced by emergent plants. Then, the remaining 1,058 ha will be floating plant area.

The floating plant area is assumed to increase at a constant growth rate every year. Then, it will increase from 697 ha in 1999 to 1,058 ha in 2020 at a growth rate of 2% per annum.

On the other hand, the submerged plant will be dead when it is covered by floating or emergent plants. Then, 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, comparing with the existing one. In 2020, approximately 90% of the Lake will be covered by the emergent and floating plants if no control measures are taken.

Classification	1999		2010		2020	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Emergent Plant	899	30.4	1,284	43.4	1,596	53.9
Floating Plant	697	23.6	867	29.3	1,058	35.8
Sub-total	1,596	54.0	2,151	72.7	2,654	89.7
Submerged Plant	1,204	40.7	649	21.9	146	4.9
Pure Water Area	159	5.3	159	5.4	159	5.4
Sub-total	1,363	46.0	808	27.3	305	10.3
Total	2,959	100.0	2,959	100.0	2,959	100.0

6.3 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.

6.3.1 Reduction of Storage Capacity of the Lake

Aquatic plants reduce the storage capacity of the Lake. However, only those in the shallow areas reduce the effective storage capacity since the deeper portion of the Lake is dead water. The reduction of the effective storage capacity will increase according to the propagation of aquatic plants in the future. The reduced effective storage capacities at present and in the future are estimated as follows.

Item	1999	2020
Total Biomass (ton)	1,203,200	1,632,100
Reduced Effective Storage (m^3)*	737,300	976,900

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

6.3.2 Deterioration of Lake Water Quality

Excessive aquatic plants make the lake water anaerobic. 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 an anaerobic condition.

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.

6.3.3 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 damages on the surrounding low areas of the Lake and damages on the water uses in the downstream of the Suarez River.

6.4 Proposed Aquatic Plant Control Measures

Aquatic plants grow by absorbing nutrients contained in the water and deposits of the Lake. However, it is difficult to reduce these nutrient sources, because the nutrients mostly come from the non-point sources, especially livestock into the Lake and are already much accumulated in the lake deposits. Then, the following control measures are proposed.

6.4.1 Dredging of the Lake Bed

Dredging of the front-zone of Bulrush will stop the expansion of Bulrush area toward the lake center since its habitat is usually limited to the wetlands or shallower water areas than 1.5 m. The excavated soils will be dumped on the low-lying lands around the Lake which are prone to habitual inundation.

A pilot project will be executed prior to the proposed full scale project to confirm the effectiveness of the dredging. The dredging works of the pilot and full scale projects are summarized below. For location of the proposed full scale project, see Fig. 4.

Item	Pilot Project	Full Scale Project
Dredging Zone Distance	1 location, 300 m	4 zones, 12,000 m
Dredging Width	20 m	20 m
Dredging Depth	2.0 m	2.0 m
Dredging Volume	12,000 m^3	480,000 m^3

6.4.2 Harvesting/Removal and Composting of Aquatic Plants

(1) General

Elodea in the Lake is being harvested by the governments at present. However, it soon recovers after machine harvesting, so that it must continuously be harvested. Removal of Water hyacinth is also urgent, however, disposal of the removed Water hyacinth is difficult due to its large quantity. Hence, use of the harvested/removed aquatic plants is the key for successful implementation of the project.

The harvested Elodea and removed Water hyacinth will be composted for the use of flower farming. In fact, compost is currently used for the flower farming. There are flower farms of approximately 4,000 ha in the metropolitan area of Bogota (mainly Zipaquira region). 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.

The uses for improvement of soil condition and for potato cultivation as an alternative of chemical fertilizer are both infeasible from economical viewpoint.

(2) Harvesting/Removal of Aquatic Plants

(a) Removal of Water hyacinth

Water hyacinth is extending at a high speed. Without project, the future biomass is projected to increase to 1.5 times of the existing one in 2020. The proposed project will decrease its biomass to approximately 50% of the existing one by 2010 and nearly zero in 2015, overcoming its high growth rate.

For this purpose, 75 ha (75,000 ton in wet weight) will be mechanically removed annually. The removal works consists of cutting floating islands by equipment, trawling by boat to port and unloading at port.

(b) Harvesting of Elodea

Elodea will be controlled by a combination of machine harvesting and grass carp feeding since grass carp eats Elodea much. This control works will be repeated every year.

Approximately 20% of the existing Elodea will be harvested by machine and the remaining Elodea will be controlled by grass carp. For this purpose, 240 ha (38,000 ton in wet weight) will be harvested by machine annually. The harvesting works consist of harvesting by machine, transportation by boat to port and unloading at port.

(3) Compost Production of Aquatic Plants

According to the field experiments of this Study, compost production of Elodea and Water hyacinth is technically viable. The chemical components of the compost satisfactorily comply to the standards of Colombian Agriculture and Livestock Institute (ICA). Concentration of heavy metals is negligible.

One (1) ton of compost is produced from seven (7) tons of raw aquatic plants. Annually, 16,100 ton of compost will be produced from the harvested Elodea and removed Water hyacinth by the proposed project. The required time for the compost production of Elodea and Water hyacinth is less than three (3) months and five (5) months respectively.

However, a pilot project will be executed prior to the full scale project to confirm the effectiveness of the compost for flower farming. The quantities of the pilot and full scale projects are summarized 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 area of compost yard is estimated to be 4.5 ha.

6.4.3 Control by Grass Carp

(1) General

The Grass Carp (*Ctenopharyngodon idellus*) 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 such soft aquatic plants as Elodea. It can live in a wide range of water temperature (0 - 35 °C). 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.

According to the field experiment of this Study, the grass carps have grown up from 75 g to 95.3 g during 90 days and they consumed Elodea by 70 g/day/fish on average. From this fact, the control of Elodea by grass carps is considered effective. This experiment will be further continued to establish the growth rate/consumption rate of grass carp - time curve.

(2) Elodea Control by Grass Carp

As mentioned before, approximately 20% of the existing Elodea will be harvested by machine and the remaining Elodea will be controlled by grass carp. For this purpose, 44,000 fingerlings of sterile triploid grass carp will be released into the Lake.

An electrical fish barrier will be constructed in the upper reaches of the Suarez River to block the grass carps swimming downward from the Lake.

6.4.4 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 estimated as shown below, comparing to the area without project.

(unit: ha)

Case	Aquatic Plant	1999	2010	2020
Without Project	Bulrush	899	1,284	1,596
	Water hyacinth	697	867	1,058
	Elodea	1,204	649	146
	Total	2,800	2,800	2,800
With Project	Bulrush	899	1,284	1,284
	Water hyacinth	697	376	0
	Elodea	1,204	Negligible	272
	Total	2,800	1,660	1,556

6.5 Project Cost

The investment and annual O&M costs for the proposed projects are estimated as shown below at the prices of October, 1999.

	Pilot Project	Full Scale project	Total
Investment Cost (million Col$)			
Dredging of Lake Bed	419.1	16,777.0	17,196.1
Harvesting/Removal and Composting	1,403.5	10,284.7	11,688.2
Control by Grass Carp	-	2,054.0	2,054.0
Total	1,822.6	29,115.7	30,938.3
Total (million US$)	(0.95)	(15.16)	(16.11)
Annual O&M Cost (million Col$/year)			
Dredging of Lake Bed	-	-	
Harvesting/Removal and Composting	210.0	1,009.6	
Control by Grass Carp	-	50.0	
Total	210.0	1,059.6	
Total (million US$/year)	(0.11)	(0.55)	

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

7. MONITORING

7.1 Improvement of Monitoring System

(1) For the optimum operation of the Hato Dam and Lake Fuquene, the existing hydrological monitoring system should be supplemented.

(2) The water quality of the Study Area has been monitored on ad hoc basis. It should be periodically monitored at the principal river stations, Lake Fuquene and major wastewater discharging points for promotion of the environment management of the Study Area. In relation to this, the existing laboratory of CAR should be improved.

(3) To know the effects or impacts of the proposed aquatic plant control projects on the environments of the Lake, the following changes should periodically be monitored: (i) change of aquatic plant area, (ii) change of species of fauna and flora (iii) change of Bulrush frontline and refilling in the dredged lake zone (iv) growth and consumption rates of grass carp.

(4) CAR has a GIS. This GIS should be employed to the maximum extent to manage the environment of the Study Area, based on the existing data and data collected by the above improved monitoring system.

7.2 Required Cost

The investment and annual monitoring costs required for the proposed improvement of monitoring system are estimated as shown below at the prices of October, 1999.

Item	Investment Cost (million Col$)	Annual O&M Cost (million Col$/year)
Hydrological Monitoring	3.6	0.4
Water Quality monitoring	1,419.4	142.8
Aquatic Plant Control Monitoring	-	13.1
Total	1,423.0	156.3
Total (million US$ or million US$/year)	(0.74)	(0.08)

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

8. ENVIRONMENTAL EDUCATION

8.1 Current Efforts in Environmental Education

No significant activity on environmental education has been performed in the Study Area. Generally speaking, there is no regular program on this field. However, some workshops and seminars are performed from time to time by CAR addressed to the community with the aim of creating the necessary awareness and changes of attitudes of the people on the environment.

8.2 Public Awareness on the Environment of Lake Fuquene

The people living in the Study Area have a high awareness on the deterioration of the environments of Lake Fuquene. They 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. In their opinion, the damages will be fatal to the economy and environments of the region.

8.3 Promotion of Environmental Education

An educational program to promote public awareness on environmental issues should be undertaken for the effective implementation of the projects proposed by this Study. The educational program will have the following four (4) objective levels: (1) Schools, (2) Farmers and Users of the Water District, (3) Dairy Factory Owners, and (4) General Public.

8.4 Required Cost

The investment and annual operation costs required for the proposed education program are estimated as shown below at the prices of October, 1999.

Item	Cost
Procurement of Education Equipment (million Col$)	65.7 (34.2 thousand US$)
Annual Operation of Education Program (million Col$/year)	48.0 (25.0 thousand US$/year)

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

9. IMPLEMENTATION PROGRAM AND PROJECT EVALUATION

9.1 Implementation and Cost Disbursement Schedules

9.1.1 Implementation Schedule

The proposed major project components 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 of 2001 – 2010 including detailed design and land acquisition periods in accordance with the priority sequence.

With regard to the projects of dredging of lake bed, and harvesting/removal and composting of aquatic plants, the pilot projects will be implemented prior to the full scale projects respectively.

The full scale dredging project will be implemented three (3) years after completion of the pilot project. Operation of the harvesting/removal and composting project will start immediately after completion of the compost yard construction and equipment procurement in both pilot and full scale projects. Three (3) years will be given for operation of the pilot project for harvesting/removal and composting.

The implementation schedules of the above projects are shown in Table 1.

9.1.2 Cost Disbursement Schedule

The estimated investment and annual O&M costs of the proposed projects are summarized below.

Project	Investment Cost (million Col$)	Annual O&M Cost* (million Col$/year)
Water Resources and Use Management	15,829.1	200.8
Irrigation	15,049.0	162.3
Drainage	-	38.5
Municipal Water Supply	780.1	0.0
Wastewater Treatment (Sewerage Treatment)	7,561.0	831.0
Aquatic Plant Control	30,938.3	1,059.6
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	54,328.4	2,091.4
Total (million US$ or million US$/year)	(28.30)	(1.09)

*: At the full operation time, Exchange rate: 1 US$ = 106 ¥ = 1,920 Col$ (October, 1999)

The disbursement schedules of the investment and O&M costs of the above projects are shown in Table 1.

9.2 Economic Analysis

9.2.1 Economic Benefits

The proposed master plan will generate the following major economic benefits.

(1) The irrigation and drainage projects will increase milk production of livestock on the

beneficial pastureland.

(2) Municipal water supply project will improve the public health of the users in the Chiquinquira City.

(3) Sewerage treatment project will improve the environments of the public water body and conserve the water resources.

(4) Aquatic plant control project will generate the following benefits: (i) compost production, (ii) reduction of water pollution and flood damages 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 above-mentioned economic benefits are estimated in monetary term as 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 (Sewerage 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)

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

9.2.2 Economic Evaluation

The economic efficiency of the proposed projects are evaluated in terms of economic internal rate of return (EIRR), benefit - cost ratio (B/C) and net present value (NPV) as follows.

Project	EIRR (%)	B/C*	NPV (million Col$)*
Water Resources and Use Management	26	2.2	10,899
Wastewater Treatment (Sewerage Treatment)	-	-	-
Aquatic Plant Control	5	0.8	- 4,553
Master Plan (Total Project)	10	1.0	0

*: Values for a discount rate of 10%

9.3 Financial Analysis

Financial analysis is made for the following three (3) sub-project components: (i) irrigation, (ii) sewerage treatment and (iii) compost production.

9.3.1 Irrigation

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) for 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 existing water charge system can cover the all O&M cost but can never cover the construction cost.

However, some portions 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.

9.3.2 Sewerage Treatment

The sewerage treatment charge (excluding charge for pipelines) for which the people in the Study Area are willing to pay at present is estimated to be 812 Col$/month/house or 0.12% of the average monthly household income (700,000 Col$/month/house) for domestic wastewater and 5,677 Col$/month/factory for industrial wastewater. The future affordable 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 above sewerage treatment charge can not cover even the O&M cost. The sewerage treatment charge for domestic wastewater should be raised from 0.12% to 0.25% of the household income to cover the O&M cost, at least. The sewerage treatment charge for industrial wastewater should be raised in proportion to the domestic wastewater charge.

9.3.3 Compost Production

(1) Bases for Financial Evaluation

The existing market price of compost is 140,000 Col$/ton in Zipaquira (largest consumption region). It can be converted to the selling price (122,000 Col$/ton) at the production site 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 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 compost produced in the pilot project stage will be given to the farmers free of charge since the project will be conducted for experimental farming.

(2) Results of 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.

9.4 Environmental Impact Assessment

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.

10. RECOMMENDATIONS

10.1 Project Implementation

(1) The three (3) irrigation blocks of Suta, Cap-1 and Cap-2 to be served by Hato Dam should be implemented at the earliest time.

(2) The water purification plant of Chiquinquira should be immediately improved to meet the standard of drinking water quality along with the improvement of pump station.

(3) Improvement of the sewerage treatment system of Chiquinquira and Ubate cities should be started at the earliest time.

(4) The excessive aquatic plants should be controlled by an integral method of dredging, harvesting/composting and grass carp. The harvested aquatic plants should be reused to the maximum extent to sustain the proposed aquatic plant control project. Then, the harvesting, compost production and marketing should be implemented as a package under joint operation of both public and private sectors.

(5) 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 projects should be commenced at the earliest time.

(6) The ongoing experiments of grass carp and growth rate of Elodea should be further continued to reach a final conclusion.

(7) 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 the most efficient way of irrigation water use should be conducted.

10.2 Monitoring and Optimum Operation of Dam/Lake

(1) For successful implementation of the proposed projects, the existing monitoring system of hydrology and water quality should be improved. Further, the effects of the proposed aquatic plant control project should be monitored.

(2) 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.

10.3 Environmental Education

Significance of the environmental conservation of the Study Area must be well understood by the people to attain a smooth implementation of the proposed projects. For this purpose, CAR should promote environmental education through frequent performance of seminars, information campaign, publication, etc. at various levels.

Table 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)