JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTERIO DEL AMBIENTE Y DE LOS RECURSOS NATURALES
RENOVABLES
THE REPUBLIC OF VENEZUELA

THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN

FINAL REPORT

VOLUME 5

SUPPORTING REPORT (II)
(SECTOR F TO J)

AUGUST 1997

CTI ENGINEERING CO., LTD.
KOKUSAI KOGYO CO., LTD.

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SECTOR F

SECUREMENT OF WATER QUANTITY

THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF
THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN

SECTOR F: SECUREMENT OF WATER QUANTITY

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SECTOR F: SECUREMENT OF WATER QUANTITY

1. METEOROLOGY AND HYDROLOGY

1.1 Available Data

An inventory of the meteorological and hydrometric stations in and around the study area is given in Table 1.1-1. The location of these stations is indicated in Fig. 1.1-1. The number of stations where data was collected is tabulated as follows:

Station Type	Organization			Total
	SM	MA	AC	
Climatology	1	1	-	2
Pluviograph	-	10	-	10
Pluviometer	-	-	1	1
Hydrometric	-	15	-	15

Note: SM: Aeronautical Meteorological Station
MA: MARNR
AC: Tuy River Basin Agency

The Team installed three automatic water level gages at the locations shown in Fig. 1.1-2.

The condition of observation, data filing, operation and maintenance at each station was investigated and compiled in "*Sistema de Control de los Recursos Hídricos en la Cuenca Alta y Media del Río Tuy, Septiembre 1995, GTZ*", which is summarized as follows:

<u>Climatological and Rainfall Stations</u>

A total of 13 stations exists in and around the study area (see Table 1.1-1). The data has been compiled on a master file by SINAIHME (Database of the Office of Hydrology and Meteorology, MARNR). In general, data gradually become inaccessible as time passes and the lack of resources for station maintenance affects the quality of information.

<u>Hydrometric Stations</u>

The majority of these 15 hydrometric stations stopped operations in the late 1970s when Ministry of Public Works (MOP) reformed to MARNR.

The monthly measurements of river flow up to 1993 have been compiled in the SINAIHME master file. It is, however, generally insufficient in quality because of data lost or interruption especially after 1978. The following four stations exist in the study area, but no continuous observations are being carried out. Accordingly, the data before 1978 will be generally used for the analysis.

Station name	River	Operation condition
Las Caballerizas	Tuy	The H-Q curve has not been updated, the profile has changed due to the erosion and sedimentation in the riverbed.
Ocumare del Tuy	Tuy	No data of levels is kept and no discharge measurement has been performed due to lack of adequate transportation means and confusion in responsibility between the Tuy River Agency and DHM (Directorate of Hydrology and Meteorology).
San Antonio	Tuy	DHM kept daily levels data up to May 1993, but no discharge measurement has been conducted.
Río Arriba	Guare	Observation of the water level is conducted. The data up to 1993 has been compiled in the master file, but with large voids in data.

1.2 General Climate

1.2.1 Large Scale Circulation

Throughout the year, but to varying degrees, Venezuela is under the influence of the equatorial trough and the Northern Hemisphere trade winds. The trade winds are present along the Caribbean coast year round and the equatorial trough never completely abate over the southern Guyana Highlands, although recurved Southern Hemisphere winds prevail there when the trough is at its farthest point north. Otherwise the generalization can be made that the trade winds occupy the country during the dry and warm part of the year ("verano" December-April) and the equatorial trough dominates during the wet and cool months ("invierno" May-November).

1.2.2 Geography and Meteorology

The entire Tuy River basin is located in the coastal north central region of the country, situated between the coordinates 65°25'W and 67°20'W and 10°00'N and 10°33'N. It covers a surface of approximately 6,600 km^2, comprising parts of Aragua and Miranda states and the Federal District.

On the entire river basin, the Study Area includes the upper and middle basins from El Consejo to the water intake at San Antonio. The Study Area is at 66°41'W to 67°20'W and 10°00'N to 10°26'N. Administratively, it covers a parts of Aragua and Miranda states.

The Study Area is bounded to the north by the southern slopes of the Coastal

Highlands, to the south by the northern slopes of Interior Highlands, to the east by the low lands of the lower Tuy River basin, and to the west by the watershed of the Valencia Lake basin.

The general orientation of the relief is in an east-west direction and the opening of the two highlands towards the west permits the penetration of air masses from the Caribbean Sea along the Barlovento Coast towards the plain and internal valleys of the basin. The air in movement towards the southwest is forced by the topography to lift, thus cooling and as a result causes precipitation mainly over the northern flank of the Interior Highlands, since it is oriented almost perpendicular to the predominant direction of the winds of the area.

In the case of Litoral Highlands, a great deal of humid air coming from the Caribbean Sea, ascends the north side, losing a great part of its water content through precipitation generated by the adiabatic lift, and descends the southern slope, towards the interior of the basin, as a drier mass of air.

The atmospheric precipitation in the area has its origin in the humid air coming from the Caribbean Sea; The rainy season is determined by the advance of the intertropical convergence zone between the months of May and August and the propagation of the east waves, mainly during the months of August and September, so as the modified cold fronts of the north, is hollowed to form the tropical depressions, whose presence is noted between the months of October and March. Due to the geographic location of the basin, 10 degrees north, the Study Area is influenced by the cold fronts from the north, whose consequence is the notable diminishing of the dry period

1.2.3 Climatological Data

The climatic condition of the study area is shown in Fig. 1.2-1 and the characteristics of climate are mentioned below:

<u>Temperature</u>

The monthly mean temperature is almost constant throughout the year. The difference between months is small; Even it is much smaller than fluctuation in daily temperature. Variation in altitude is more pronounced than the horizontal variation which is constant. The temperature in the middle basin of the Study Area, Cúa-Tovar to Santa Teresa is approximately 26°C on an average, while it is 15-17°C in the mountainous area, Colonia Tovar and Agua Fría in the upper basin.

The variation in maximum and minimum temperatures is small at ±1°C to 2°C from the average temperature in both mountainous and plain areas. At either locations, the maximum temperature occurs in May and the minimum in January.

<u>Relative Humidity</u>

Monthly variation of relative humidity is illustrated in Fig. 1.2-1. At Colonia Tovar, at an elevation of 1,435 m, the relative humidity is slightly higher than those in the lowlands varying from about 80% to 90%. In the relatively lower lands at Cúa-Tovar and Santa Teresa, these vary in the range from 70% to 80%.

The relation between the patterns of relative humidity and rainfall is clear at all the stations. It rises in May, at the beginning of the rainy season, and is lowest in March.

Winds

Data of mean wind velocity in the study area is available only at Colonia Tovar. According to these, no distinct variations are obvious throughout the year. It is slightly higher from January to March at about 3.3-3.5 km/hour and the lowest in November at about 2.5 km/hour.

The prevailing wind direction in Colonia Tovar is NW to NNW from January-April and SSE to ESE from May to December. In Cúa-Tovar, winds from ENE-ESE prevail throughout the year.

Evaporation

Annual evaporation is high at approximately 1,700 to 2,100 mm in the lowlands. The monthly evaporation ranges between 180-250 mm in the dry season and 110-150 mm in the rainy season. The monthly variation presents a peak in March, at the end of dry season, with higher values until May. It decreases when the rainy season starts.

1.3 Rainfall

1.3.1 Annual Rainfall

Average annual and monthly distribution of rainfall in the Study Area are illustrated in Fig. 1.3-1. The average annual rainfall ranges from 800 to 1,000 mm. In the flat valley in the areas of Cúa-Tovar to Santa Teresa, it is relatively higher at about 1,100 mm. It is less on the mountain slopes to the north and the south. The annual rainfall in the valley, namely, at El Consejo, Las Tejerías, Paracotos and Charallave is the lowest at about 800 mm.

Effect of the altitude is not very clear except in the area of northern mountains, even there it is not very distinguished. Geomorphological effect or difference by location on the basin is more pronounced to the amount of annual rainfall.

1.3.2 Monthly Rainfall

The monthly rainfall increases in May and continues until November or December at all the stations on the basin. Although some varieties exist by location, the rainy season is from May-December and the dry season in the rest of the year.

The rainfall pattern of Venezuela can be broadly divided into two; (1) the Llanos pattern which has a single maximum occurring during the high-sun months and distinct low-sun dryness; and (2) the semi-annual pattern which during the course of the year completes two oscillations between wet and dry. The Llanos pattern is characteristic of the entire central area of Venezuela, while the semiannual pattern is most prevalent over the coastal areas.

When this is compared to the patterns in the study area, the distribution in the lower lands in the east of Cúa is similar to the complete Llanos pattern. Areas in the western part, El Consejo and to the north, presents some influence of semi-annual pattern with two peaks in the year.

Approximately 95% of an annual rainfall concentrates in May to December. The dry season is very distinct from January to March nearly without rainfall.

1.3.3 Daily Rainfall

Daily rainfall distributions of representative stations are presented in Fig. 1.3-2. Annual number of rainy days in 1983 is 132 (4.4 months) at Las Tejerías and approx. 170 (5.7 months) at Colonia Tovar, Cúa-Tovar, Rio Arriba and Santa Teresa. Rainfall in the rainy season is usually 5-10 mm per day.

1.3.4 Short-term Duration Probable Rainfall Intensity

Fig. 1.3-3 presents 2-year return period probable 1-hour and 24-hour rainfalls calculated at each station in the study area. The rainfall in the study area is characterized by concentration in a short period.

1.4 River Morphology

The division of the catchment basin for major tributaries is presented in Fig. 1.4-1, and the longitudinal profile of the Tuy River and major tributaries is shown in Fig. 1.4-2. The river features, e.g., catchment area, river length, by tributary are summarized in Table 1.4-1. The catchment basin of the Tuy River at the water intake of San Antonio is 2,162 km^2, while the total river length is 129 km.

The Tuy River originates at near Colonia Tovar (EL 1,900 m), 10°25'00"N and 67°18'20"W. The river generally flows south in the mountainous area, joins a left bank tributary, the Lagunetas River at 127.3 km (a distance from the confluence point with the Guaire River at the downstream end of the medium Tuy River basin, the same for the other part of this report), and reaches to El Consejo at 114 km point.

At El Consejo, the Tuy River abruptly changes its direction to the east and flows in a 500 to 1,000 m wide valley until it arrives at Las Tejerías, 101 km point. In this area, it joins right bank tributaries of Tiquirito Canal (113.3 km point) and Qda. Morocopo (104.2 km point) and a left bank tributary of Qda. Guayas (100.5 km point).

After the Tuy River flows through the industrial zone in Las Tejerías, it joins the Cagua River, a right bank tributary with a catchment area of 49.9 km^2 at 93 km point. The river then flows down in a steep and rocky valley to Tácata. Human habitation is sparse along this stretch because of the steep terrain. Along this stretch with 87 km point, Qda. Maitana, a left bank tributary, flows into the Tuy.

The Tuy River flows southeastward near Tácata, joins the Guare River at 74 km point and the Aniagua River at 61.8 km point. The river gradient becomes gentler from around Tácata and further gentler from around Cúa. After Cúa, the river flows in a heavily meandered channel in a 1,000 m-wide flood plain. Both banks are used for orchards and other crop lands.

The Ocumarito River, a right bank tributary, and the Qda. Charallave flow into the Tuy River at 39 km point and at 36 km point, respectively. Ocumare del Tuy, the capital of Lander Municipality, is on the right bank near 35 km point. The river turns to the north here. San Francisco de Yare, the capital of Simon Bolivar Municipality is at 23.2 km point and it reaches the water intake at San Antonio at 15 km point.

1.5 Runoff

The purposes of river runoff analysis to be conducted in the present study are as follows:

- Confirmation of available water at water intake of San Antonio
- Development of tributary water for securement of water supply source

The available discharge data with a sufficient observation period in the study area are limited as discussed in 1.1. The following study has been conducted.

1.5.1 Discharge in the Tuy River at Toma de Agua

<u>Available Data</u>

As discussed in Section 1.1, the following data are available for the discharge of the main stream of the Tuy River.

Location	C.A. (km^2)	Observation Period
Hda. Barrios	248	1941-77
Hda. Tazon	1,180	1941-77
San Antonio	1,843	1989-92

<u>Historical Trend in Monthly and Annual Average Discharge</u>

The discharge at San Antonio includes supply from Camatagua Reservoir through Ocumarito Reservoir. Accordingly the discharge at Hda. Tazon shall be used for the discussion of the discharge of the Tuy River in the middle stream. Fig. 1.5-1 illustrates the monthly average, maximum and minimum discharges of the Tuy River at Hda. Barrios (248 km^2) and Hda. Tazón (1,180 km^2) for the 37-year period from 1941-1977. These values for 20-year period from 1958-1977 are presented in Table 1.5-1.

At both stations, it shows a pronounced decreasing trend in the discharges. It is assumably due to human intervention of water balance. Historical change in the annual average discharges of the Tuy River at Toma de Agua is presented in

Fig. 1.5-2. As seen in the figure, there is a decreasing trend in the annual average discharge. The degree of decrease, however, seems less in the latter years compared to 1940s and 50s.

Monthly Average Discharge

Monthly average specific discharges at Hda. Barrios and Hda. Tazón are as follows: Specific discharge at Hda. Barrios is small due to the use in the basin.

Monthly Average Specific Discharge of the Tuy River

$m^3/s/100km^2$

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Hda. Barrios	0.11	0.08	0.08	0.12	0.23	0.36	0.37	0.44	0.42	0.40	0.35	0.19	0.27
Hda. Tazón	0.23	0.16	0.12	0.12	0.21	0.51	0.61	0.83	0.68	0.70	0.51	0.34	0.39

Note: Values in $m^3/s/100km^2$ are calculated as: discharge divided by catchment area (km^2) and multiplied by 100.

The monthly discharge at Toma de Agua calculated on the basis of the specific discharge at Hda. Tazon is presented in Table 1.5-1. Monthly average values are as follows:

Monthly Average Discharge of the Tuy River

$m^3/s/100km^2$

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
San Antonio	4.34	2.91	2.14	2.22	3.89	9.49	11.27	15.31	12.60	12.93	9.39	6.29	7.19

Note: Data is calculated based on the specific discharge data at Hda. Tazón
Values in $m^3/s/100km^2$ are calculated as: discharge divided by catchment area (km^2) and multiplied by 100.

Flow Duration

Daily discharge data of the Tuy River is available at San Antonio. A flow duration curve has been accordingly prepared at San Antonio as presented in Fig. 1.5-3.

1.5.2 Discharge in Tributaries

Discharge data in tributaries of the Tuy River are available at the following stations:

Available Data

River	Location	C.A. (km^2)	Observation Period
Guare	Rio Arriba	92.0	1978-93
Ocumarito	El Desecho	122.7	1960-67

Monthly Average Discharge

At Rio Arriba in the Guare River, a right bank tributary that flows into the Tuy River at Tácata, relatively latest observed data from 1978 are available, but with a lot of missing data.

Accordingly as discharge data for tributaries, those at El Desecho in the Ocumarito River have been used. The monthly average discharge is presented in Table 1.5-2, and the daily discharge plot and the duration curve are illustrated in Fig. 1.5-4. Monthly average discharges are summarized as follows:

Monthly Average Discharge of the Ocumarito River

$m^3/s/100km^2$

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
El Desecho	0.84	0.61	0.42	0.31	0.55	1.49	2.71	3.78	3.02	1.95	1.49	1.42	1.56

Note: Catchment area: 122.7 km^2

Values in $m^3/s/100km^2$ are calculated as: discharge divided by catchment area (km^2) and multiplied by 100.

2. PRESENT CONDITION OF WATER SUPPLY SOURCE

2.1 Existing Dam/Reservoirs and Regulation Ponds

2.1.1 Major Features

Major features of reservoirs in and around the Tuy River basin are presented in Table 2.1-1. The summary of those features is represented by effective storage capacity in the table below:

Reservoir and Regulation Pond	Effective Storage Capacity (million m^3)
Ocumarito	8.4
Lagartijo	70.0
Taguacita	2.0
Camatagua	1,532.1
Qda. Seca	6.5
La Mariposa	7.0
La Pereza	8.0

2.1.2 Function

The functions of the reservoirs are summarized as follows:

(1) Ocumarito Reservoir

Water stored in Ocumarito Reservoir is supplied through Ocumarito treatment plant to the cities of middle basin area of the Tuy River, namely, Ocumare del Tuy, Cúa, Charallave, San Francisco de Yare, Santa Teresa and Santa Lucia. The supply capacity of Ocumarito treatment plant is 1.06 m^3/s.

Another function of the Ocumarito Reservoir is to receive supplementary water from Camatagua Reservoir at Caicita, the upstream end of the Ocumarito Reservoir basin. It is called as Camatuy system. Camatagua Reservoir is the water source of Tuy III system. Water supplemented from Camatagua Reservoir is released into the Tuy River through the Ocumarito River during the low flow period of the Tuy River. This water is then pumped up to Tuy I system at the San Antonio intake.

(2) Lagartijo Reservoir

Lagartijo Reservoir is mainly a water source of the Tuy II system, which is connected also to Tuy I system.

(3) Taguacita Reservoir

Taguacita Reservoir is also a water source of Tuy II system, which is also connected to Tuy I system.

(4) Camatagua Reservoir

Camatagua Reservoir, a multipurpose one, is on the Guárico River, a tributary of the Apure River, with the functions below:

- Water source of Tuy III system
- Water source for the Hidrocentro system
- Irrigation (6,000 ha)
- Recreation

(5) Qda. Seca Reservoir

Qda. Seca Reservoir regulates pre-treated water of a pre-treatment facility at San Antonio. The construction of the reservoir has recently been completed to receive water from Tuy III system.

(6) La Mariposa Reservoir

La Mariposa Reservoir is in the Guaire River basin, where Metropolitan Caracas is located. It has been created in 1950s as a water source for the supply to Caracas. It is presently used as a regulation reservoir to Mariposa treatment plant.

(7) La Pereza Regulation Pond

La Pereza Regulation Pond has the highest altitude in Tuy II system. The water is pumped up to the pond for regulation before La Guaicita treatment plant.

2.1.3 Operation Condition of the Reservoirs

These reservoirs' daily stored water volume for the 11-year period for 1986-96 are plotted in Fig. 2.1-1 which is discussed as follows:

(1) Ocumarito Reservoir

According to the record, Ocumarito Reservoir is in full capacity for 4.3 months of the year on average. This means that water flowing into the reservoir in this period is spilled over and flown downstream. If the total water volume including this spilled water from Ocumarito Reservoir at the intake of San Antonio exceeds the intake capacity, water flows down without use.

(2) Lagartijo Reservoir

An intake capacity of 7.0 m^3/s is designed for Lagartijo Reservoir. Spill rarely occurs and water stored in the reservoir is effectively used.

(3) Camatagua Reservoir

It has a large capacity of 1,530 million m^3 and seldom spills water. The water for Tuy-III system is taken from Camatagua Reservoir basically to supply the Tuy-I and Tuy-II systems.

(4) Qda. Seca Reservoir

The reservoir had been used by 1993 mainly in the dry season of December to April. Based on the reservoir operation results, it has not been effectively used since 1994.

(5) La Mariposa Reservoir and La Pereza Reservoir

From the reservoir curve, it is used for a short time (daily or weekly) regulation.

2.2 Status of Presently Proposed Water Resources Development Project

<u>Tuy IV Taguaza System</u>

Tuy-IV and Taguaza-Ciudad Fajardo System is presently under construction. The outline and progress of the work is as follows:

The purpose is to complement water supply systems of the Metropolitan Area of Caracas and Ciudad Fajardo (Guarenas, Guatire and Caucagua). Source of the water is Taguaza and Cuira reservoirs to be constructed on the right bank tributaries of the Tuy River. Water to Metropolitan Caracas area is delivered by Tuy-IV system to Caujarito treatment plant. The capacity of Tuy IV system is 8.0 m^3/s with Taguaza Reservoir and 10 m^3/s with Cuira Reservoir.

The pipe for water transmission from Taguaza Reservoir to Caujarito treatment plant is 51.75 km-long and 3,000 mm-diameter.

Currently Taguaza Dam and a water transmission system is under construction. Taguaza dam has progressed to 60%. Of the 52 km transmission pipe line, 25 km has been completed.

<u>Taguaza-Taguacita Interconnection</u>

Taguaza-Taguacita interconnection project is presently proposed for construction. This project is to divert water stored in Taguaza Reservoir to Taguacita Reservoir through a connection pipe. The connection pipe has a capacity of 4.0 m^3/s, and annual average developed water is approximately 1.5 m^3/s. According to the plan of Hidrocapital, it will start operation when Taguaza Dam is embanked to a 4×10^6 m^3 of the final volume of 6×10^6 m^3. However, construction of the interconnection pipeline has not started.

2.3 Possible Water Supply Source in the Study Area

As discussed in the previous sections, the present river water use in the upper and middle stream of the Tuy River basin is the following:

- Intake at San Antonio by Hidrocapital
- Intake at Ocumarito Reservoir
- Intake at Lagartijo Reservoir

The potential sites for supplemental water supply sources in the study area are studied from the view of water quality and quantity and identified as listed below (see Table 2.3-1):

River	Location	Catchment Area (km^2)
Cagua River	Upstream of confluence of the Tuy River	49.9
Guare River	Tácata	186.0
Aniagua River	Upstream of confluence of the Tuy River	53.3
Tarma River	ditto	78.0
Sucuta River	ditto	65.0
Ocumarito River	ditto	122.7

3. MASTER PLAN STUDY FOR THE SECUREMENT OF WATER QUANTITY

In this part of the report, target and policy to secure water quantity have been confirmed firstly. Applicable measures are accordingly identified, and the optimization study has been conducted:

3.1 Confirmation of Target and Policy

On the basis of the present problems on water quantity as identified in the previous part, the target for the securement of water quantity has been defined as follows:

- Stable water supply to the Caracas Metropolitan Area
- Securement of water for the demand increase in the Caracas Metropolitan Area

To achieve the stable water supply to Caracas Metropolitan Area, it is important to maximize the use of water in the upper and middle streams of the Tuy River. Maximization of the use of water would be attained by utilizing water that would otherwise be wasted at Toma de Agua. It would resultantly reduce the dependency on Tuy III system. The Tuy III system has higher potential of water supply failures due to long pipelines with many pumps.

For the securement of water for the demand increase in the Caracas Metropolitan Area, the concrete target has been obtained as follows: The amount of 19 m^3/s is presently being taken by Hidrocapital for water supply to the Caracas metropolitan and neighboring areas. To cope with the demand increase due to population increase, Hidrocapital is presently implementing Taguaza-Taguacita Interconnection Project. The project will increase the above amount by approximately 1.5 m^3/s. This increase of 1.5 m^3/s roughly corresponds to a 8% of the current water intake of 19 m^3/s. The increase of 8% will cover the population increase for approximately 4 years since the population increase rate in the area is about 2.2%. Consequently, a water shortage is foreseen after then unless new water sources are secured, because it will take a longer time to complete the Tuy IV system. The system would cope with the future water shortage with the water intake capacity of about 8 m^3/s.

Accordingly, the concrete target for the securement of water quantity is: to develop by the year 2003 approximately 2.0 m^3/s of water that would otherwise be wasted in the upper and middle streams of the Tuy River basin. The adequacy of this quantity, however, should be confirmed through a study on the availability of water resources in the study area.

Item	Value
Monthly average secured water from the upper and middle streams of the Tuy River basin	4.0 m^3/s
Intake at Toma de Agua	2.0 m^3/s
Newly developed water	approx. 2.0 m^3/s

3.2 Applicable Measures

Applicable measures for the development of water in the upper and middle streams of the Tuy River basin include the following:

(1) Torrent Diversion

Water of tributaries are taken and diverted to the existing reservoirs or to regulation ponds to minimize spill at Toma de Agua in the rainy season.

(2) Effective Utilization of Existing Reservoirs

According to the results of the study to secure a water supply source as presented in Section 2.1, Ocumarito Reservoir is full to capacity for 4.3 months of the year on average. During this period, water is spilled from Ocumarito Reservoir and is finally flown down at Toma de Agua.

Accordingly, utilization plan for the Ocumarito River is studied to minimize spill at Toma de Agua in the rainy season.

(3) Development of New Dams

Construction of dams on tributaries to minimize spill at Toma de Agua in the rainy season is considered. Guare Dam and El Peñón Dam are the possible ones.

3.3 Optimization of Alternative Measures

The optimum plan for each alternative measure is studied and determined. A master plan study has been conducted for the torrent diversion plan. For the utilization plan of the Ocumarito River, Guare Dam plan and El Peñón Dam Plan, pre-feasibility studies have been conducted as presented in "4. Pre-Feasibility Study on Water Resources Development" and the final results are presented in this section.

3.3.1 Torrent Diversion

Method of Torrent Diversion

The following five tributaries are studied (see Fig. 3.3-1). All these tributaries are located on the right bank of the Tuy River.

Name of Tributary	Catchment Area (km^2)
Cagua	49.9
Guare	186.0
Aniagua	53.3
Tarma	78.0
Súcuta	65.0
Total	432.2

Water is taken at an intake structure (see Fig. 3.3-2) and transported by a diversion pipeline to the existing reservoir for storage to minimize spill at Toma de Agua in the rainy season. For transportation, gravity flow is considered for no operation costs. Diversion of water in the dry season when water is not spilling at Toma de Agua is not considered because this will cause the deterioration of water in the Tuy River

Existing Reservoirs Available for Use

The availability of the existing reservoirs is studied. Topographically, three reservoirs can be used, namely Ocumarito Reservoir, Qda. Seca Reservoir and Lagartijo Reservoir. Historical reservoir operation curves at each reservoir are presented in Fig. 2.1-1 and the possibility of use is studied. As a result, it has been confirmed that only Lagartijo Reservoir could be used.

- Ocumarito Reservoir : According to the operation records, the reservoir is full to capacity level 4.3 months a year on average. Therefore, no capacity is available for use.
- Qda. Seca Reservoir : The capacity is planned to be used for the regulation of water supply from the Tuy III system (construction of diversion structure is completed), so that no capacity is available.
- Lagartijo Reservoir : In accordance with the operation curve, available capacity for each year is obtained as tabulated below.

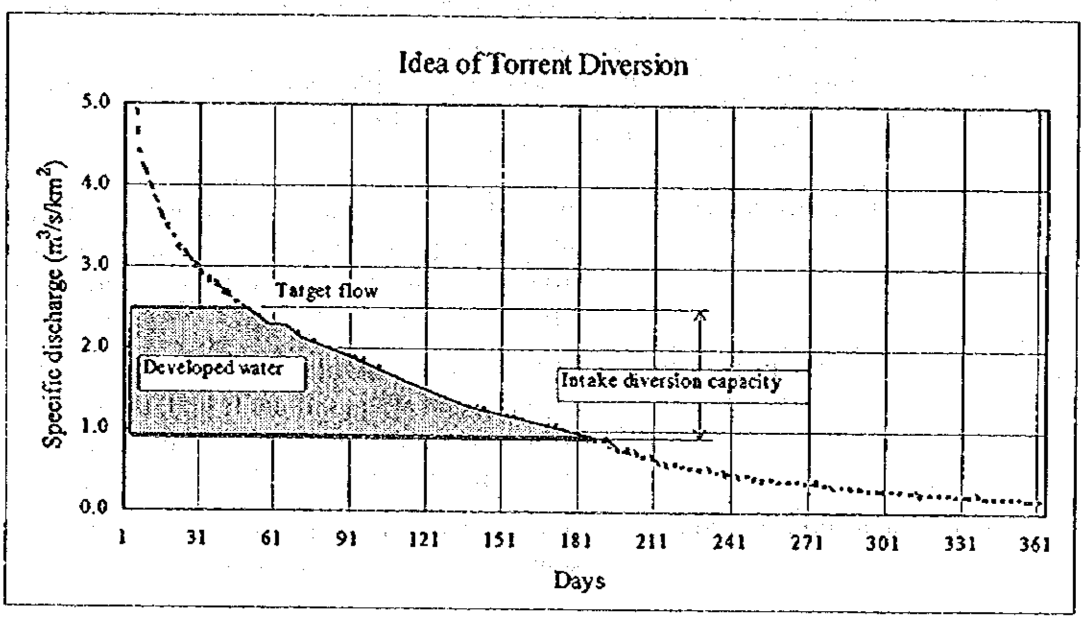
(Unit: million m^3)

Year	Available capacity
1986	0
1987	0
1988	15
1989	57
1990	0
1991	15
1992	2
1993	48
1994	32
1995	57
1996	0

Flow Duration and Water Volume to be Taken at the Intake

A flow duration curve is available for the Ocumarito River, a tributary of the Tuy River. This is used to obtain the possible water volume to be developed. The flow duration curve is presented in Fig. 1.5-4. The possible water volumes to be taken at the intake are as follows:

The torrent diversion plan is proposed to develop water to minimize spill at Toma de Agua in the rainy season. It has been determined that the water exceeding 50% discharge of the flow duration curve up to the target flow would be diverted to Lagartijo Reservoir as presented in the illustration below. The reason is as follows: The period when water of the Tuy River is spilling at Toma de Agua has been checked. The simulated flow of the Tuy River at San Antonio for 1972-78 exceeds the monthly average intake capacity at 5.5 m^3/s of Toma de Agua for six month a year on average (see Fig. 3.3-3).



The water volume taken at the intake by target flow is as follows:

Target flow ($m^3/s/100km^2$)	Intake water volume (mcm/year)
0.933 (50% in duration curve)	0.00
1.0	1.03
1.5	7.26
2.0	11.60
3.0	15.95
4.0	17.54

Note: Values are of 100 km^2

Volume of Water to be Developed

The water volume to be taken at the intake and diverted to Lagartijo Reservoir is as presented in the above table. Actual volume of water to be developed is determined on the basis of the intake water volume considering the available capacity in Lagartijo Reservoir. Namely, even the water is taken at torrents and diverted to Lagartijo Reservoir, the water could not be used if the reservoir is in full supply capacity. The average water to be developed has been calculated as presented in the following table considering the availability of Lagartijo Reservoir. In the case of annual average diversion of 18 m^3/s, an average of 9.5 m^3/s would be developed.

(Unit: million m^3)

Year	Available capacity	Diverted water	Developed water
1986	0	18	0
1987	0	18	0
1988	15	18	15
1989	57	18	18
1990	0	18	0
1991	15	18	15
1992	2	18	2
1993	48	18	18
1994	32	18	18
1995	57	18	18
1996	0	18	0
Average		18	9.5

Comparison of Alternative Development Cases

The following five cases of intake and diversion have been studied.

- Intake at Súcuta and diversion to Lagartijo
- Intake at Tarma and diversion to Lagartijo
- Intake at Aniagua and Tarma and diversion to Lagartijo
- Intake at Guare, Aniagua and Tarma and diversion to Lagartijo
- Intake at Cagua, Guare, Aniagua and Tarma and diversion to Lagartijo

For each case, the optimum development scale has been determined comparing the target flow of 1.0, 1.5, 2.0, 3.0 and 4.0 m^3/s per 100 km^2. The calculation sheet is presented in Table 3.3-1. Cost curves by diversion capacity are presented in Fig. 3.3-4.

The values of the optimum scale for each development case are summarized in the table below:

Development tributary	Catchment area	Annually developed water		Annual benefit (B)	Annual cost (C)	B-C	B/C	Unit cost
	km²	mcm/yr	m³/s	$mil/yr	$mil/yr	$mil/yr		$/m³
Súcuta	65.0	5.84	0.19	1.91	1.97	-0.06	0.97	0.337
Tarma	78.0	6.97	0.22	2.28	3.50	-1.23	0.65	0.503
Anjagua-Tarma	131.3	8.45	0.27	2.76	4.06	-1.29	0.68	0.480
Guare-Tarma	317.3	15.86	0.50	5.19	7.52	-2.34	0.69	0.475
Cagua-Tarma	367.2	17.44	0.55	5.70	8.96	-3.26	0.64	0.514

Note: Unit benefit of $0.327/m³ is applied (see pre-feasibility study for detail).
Annual O&M cost is assumed to be 2% of the construction cost.

<u>Conclusion</u>

In the case of Súcuta Intake, the best case among the five, B/C is 0.97 and it is close to 1.0. Annual developed water is, however, small at 0.19 m³/s and it is not recommendable. Other cases give lower value of B/C below 0.7 and it is economically not recommendable.

As a conclusion, no torrent diversion is proposed.

3.3.2 Utilization Plan for the Ocumarito River

The results of the Pre-Feasibility Study are referred as follows:

<u>Ocumarito-Lagartijo Diversion Plan</u>

Item	Unit	Value
Average Annual Development Water	mcm/year	10.20
- ditto -	m³/s	0.32
Initial Cost	$mil	19.44
Annual Benefit (B)	$mil/year	3.34
Annual Cost (C)	$mil/year	2.33
B-C	$mil	1.01
B/C		1.43
Unit Cost	$/m³	0.228

<u>Pumping Plan</u>

Item	Unit	Value
Average Annual Development Water	mcm/year	20.30
- ditto -	m^3/s	0.64
Initial Cost	$mil	9.88
Annual Benefit (B)	$mil/year	6.64
Annual Cost (C)	$mil/year	2.64
B-C	$mil	4.00
B/C		2.52
Unit Cost	$/m³	0.130

3.3.3 Development of a New Dam

As discussed in Section 3.2, Guare Dam and El Peñón Dam are considered. El Peñón Dam has been studied in combination with Ocumarito-Lagartijo Diversion Plan. In this sub-section, the study for Guare Dam has been conducted.

The results of the pre-feasibility study is referred as follows:

Item	Unit	Value
Average Annual Development Water	mcm/year	55.43
- ditto -	m^3/s	1.76
Initial Cost	$mil	76.1
Annual Benefit (B)	$mil/year	18.1
Annual Cost (C)	$mil/year	9.94
B-C	$mil	8.19
B/C		1.82
Unit Cost	$/m³	0.179

3.3.4 Conclusion of the Master Plan Study

The following table summarizes the results of the study.

Gross storage capacity	Ave. Annual Diverted Water	Initial Cost	Unit Cost	Conclusion
$\times 10^{6m3}$	m^3/s	$mil	$/m³	
Torrent diversion	0.19	16.4	0.337	not selected
Ocumarito-Lagartijo diversion	0.32	19.4	0.228	not selected
Pumping Ocumarito Water to Tuy III System	0.64	9.9	0.130	given top priority
Guare Dam	1.76	76.1	0.179	given second priority

Torrent diversion has not been selected for implementation because of the high unit construction cost.

Ocumarito-Lagartijo diversion and pumping plan are competitive and both of them could not be implemented simultaneously. Accordingly, the pumping plan has been selected considering higher economic efficiency.

Guare Dam plan has also been selected for implementation considering its higher economic efficiency.

On the basis of the economic efficiency, the top priority has been given to the pumping plan, and the second to Guare Dam plan.

After the implementation of pumping plan and Guare dam plan, a total of 2.4 m^3/s of water will be developed.

4 PRE-FEASIBILITY STUDY ON SECUREMENT OF WATER QUALITY

4.1 Subject Plans for Pre-Feasibility Study

Pre-Feasibility studies have been conducted for the following projects:

- Utilization Plan of the Ocumarito River
- Guare Dam Plan
- El Peñón Dam Plan

The outline of the plans is as follows:

(1) Utilization Plan of the Ocumarito River

Ocumarito Dam is located on the Ocumarito River, a right bank tributary of the Tuy River. The dam has been constructed to regulate flow of the Ocumarito River and send to the Ocumarito treatment plant for the domestic water supply to Tuy Medio. Due to its small capacity compared to the catchment area, Ocumarito Reservoir is full to capacity for four months of the year on average. During this full capacity period, water is spilled from Ocumarito Reservoir to the downstream stretch and it flows down the Tuy River without use.

Two options have been studied to utilize the spilling water from Ocumarito Reservoir. One is to divert water from Ocumarito Reservoir to Lagartijo Reservoir. In this plan, water to be spilled from Ocumarito Reservoir is diverted to Lagartijo Reservoir through a diversion pipeline. Lagartijo Reservoir has a larger capacity. The water is finally send to Tuy I or II systems of Hidrocapital.

The other option is to pump up water to be spilled from Ocumarito Reservoir directly to the pipeline of Tuy III system that runs near Ocumarito Dam (an idea has been given by Ing. Luis Miguel Suarez Villar, a counterpart from Hidrocapital). The water is to be sent to Caujarito treatment plant together with the water pumped from Camatagua Reservoir. In this plan, the amount of water equivalent to the amount to be pumped from Ocumarito Reservoir is stored in Camatagua Reservoir saving the energy at pumping stations between Camatagua and Tunnel de Las Ollas.

(2) Guare Dam Plan

The Guare River is a right bank tributary of the Tuy River with a catchment area of 185 km^2. It flows into the Tuy River at Tácata. The Guare Dam plan is to develop water resources by the construction of a dam on the Guare River.

(3) El Peñón Dam Plan

The Lagartijo River is a right bank tributary of the Tuy River. It flows into the Tuy River at a just upstream point of Toma de Agua. Lagartijo Dam has been constructed on the Lagartijo River at near the downstreammost point with a catchment area of 300 km^2. Water stored in Lagartijo Reservoir is lead to Tuy I & II systems of Hidrocapital for domestic use in the Caracas metropolitan area. Lagartijo Reservoir has a larger storage capacity compared to its catchment area, and the historical records show that the water of the Lagartijo River has been almost fully utilized without spilling from the dam.

The proposed El Peñón Dam site is located on the Lagartijo River in the upstream side of Lagartijo Dam with a catchment area of 206 km^2. Since the water of the Lagartijo River is almost fully utilized by Lagartijo Reservoir, there is no need of construction of El Peñón Dam in this respect. However, El Peñón Dam could be taken into consideration if it is proposed with the combination of the Ocumarito-Lagartijo diversion plan. Namely, if Lagartijo Reservoir is in the full supply level when water is to be diverted from Ocumarito Reservoir through the proposed Ocumarito-Lagartijo diversion pipeline, El Peñón Reservoir could be used to store water to keep sufficient vacant capacity at Lagartijo Reservoir for the diverted water from Ocumarito Reservoir.

Accordingly, the El Peñón Dam plan has been studied in combination with the Ocumarito-Lagartijo diversion plan.

The following part is the pre-feasibility study of the above water resources development plans.

4.2 Unit Benefit for Water Resources Development

Unit benefit for the calculation of benefit of the water resources development plan has been determined. Two kinds of values are deemed applicable for the unit benefit in the present study. Namely, the unit construction cost of the Tuy IV-Taguaza-Cuira system and the annual production cost of the Tuy System used by Hidrocapital for the evaluation of new projects.

4.2.1 Unit Construction Cost of Tuy IV-Taguaza-Cuira System

The reason of application of the unit construction costs of Tuy IV-Taguaza-Cuira system is the following:

The Tuy IV-Taguaza system is presently under construction for the water resources development to assure domestic water supply to the Caracas metropolitan and other areas. The construction works are, however, behind the schedule. Tuy IV-Cuira system is proposed to be implemented in the next stage after the completion of the Tuy IV-Taguaza system.

Accordingly, water resources development projects that are more economical compared to the Tuy IV-Taguaza-Cuira system could be implemented prior. Thus, the unit construction cost for the Tuy IV-Taguaza-Cuira system would be used as the unit benefit.

The major features of the Tuy IV-Taguaza-Cuira system are presented in Table 4.2-1. The unit construction costs are summarized in the following table:

System	Unit construction cost (US$/m^3)
Taguaza-Taguacita Interconnection	0.262
Tuy IV-Taguaza	0.143
Tuy IV-Cuira	0.109

4.2.2 Average Production Cost for the Overall Tuy System

Another value that could be used for the unit benefit for the water resources development is the annual production cost of the Tuy System used by Hidrocapital for the evaluation of new projects.

Necessary information for the calculation of the annual production cost of the Tuy System is presented in "*Hidrocapital Proyecciones de ingresos y gastos, Años 1995-2005, (23 de abril de 1996)*". In accordance with this report, annual water production, value of assets and annual costs of the Tuy System are given as follows:

(1) Annual Water Production

Annual water production of the Tuy System in 1996 has been estimated at 561.34×10^6 m^3 (see Table 4.2-2).

(2) Value of Assets

Value of assets of the Tuy System as of 1996 has been estimated as follows (see Table 4.2-2).:

Item	Value (US$ million)
Production	986.0
Treatment	101.6
Total Cost	1,087.6

(3) Annual Costs

Annual operation costs of the Tuy System in the year 1996 have been estimated by category as follows:

Item	Value (US$ million)
Fixed Cost	
Personal	3.336
Indirect	0.412
Materials	2.722
Sub-total	6.470
Variable Cost	
Chemicals	3.898
Energy	53.426
Sub-total	57.324
Total Cost	63.794

An annualized cost for the production of water by Tuy System is accordingly calculated as follows:

Item	Unit	Value	Calculation
Water production	m^3	561.34	
Project life	year	50	
Interest (opportunity cost of capital)	%	12	
Present worth of an annuity factor		0.11	
Annualized capital cost	US$ million	119.6	1,087.6×0.11
Annual operation cost	US$ million	63.8	
Annual cost	US$ million	183.4	119.6+63.8
Annual production cost per m^3	US$/$m^3$	0.327	183.4/561.34

4.2.3 Unit Benefit Applied for the Present Study

The following table presents the summary of the values obtained in the above analysis.

System	Unit construction/Marginal cost (US$/$m^3$)
Taguaza-Taguacita Interconnection	0.262
Tuy IV-Taguaza (overall)	0.143
Tuy IV-Cuira	0.109
Annual production cost of Tuy System	0.327

As the unit benefit, the annual production cost of the Tuy System has been applied considering the effectiveness of the project implementation in comparison with the present system.

4.3 Utilization Plan for the Ocumarito River

4.3.1 General

Ocumarito Dam is located on the Ocumarito River, a right bank tributary of the Tuy River. The dam has been constructed to regulate flow of the Ocumarito River and send the regulated flow to the Ocumarito treatment plant for the domestic water supply to the middle Tuy basin.

An operation record from 1986-96 for Ocumarito Reservoir together with those for Lagartijo and Camatagua reservoirs is illustrated in Fig. 4.3-1. As shown in the illustration, Ocumarito Reservoir is full to capacity for 4.3 months of the year on average due to its small capacity compared to the catchment area. The effective storage capacity of the reservoir is $8.45\times10^6 m^3$ and it corresponds to an equivalent rainfall of 69 mm over a catchment area of 123 km^2. The equivalent rainfall of 69 mm is small compared to the annual rainfall of about 1,140 mm. During this full to capacity period, water is spilled from the reservoir to the downstream stretch and it flows down the Tuy River without use.

In this pre-feasibility study, two options have been studied to minimize the spilling water from Ocumarito Reservoir: One is to divert water from Ocumarito Reservoir to Lagartijo Reservoir and the other one is to pump up water of Ocumarito Reservoir directly to the pipeline of Tuy III system.

The general concept to be studied in this section is illustrated in Fig. 4.3-2.

4.3.2 Hydrological and Hydraulic Data

<u>Available Data</u>

Hydrological data necessary for the analysis are river flow data and reservoir operation records. The availability of the records is summarized as follows (see also Fig. 4.3-3).

Item	Description	Period	Source
River flow			
Ocumarito, El Desecho	monthly, simulated	1939-78	*1
Ocumarito, El Desecho	daily, observed	1960-67	*2
Lagartijo, La Esperanza	monthly, simulated	1939-78	*1
Lagartijo, El Peñón			
Taguacita, La Botica	monthly, simulated	1939-78	*1
Tuy, Had. Tazón	monthly, simulated	1939-78	*1
Tuy, San Antonio	monthly, simulated	1939-78	*1
Reservoir water volume			
Ocumarito	daily, observed	1986-96	*3
Lagartijo	daily, observed	1986-96	*3
Camatagua	daily, observed	1986-96	*3
Intake by Hidrocapital			
from Lagartijo	monthly, observed	1991-96	*3
from Taguacita	monthly, observed	1991-96	*3
at Toma de Agua	monthly, observed	1991-96	*3
to Ocumarito T/P	monthly, observed	1986-96	*3

Note: T/P: treatment plant

Source: *1: "*Estudio Hidrologico para el Aprovechamiento de Fuentes del Sistema de Abastecimiento de Agua Potable de la Zona Metropolitana, MARNR-INOS, Septiembre de 1981*"

*2: "MARNR-INOS, 1972

*3: Hidrocapital

Reliability of the Data

The reservoir operation simulation has been conducted to obtain water volume to be developed by diversion. Flow data of the related rivers for the period of 10 to 20 years are necessary for this purpose. The available data are monthly simulated flow from 1939-78. It was decided to use the data for the 20 years 1959-78 for the simulation. The simulation is discussed later in the sections concerning the optimization study. Monthly hydrographs from 1959-78 are illustrated in Fig. 4.3-4.

The reliability of the monthly simulated flow and the historical tendency of the river flow have been checked. Table 4.3-1 presents average discharges, depth of runoff, catchment areas, etc. of relevant rivers for the study. According to the table, the Tuy River has a tendency to decrease in flow volume year by year, while the other rivers have no such tendency. However, as discussed in the section on optimization, this will not affect the simulation.

The annual depths of runoff are also compared in the table. They are wide ranging with the lowest value of 110 mm for the Tuy River at Hda. Tazón and the highest value of 820 mm for the Taguacita River at La Botica. The simulated river flow of the Taguacita River is higher than the actual value. Accordingly, the river flow data are adjusted by verification with reservoir operation records.

4.3.3 Topographical and Geological Condition

Topography

Maps with a scale of 1/5,000 are available for the study area. The Ocumarito River flows northward from Ocumarito Dam and flows into the Tuy River. From the confluence with the Ocumarito River, the Tuy River flows easterly till about 2.5 km past the city of Ocumare del Tuy where it meets the Súcuta River. From this point the flow is generally in a north-northeast direction to San Antonio. Lagartijo Reservoir is located on the right bank of the Tuy River, just south of San Antonio.

On the right bank of the Tuy River, along the stretch between the Ocumarito-Tuy confluence and Lagartijo, lies an alluvial plain, approximately 1 km wide. Beyond this point is mountainous terrain from which the Súcuta & Lagartijo rivers flow.

Geology

According to the geological map (see Fig. 4.3-5), the right bank of the Tuy River in this stretch is dominated by Paracotos formation. The Paracotos formation consists of metamorphic rocks of the Mesozoic Cretaceous. A possible route of the Ocumarito-Lagartijo diversion pipeline is along the foot of the mountains, the border of Paracotos formation and terrace deposits. The possible route of the pipeline for the pumping plan is in the mountainous terrain.

The Paracotos formation contains much schistosity. The schistosity generally trends east-west to northeast-southwest and dips southward. Accordingly, trends and dips of the schistosity should be taken into consideration for the excavation works. It is especially important in the south-facing slopes. No large faults cross the proposed line. Although there are numerous minor faults, non of them affect the installation of the pipeline.

4.3.4 Major Features of the Existing Structures and Facilities

The existing structures and facilities related to the present plan are reservoirs, and intake and transmission facilities.

Reservoirs

Reservoirs related to the present plan are Ocumarito, Lagartijo, Taguacita and Camatagua. Taguacita Reservoir influences this plan because the water taken from Taguacita Reservoir is sent to the Tuy I/II systems together with the water taken from the Tuy River at Toma de Agua, and the water from Lagartijo Reservoir.

Major features of the reservoirs are tabulated in Table 4.3-2, and elevation relations between the reservoirs are illustrated in Fig. 4.3-6.

Intake, Transmission and Other Facilities

Intake and transmission facilities related to the present plan include Ocumarito treatment plant, intake and transmission facilities of Lagartijo and Taguacita reservoirs, intake facility of Toma de Agua for the Tuy River, the transmission facilities of Tuy I and II systems, and transmission pipeline of Tuy III system.

(1) Ocumarito Treatment Plant

The Ocumarito treatment plant is located on the right bank of the Ocumarito River in the downstream area of Ocumarito Dam. The water taken at Ocumarito Reservoir is purified at the plant and supplied as domestic water to urban areas of Ocumare del Tuy, Charallave, Cúa, San Francisco de Yare, etc. in the so-called middle Tuy area.

The installed capacity of the treatment plant is 1.06 m^3/s. Historical operation records are available in the form of monthly intake and treated quantities. The historical monthly intake for the period 1986-96 has been plotted in Fig. 4.3-7. As seen in the illustration, although there were some falls in the past, intake water volume is somewhat stable after 1992.

There is an idea to expand the treatment plant. Details are, however, not clear at this moment. The expansion idea has accordingly not been taken into consideration.

(2) Taguacita-Tuy-Lagartijo Intake and Transmission System

Fig. 4.3-8 shows monthly variation of intake from Taguacita Reservoir, Lagartijo Reservoir and the Tuy River. The total intake is also plotted in the illustration.

As shown in the illustration, the target intake from the three sources is approximately 8 to 9 m^3/s. General intake rules are summarized as follows:

- Available water is taken from Taguacita Reservoir
- Available water is taken from the Tuy River
- The deficit of water to the total amount of approximately 9 m^3/s is taken from Lagartijo Reservoir
- If Lagartijo Reservoir is full, priority is given to the intake from Lagartijo Reservoir

The capacity for each structure is the following:

System/Facility	Capacity (m^3/s)
Taguacita intake	4.1
Lagartijo intake	7.0
Toma de Agua (monthly average capacity)	5.5

The capacity for Tuy I/II systems is the following:

System/Facility	Capacity (m^3/s)
Tuy I (No.11 pumping station)	3.6
Tuy II (No.21 pumping station)	5.6
Neighboring towns	0.4
Total	9.6

(3) Tuy III System

The plan and longitudinal profile of the Tuy III system are presented in Fig. 4.3-9. As shown in the illustration, the pipeline crosses Ocumarito Reservoir by a bridge and passes 1.5 km point from Ocumarito Dam. A piezometric profile is also presented in the illustration.

4.3.5 Optimization of Ocumarito-Lagartijo Diversion Plan

In this sub-section, the optimum scale of the Ocumarito-Lagartijo diversion plan has been studied. The optimization has been conducted for the cases with and without the construction of El Peñón Dam.

<u>General Features of Structures</u>

Structures considered for the optimization study are an intake at Ocumarito Dam, a diversion tunnel to pass through the right bank abutment and a diversion pipeline to divert water from the outlet of the tunnel to Lagartijo Reservoir.

(1) Intake Structure

The intake tower will be constructed in the right bank of Ocumarito Dam with a minimum intake water level of EL 232.80 m (L.W.L.: lowest water level of the reservoir). This has been determined considering that water is to be diverted even during the minimum water level for the case of using this system as an emergency route from Camatagua to Lagartijo.

(2) Transmission Method

Considering the topographic condition, a tunnel is required to divert water across the right bank abutment to the downstream of the dam.

From the outlet of the tunnel, a pipeline will be installed to convey water by gravity to Lagartijo Reservoir. The diameter of the pipe will be determined for the design discharge. A tunnel leading directly to Lagartijo Reservoir has not been considered because of a huge construction cost.

<u>Confirmation of Prerequisite for the Planning</u>

The following conditions have been considered as prerequisite for the optimization study.

(1) Simulation Period

Reservoir operation records are available for the period 1986-96. It is accordingly desirable to select this period for simulation, since the verification of the simulation results is easy. However, the river flow data are not available for this period. The simulation period was selected for the 20 years, 1959-78. Verification is to be made for reservoir operation condition, e.g. an average storage water, spilling and/or empty periods.

(2) Supply to Middle Tuy through Ocumarito Treatment Plant

An installed capacity of 1.06 m^3/s has been considered to be taken at Ocumarito Reservoir. An idea of expansion of the plant has not been taken into consideration.

(3) Operation of Caicita Diversion Structure

The Caicita diversion structure is to divert water from Camatagua Reservoir to Ocumarito Reservoir. The purpose is to supply water to the Ocumarito treatment plant and/or to Toma de Agua during dry periods. The water supply is controlled by a gate at the diversion structure.

The rule for the supply to Toma de Agua is not clear. Supply to the Ocumarito treatment plant has been taken into consideration only for the deficit in the supply to the Ocumarito treatment plant, and it will not affect reservoir operation.

(4) Reservoir Operation Condition

Rainfall in and evaporation from the reservoir have been taken into consideration. In accordance with the rainfall and evaporation records at Cúa, Tovar and Santa Teresa. Constant values by month have been applied. The data at Cúa, Tovar have been used for the simulation of Ocumarito Reservoir, and those at Santa Teresa for Lagartijo Reservoir. For Taguacita Reservoir, it has not been considered because the effect is minimal.

(5) Reservoir Features

Major features of the reservoirs are as presented in Table 4.3-2.

(6) Capacity of Taguacita-Tuy-Lagartijo

The condition presented in sub-section 4.3.4 has been applied for the simulation.

<u>Simulation of Ocumarito Reservoir</u>

The reservoir operation has been simulated on the basis of the above prerequisite. Present condition of Ocumarito Reservoir has been simulated for verification. Reserved water volume and volume of spill of Ocumarito Reservoir are presented in Fig. 4.3-10. The key values of observed condition (1986-96) and simulated condition

(1959-78) have been compared in the following table:

Item	Unit	Simulated (1959-78)	Observed (1986-96)
Average stored water volume	$\times10^6$ m^3	8.6	8.4
At full supply level	month/year	5.4	4.3
At or below $4.0\times10^6 m^3$	month/year	1.5	1.1

Diversion Water Volume from Ocumarito Reservoir

The following table shows the possible amount of water to be diverted from Ocumarito Reservoir by the diversion capacity:

Diversion capacity	Average annual diverted water (potential)	
m^3/s	mcm/year	m^3/s
0.5	6.09	0.19
1.0	10.5	0.33
2.0	15.4	0.49
3.0	17.9	0.57
4.0	19.5	0.62
5.0	20.3	0.64

Simulation of Taguacita Reservoir, Toma de Agua and Lagartijo Reservoir (Present Condition)

The proposed plan is to divert water from Ocumarito Reservoir to Lagartijo Reservoir. Since Lagartijo Reservoir is operated within a system of three water sources, namely, Taguacita Reservoir, Toma de Agua and Lagartijo Reservoir, the operation of the system should be also simulated.

The operation rule of the system is as presented in the previous part.

The actual intake from the three sources from 1991-95 is as follows (see Fig. 4.3-8):

Source	1991-95 average intake (m^3/s)
Taguacita	2.40
Toma de Agua	2.39
Lagartijo	3.44
Total	8.24

The following part is the results of simulation of the present condition:

(1) Taguacita Reservoir

The discharge data of the Taguacita River have been adjusted referring to the actual average intake from 1991-95 of 2.40 m^3/s. The simulated monthly average intake is illustrated in Fig. 4.3-11.

(2) Toma de Agua

Actual operation of water intake at Toma de Agua of the Tuy River is complicated since it is affected by water quality. Accordingly for the purpose of simulation, the maximum intake is temporarily fixed at 3.15 m^3/s so as to obtain the recorded actual value of 2.39 m^3/s.

(3) Lagartijo Reservoir

Intake volume from Lagartijo Reservoir has been determined following the operation rule as presented in Fig. 4.3-11. The key values of the observed and simulated condition have been compared for verification as follows:

Item	Unit	Simulated (1959-78)	Observed (1986-96)
Average stored water volume	$\times 10^6$ m^3	39.5	40.4
At or above $78\times10^6 m^3$	month/year	0.9	1.1
At or below $20\times10^6 m^3$	month/year	3.2	3.7
Average intake from Lagartijo	m^3/s	3.63	3.44 *2
Average total intake *1	m^3/s	8.43	8.24 *2

Note: *1: Total intake is of Taguacita, Toma de Agua and Lagartijo
*2: 1991-95

<u>**Newly Developed Water by Ocumarito-Lagartijo Diversion without El Peñón Dam**</u>

The simulation has been conducted to obtain newly developed water by diversion from Ocumarito Reservoir to Lagartijo Reservoir. In the case of diversion from Ocumarito Reservoir, the capacity of the intake from the three sources of Taguacita, Toma de Agua and Lagartijo has been determined at 9.6 m^3/s, an installed capacity.

The simulation results are as follows (see Fig. 4.3-12): Calculation sheets are presented in Table 4.3-3.

Simulation results of Lagartijo Reservoir

Item	Unit	Diversion capacity (m^3/s)						
		0	0.5	1.0	2.0	3.0	4.0	5.0
Average stored water volume		28.4	33.7	37.4	40.7	41.7	42.1	42.3
At or above $78\times10^6 m^3$	month /year	0.3	0.4	0.9	1.4	1.6	1.6	1.7
At or below $20\times10^6 m^3$	month /year	5.0	4.0	3.5	3.4	3.3	3.3	3.3
Average intake (from Lagartijo)	m^3/s	3.73	3.89	3.97	4.05	4.06	4.06	4.06
Average total intake *1	m^3/s	8.53	8.69	8.78	8.85	8.86	8.86	8.86
Average annual increment	$\times10^6 m^3$	0.0	5.1	7.8	10.2	10.6	10.6	10.6
Average spill	m^3/s	0.08	0.11	0.16	0.24	0.31	0.36	0.39

Note: *1: Total intake is of Taguacita, Toma de Agua and Lagartijo

Newly Developed Water by Ocumarito-Lagartijo Diversion with El Peñón Dam

The simulation has been conducted to obtain newly developed water by diversion from Ocumarito Reservoir to Lagartijo Reservoir in the case with El Peñón Dam. In this case, it is considered that water spilled from Lagartijo Reservoir is stored in El Peñón Reservoir in advance within the capacity.

Intake from the three sources of Taguacita, Toma de Agua and Lagartijo has been determined at 9.6 m^3/s, an installed capacity as in the case without El Peñón Dam.

The simulation results are as follows (see Table 4.3-4 and Fig. 4.3-12):

Annual average total intake (Taguacita, Toma de Agua, Lagartijo)

Item	Unit	Diversion capacity (m^3/s)						
		0	0.5	1.0	2.0	3.0	4.0	5.0
without El Peñón	$\times10^6 m^3$	269.11 0.00	274.24 5.13	276.91 7.80	279.31 10.20	279.67 10.56	279.74 10.63	279.74 10.63
El Peñón $10\times10^6 m^3$	$\times10^6 m^3$	269.61 0.50	274.74 5.63	278.11 9.00	280.88 11.77	281.51 12.40	281.80 12.69	281.93 12.82
El Peñón $20\times10^6 m^3$	$\times10^6 m^3$	270.11 1.00	275.24 6.13	278.75 9.64	282.05 12.94	282.78 13.67	283.07 13.96	283.21 14.10
El Peñón $30\times10^6 m^3$	$\times10^6 m^3$	270.61 1.50	275.74 6.63	279.25 10.14	282.97 13.86	283.78 14.67	284.07 14.96	284.21 15.10
El Peñón $40\times10^6 m^3$	$\times10^6 m^3$	271.11 2.00	276.24 7.13	279.75 10.64	283.47 14.36	284.52 15.41	285.07 15.96	285.21 16.10

Note: Upper column: total intake; Lower column: increment

Cost Curve for Optimization

Cost curves for an intake, a diversion pipeline and El Peñón Dam have been prepared for the optimization study.

(1) Intake and Diversion Pipeline

Construction Cost

The cost for diversion pipeline for the use of optimization study has been estimated as follows (for detail, see Table 4.3-5):

	Pipeline *1				Others	Total
Q	dia	Steel	Installation	Cost	*1	*3
m^3/s	mm	$/m	$/m	$ mil	$ mil	$ mil
0.5	900	374	70	7.99	0.77	10.95
1.0	1,050	550	80	11.34	0.77	15.14
2.0	1,350	761	90	14.78	0.77	19.44
3.0	1,650	894	100	17.89	0.77	23.33
4.0	1,800	974	110	19.51	0.77	25.35
5.0	2,000	1,083	120	21.65	0.77	28.03

Note: *1: Pipeline length is 18 km
*2: Others include direct cost for intake and river crossing, considered constant at $451,000 and $320,000, respectively.
*3: Include 25% contingency

O&M Cost

The flow is by gravity and the structures basically need no operation. Accordingly, operation and maintenance cost is assumed at 1% of the construction cost.

Annualized Cost

Annualized cost has been obtained as the sum of annualized construction cost and annual operation and maintenance cost. Annualized construction cost has been calculated with a present worth of an annuity factor of 0.11 (design life of 30 years and an interest rate of 12%).

Q m^3/s	Construction $ mil	O&M $ mil	Total $ mil
0.5	1.20	0.11	1.31
1.0	1.66	0.15	1.81
2.0	2.14	0.19	2.33
3.0	2.57	0.23	2.80
4.0	2.79	0.25	3.04
5.0	3.08	0.28	3.36

(2) El Peñón Dam

Construction Cost

The construction cost of El Peñón Dam for the purpose of optimization study has been estimated as follows:

Effective capacity	Embankment		Other	Total
	Volume	Cost *1	cost *2	cost *3
$\times 10^6\ m^3$	m^3	$ mil	$ mil	$ mil
10	370,000	8.5	5.0	16.9
20	470,000	10.8	5.0	19.8
30	535,000	12.3	5.0	21.6
40	590,000	13.6	5.0	23.3

Note: *1: Unit cost for embankment is assumed at $23
*2: include intake and spillway cost
*3: include 25% contingency

O&M Cost

Operation and maintenance cost is assumed at 2% of the construction cost.

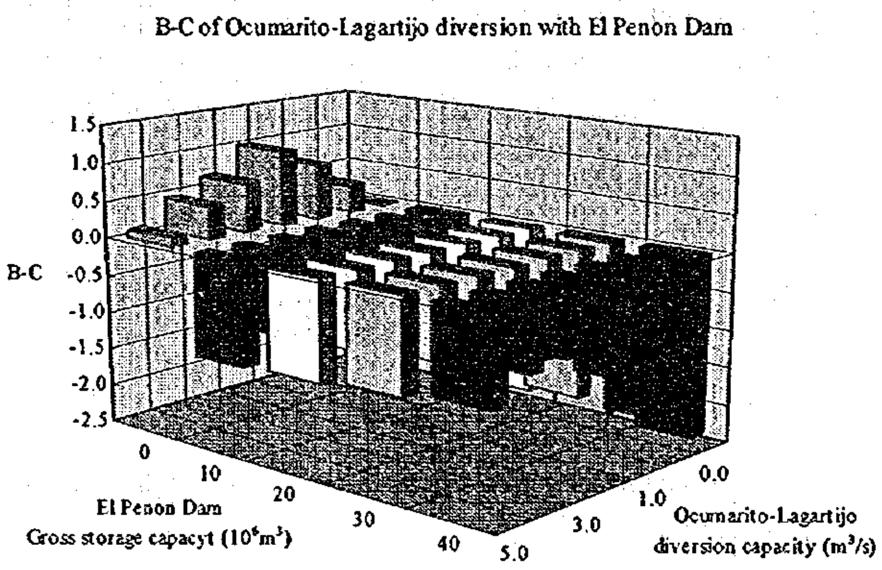
Annualized Cost

Annualized cost has been obtained as the sum of annualized construction cost and annual operation and maintenance cost. Annualized construction cost has been calculated with a present worth of an annuity factor of 0.11 (project life of 50 years and an interest rate of 12%).

Effective capacity	Construction	O&M	Total
$\times 10^6 m^3$	$ mil	$ mil	$ mil
10	1.86	0.34	2.20
20	2.18	0.40	2.58
30	2.38	0.43	2.81
40	2.56	0.47	3.03

Benefit-Cost Comparison of Alternative Development Cases

On the basis of the simulation results, the intake and diversion capacity of 0, 0.5, 1, 2, 3, 4 and 5 m^3/s for each without and with various capacity cases of El Peñón Dam are considered. The following illustration compares the Annual Net Present Value (B-C).



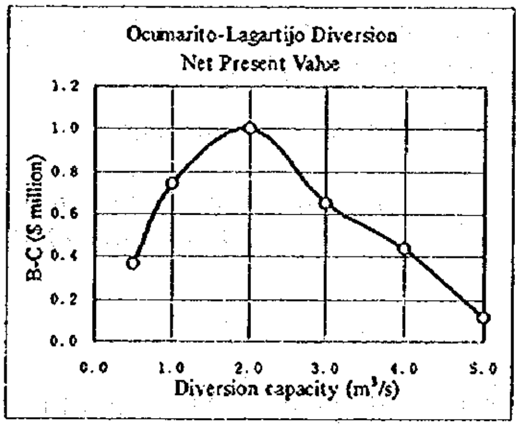
The following table shows the Annual Net Present Value (B-C), Benefit-Cost Ratio (B/C) and unit cost per cubic meters of water. The case with El Peñón Dam is the case with the effective capacity of $30\times10^6 m^3$, the best case among those with El Peñón Dam (for detail, see Table 4.3-4).

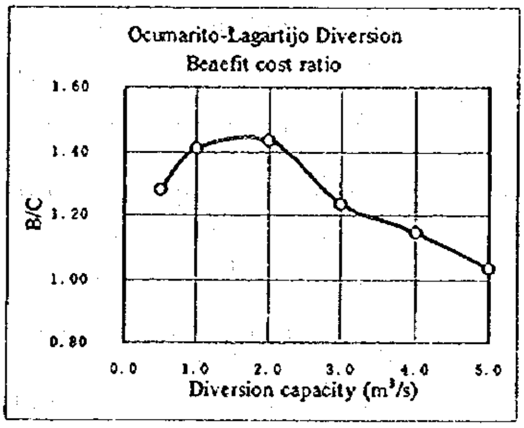
Diversion Capacity	Ave. Annual Diverted Water	Ave. Annual Diverted Water	Annual Benefit (B)	Annual Cost (C)	B-C	B/C	Unit Cost
m^3/s	mcm/yr	m^3/s	$mil/yr	$mil/yr	$mil/yr		$/m^3$
without El Peñón							
0.5	5.13	0.16	1.68	1.31	0.37	1.28	0.255
1.0	7.80	0.25	2.55	1.81	0.74	1.41	0.232
2.0	10.20	0.32	3.34	2.33	1.01	1.43	0.228
3.0	10.56	0.33	3.45	2.80	0.65	1.23	0.265
4.0	10.63	0.33	3.48	3.04	0.44	1.14	0.286
5.0	10.63	0.33	3.48	3.36	0.12	1.03	0.316
with El Peñón of	30×10^5 m^3						
0	0.50	0.05	0.49	2.81	-2.32	0.17	1.873
0.5	6.63	0.21	2.17	4.12	-1.95	0.53	0.621
1.0	10.14	0.32	3.32	4.62	-1.30	0.72	0.456
2.0	13.86	0.44	4.53	5.14	-0.61	0.88	0.371
3.0	14.67	0.47	4.80	5.61	-0.81	0.86	0.382
4.0	14.96	0.47	4.89	5.85	-0.96	0.84	0.391
5.0	15.10	0.48	4.94	6.17	-1.23	0.80	0.409

Note: *1: Unit benefit is $0.327

As shown in the above table, in the case of the effective capacity of 30×10^6 m^3 for El Peñón Reservoir, average annual diverted water increase by 3.66×10^6 m^3 (=13.86-10.20). The benefit increase by the construction of El Peñón Dam is accordingly US$1.19 million. The increase in the annual cost is, on the other hand, US$2.44 million and this corresponds to the unit cost of $0.768/m³. It has been concluded that El Peñón Dam is uneconomical.

The following illustration compares the Annual Net Present Value (B-C) and Benefit-Cost Ratio (B/C) in the case without El Peñón Dam.





As illustrated above, both B-C and B/C are the maximum with the diversion capacity of 2 m³/s. The diversion capacity has been accordingly determined at 2 m³/s considering the higher value of B-C and B/C. The construction cost is estimated at

US$19.44 million.

4.3.6 Optimization of Ocumarito-Tuy III Pumping Plan

In this sub-section, the optimum scale of the pumping plan to Tuy III pipeline has been studied. This plan is to pump up water from Ocumarito Reservoir to the pipeline of Tuy III System to minimize spill from the reservoir. The equivalent amount of water is to be saved in Camatagua Reservoir, and reduce the energy required by Pumping Station No.31 and Mamonal booster pumping station.

General Features of Structures

Structures considered for the optimization study are pumps, a pipe connecting the pump to the pipeline of Tuy III System.

(1) Pumping Station

A pumping station will be constructed near the left bank abutment of Ocumarito Dam. Hydraulic head of the pumps is assumed at 180 m, considering piezometric profile of the Tuy III pipeline. Cases with design flow of 0.5, 1, 2, 3, 4 and 5 m^3/s have been considered as alternative cases.

(2) Connecting Pipe

A 1.5 km-long connecting pipe has been considered. The diameter has been determined based on the installed capacity.

Confirmation of Prerequisites for the Planning

The following conditions have been considered as prerequisites for the optimization study.

(1) Simulation Period

The simulation period has been selected for 20 years from 1959-78 for the same reason as the Ocumarito-Lagartijo diversion plan.

(2) Supply to middle Tuy through Ocumarito Treatment Plant

An installed capacity of 1.06 m^3/s has been considered to be taken daily at Ocumarito Reservoir, the same condition as the Ocumarito-Lagartijo diversion plan.

(3) Operation of Caicita Diversion Structure

This is to divert water from Camatagua Reservoir to Ocumarito Reservoir. The purpose is to supply water to the Ocumarito treatment plant and/or to Toma de Agua during dry period. The water supply is controlled by a gate at the diversion structure.

Supply to the Ocumarito treatment plant from the Caicita diversion structure in the case of water deficit has been taken into consideration.

Diversion Water Volume by Pumping Capacity

The diversion water volume by the pumping capacity is the same as that calculated for Ocumarito-Lagartijo diversion plan as follows:

Diversion Capacity	Average Annual Diverted Water	
m^3/s	mcm/year	m^3/s
0.5	6.09	0.19
1.0	10.5	0.33
2.0	15.4	0.49
3.0	17.9	0.57
4.0	19.5	0.62
5.0	20.3	0.64

Cost Curve for Optimization

Cost curves for the pumping station, the connecting pipeline and operation cost have been prepared for the optimization study.

(1) Pumping Station

Construction Cost

The cost for a floating pumping station and a connecting pipeline for the use of optimization study has been estimated as follows (for detail, see Table 4.3-6):

Pumping Capacity *1	Pump				Pipe *2		Civil	Total
	unit capacity	unit	unit cost	cost	dia	cost	*3	*4
m^3/s	m^3/s	no.	$/no	$ mil	mm	$ mil	$ mil	$ mil
0.5	0.50	2	0.400	0.80	600	0.89	0.94	3.29
1.0	0.50	3	0.400	1.20	800	1.13	1.12	4.31
2.0	1.00	3	0.600	1.80	1,050	1.89	1.30	6.24
3.0	1.00	4	0.600	1.80	1,200	2.14	1.49	6.79
4.0	1.00	5	0.600	3.00	1,350	2.46	1.49	8.69
5.0	1.00	6	0.600	3.60	1,500	2.63	1.67	9.88

Note: *1: Pumping capacity
*2 Length of a connection pipe is 1.5 km
*3: include access road, etc.
*4: include contingency of 25%

O&M Cost

O&M cost has been estimated as power cost on the basis of Bs.8.47/kWh and Bs.1,185/kVA as follows:

Pumping capacity	Operation cost	Maintenance cost	Total O&M cost
m^3/s	$ mil	$ mil	$ mil
0.5	0.150	0.033	0.183
1.0	0.285	0.043	0.328
2.0	0.560	0.062	0.622
3.0	0.830	0.068	0.898
4.0	1.088	0.087	1.175
5.0	1.354	0.099	1.453

Annualized Cost

Annualized cost has been obtained as the sum of annualized construction cost and annual operation and maintenance cost. Annualized construction cost has been calculated with a present worth of an annuity factor of 0.12 (project life of 15 years for pumps, 30 years for pipes and 50 years for civil structures, and an interest rate of 12%).

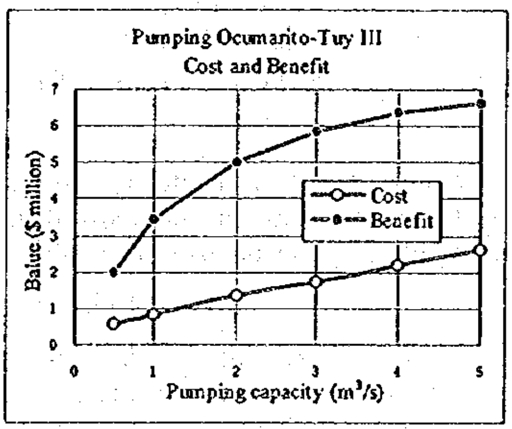
Pumping capacity	Construction	O&M	Total
m^3/s	$ mil	$ mil	$ mil
0.5	0.395	0.183	0.578
1.0	0.517	0.328	0.846
2.0	0.749	0.622	1.371
3.0	0.815	0.898	1.713
4.0	1.043	1.175	2.218
5.0	1.186	1.453	2.639

Benefit-Cost Comparison of Alternative Development Cases

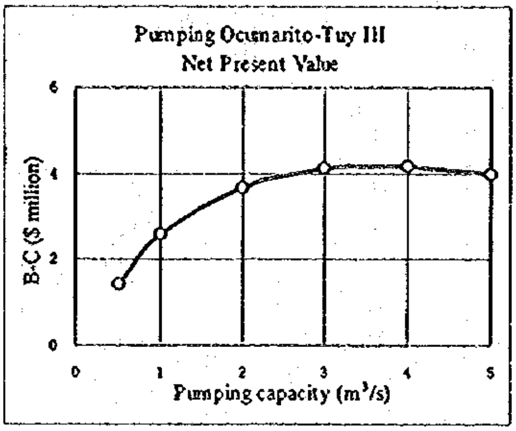
On the basis of the simulation results, the pumping and diversion capacity of 1, 2, 3, 4 and 5 m^3/s are considered. The following table and figures show the Annual Net Present Value (B-C), Benefit-Cost Ratio (B/C) and unit cost per cubic meter of water.

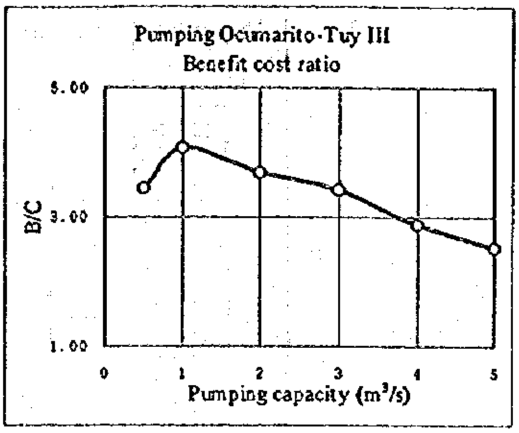
Diversion Capacity	Ave. Annual Diverted Water	Ave. Annual Diverted Water	Annual Benefit (B)	Annual Cost (C)	B-C	B/C	Unit Cost
m^3/s	mcm/yr	m^3/s	$mil/yr	$mil/yr	$mil/yr		$\$/m^3$
0.5	6.09	0.19	1.99	0.578	1.414	3.45	0.095
1.0	10.5	0.33	3.43	0.846	2.588	4.06	0.081
2.0	15.4	0.49	5.04	1.371	3.665	3.67	0.089
3.0	17.9	0.57	5.85	1.713	4.141	3.42	0.096
4.0	19.5	0.62	6.38	2.218	4.159	2.88	0.114
5.0	20.3	0.64	6.64	2.638	4.000	2.52	0.130

The cost and benefit by pumping capacity are as follows:



The following illustration compares the Annual Net Present Value (B-C) and Benefit-Cost Ratio (B/C).





The Annual Net Present Value is the highest value with the pumping capacity of 4 m^3/s. While the benefit-cost ratio takes the highest value with a pumping capacity of 1 m^3/s. The values of B/C are high in all case at more than 3. The values of B-C for the pumping capacity of 3, 4 and 5 are almost the same. Accordingly, the pumping capacity of 5 m^3/s is recommendable.

4.3.7 Preliminary Design

Preliminary design has been conducted for the optimum plan for each Ocumarito-Lagartijo Diversion Plan and Ocumarito-Tuy III Pumping Plan.

<u>Ocumarito-Lagartijo Diversion Plan</u>

The layout of the Ocumarito-Lagartijo Diversion Plan is shown in Fig. 4.3-13. To select the best route for the pipeline the following factors were analyzed: 1) hindrance to existing residents and structures, 2) constructability, 3) the grade of the route, and 4) length of route. The route selected for the pre-feasibility study is the one that best meets the above factors.

The pipeline will primarily be on the surface. A problem with the proposed site is that the area is heavily populated and where there are not urban areas there are either mountains or farmland. Therefore all possible routes have negative points. The route selected is clearly the one with the least.

The first 1 km section of the route from the Ocumarito Reservoir intake is along steep terrain and construction of the pipeline is expected to be the most difficult. Realistically there is no choice but to roughly follow the Ocumarito River along this section.

From the 1 km point to the first crossing of the Tuy River the terrain is flat open farmland and there are no major obstacles. From the first Tuy crossing to the second Tuy crossing the route follows the road to Hacienda Hazon. There is space to the north of the road and the terrain is relatively flat. However, work is made difficult as several roads must be crossed, in particular the Ocumare del Tuy - Charallave road. The pipeline should be installed underground from the Ocumare del Tuy - Charallave road for about 500 meters.

From the second crossing to the Lagartijo Reservoir the route runs north along the base of the mountainous terrain. This section is also flat and there are no major obstacles. The pipeline discharges adjacent to the southern dam of the Lagartijo Reservoir.

The only possible alternative to the chosen route is a route to the south of Ocumare del Tuy. This route is very windy and has abrupt changes in grade, severe space restrictions, and is at least 20 % longer. It was therefore not considered.

The intake was proposed on the right bank of Ocumarito Dam (see Fig. 4.3-13). The tunnel route was aligned maintaining the minimum distance of 30 m from the dam body, considering the effect of blasting. Intake structures have been designed to take water of 2.0 m^3/s at a water level of EL 245.50 m.

Steel pipe was selected as the type of pipe. Hidrocapital's Tuy I, II, III, and IV (under construction) transmission systems pipelines are all steel pipelines. Steel pipe is readily available in Venezuela and the technology and equipment exist to install and maintain steel pipeline. General structural drawing is presented in Fig. 4.3-13

A coefficient of roughness of C_{HW} = 100 was assumed and this was the basis for size selection. The available head is dependent on the levels of the two reservoirs, it was assumed that the minimum head difference is 25 meters. Thus the pipe diameter of 1,350 mm has been selected for the diversion capacity of 2.0 m^3/s.

<u>Ocumarito-Tuy III Pumping Plan</u>

See Fig. 4.3-14 for layout plan of Ocumarito-Tuy III Pumping Plan. The preliminary design was undertaken as follows:

(1) Site Selection

The site selected for the pumping station was chosen for the following reasons: an existing road runs by the proposed site so the site is accessible from a construction and operation point of view, the pumping station is situated in a part of the reservoir not likely to be significantly affected by sediment or submerged debris, and near a point of sufficient elevation for the installation of a surge shaft.

The banks on both sides of the Ocumarito Reservoir are steep. The selected site is in an area that is less steep relative to other parts of the bank, however, the grade of the selected site is approximately 30° from the horizontal.

(2) Pumping Station

The pumping station, shown in Fig. 4.3-14, is proposed to be founded on the rock base. Vertical pumps pump the water to the Tuy III pipeline approximately 2 km from the pumping station. Debris and fish are to be kept out by use of a manually cleaned trash rack.

Pipeline

Hidrocapital has vast experience with conduction of water in steel pipeline and the technology and equipment are readily available in Venezuela to operate and maintain it so steel pipe was selected.

The most direct and easily constructable route was selected. Also the location of the route was influenced by the availability of places a surge shaft could be constructed. Because of the high pressure in the pipeline a surge mitigation device is necessary (the estimated pressure head at the pumps is over 200 meters). The surge shaft was chosen as it is easy to maintain and because it is the method used on other parts of the Tuy systems.

Construction

Basically the construction is divided into two, the pumping station and the conduction pipeline (see Fig. 4.3-14).

The construction of the pumping station will roughly follow the following procedure:

(a) Construct access road from existing road and level site.

(b) Excavation for pumping station. The excavation is to be below the maximum water level so during this stage the level of the reservoir will be maintained at a level low enough to allow works to be undertaken. To lessen the burden on residents reliant on the water of the Ocumarito Reservoir it is essential that these works be completed as soon as possible.

(c) Construction of the structure of the pumping station will be cast in place reinforced concrete. A more detailed investigation of the site's geology is necessary to determine the depth and form of the foundations.

(d) Installation of vertical pumps and instrumentation.

Construction of the conduction pipeline is expected to be carried out as follows:

(a) Clearing and construction of work road.

(b) Installation of pipeline.

(c) Connection to Tuy III pipeline.

4.3.8 Cost Estimate

Project costs are estimated

Ocumarito-Lagartijo Diversion Plan

Construction cost has been estimated as follows:

Item	Cost (US$ million)
Construction (incl. preparatory works)	
Intake	0.39
River crossing 4 site	0.30
Tunneling	0.17
Pipeline 1,350 mm × 16,500 m	11.37
Pipeline installation	1.29
(Sub-total)	13.52
Engineering and administration (15%)	2.03
Physical contingency (25%)	3.89
Total	19.44

Ocumarito-Tuy III Pumping Plan

Construction cost has been estimated as follows:

Item	Cost (US$ million)
Construction (incl. preparatory works)	
Transmission Pipeline 1,500 mm × 3,000 m	2.29
Pump 1.0 m^3/s × 200 m × 6 unit	3.12
Excavation and removal	0.69
Concrete	0.61
Reinforcing bar	0.15
(Sub-total)	6.86
Engineering and administration (15%)	1.03
Physical contingency (25%)	1.98
Total	9.87

4.4 Guare Dam Plan

4.4.1 General

The Guare River is a right bank tributary of the Tuy River with a catchment area of 185 km^2. It flows into the Tuy River at Tácata. The Guare Dam plan is to develop water resources by the construction of a dam on the Guare River.

A preliminary study (hereinafter called as the INOS Study) was conducted by INOS, and the report "Estudio Preliminares para un Embalse en el Río Tácata, 1962, INOS" has been prepared. This pre-feasibility study has been conducted by a group of specialists consisting of a water resources development planner, a dam planner and a geologist through field investigation and review of the existing data and information as well as referring to the results of the INOS Study.

4.4.2 Topographical Condition

The proposed site of the Guare Dam is located on the Guare River 1.5 km upstream of the confluence with the Tuy River (see Fig. 4.4-1). The catchment area at the proposed damsite is 183 km^2 occupying almost all 185 km^2 of the Guare River basin. The proposed damsite is located in a narrow gorge and the upstream side provides a favorable topography, a wider valley, to create a reservoir.

Downstream of the proposed damsite, the width of the valley becomes much larger and there are no alternative damsites in this stretch. Also upstream, the valley is wider. Another possible alternative site is at a 4 km upstream point from the proposed damsite. This point is however in the upper side of the confluence of the Mesía River, a left bank tributary of the Guare River with a catchment area of 90 km^2. Accordingly, this site has a smaller catchment of 92 km^2 and the reservoir efficiency is also low. It has been finally concluded that the proposed site is the best site for the construction of a dam on the Guare River. (Refer to Fig. 4.4-2.)

The topography of the damsite is characterized by a thin ridge projects from along the left bank from downstream to upstream. The width of ridge at the crown of the proposed dam is approximately 45 m. The elevation of the ridge top near the proposed dam axis is approximately EL 360 m.

The right bank of the damsite is a massive ridge that extends from the upstream to the downstream. The elevation at the top of this ridge near the proposed dam axis is approximately EL 385 m.

The width of the river itself at the proposed damsite is approximately 15 m. There is, however, a 50 m-wide flat plain on the right bank. The slopes of both left and right banks are steep at approximately 40°.

Topography of the reservoir area is presented in Fig. 4.4-2. Landslide topography has been identified on the map at eight locations. The scales are 30×40 m to 50×70 m, and there are no large ones. Accordingly, there is no problem if proper measures are taken.

4.4.3 Geological Condition

The upper and middle basins of the Tuy River are geologically in the northern zone of Venezuela (coastal mountains). This area consists of mountains extending in an east-west direction along the Caribbean Sea coast with elevations of approximately 2,500 m. Mainly Mesozoic strata exists in the area.

The Mesozoic strata consists of metamorphosed accumulated rocks and volcanic rocks, and small masses of intruded rocks, e.g. serpentine and diorite, occur at places. Regional geological structure is characterized by a series of faults mainly of east-west to northwest-southeast orientation (see Fig. 4.4-3 and 4.4-4).

Mesozoic Cretaceous metamorphic rocks are widely distributed in the area of the proposed damsite. Calcareous phyllite dominates, schists, red phyllite and serpentine are also found. Phyllite is generally hard, but is fragile in the schistosity phase. The schistosity is much developed in red phyllite and serpentine. Covering layers are talus and terrace deposits. Talus deposits are distributed locally and terrace deposits are distributed widely along the Guare River forming plains. (See Fig. 4.4-5)

Many wrench faults occurred in the Cenozoic. Tácata Fault is an obvious one in this area. The Tuy River in the 7 km stretch after the confluence with the Guare River flows along Tácata fault. A major fault in the proposed damsite area is a branch fault of the Tácata fault, see Fig. 4.4-5, with the northwest-southeast direction and dipping south (N68°W, 80°S). It is not a large fault with a 20 cm-thick clayey layer and a 2 m-thick fragmented zone. It is not clear that this fault is active or not.

A geological cross section of the proposed damsite is presented in Fig. 4.4-6. Judging from outcrops near the damsite, it seems that fresh rocks exist in relatively shallow places. A highly weathered layer exists 2-5 m thick. The bedrock itself appears to be hard with a compression strength of around 1,000 kgf/cm^2. However, attention should be paid to the schistosity in relation to the bearing capacity in the latter stages.

There are not enough data regarding permeability. Judging from the core recovery rate and the distribution of cracks, there is a possibility that highly permeable layers extend relatively deep.

In accordance with a literature, earthquakes with magnitudes of 5.5-7.2 have occurred six times in the last 450 years within 60 km of Caracas. The proposed damsite is located at 30 km from Caracas. Therefore, seismicity should be taken into consideration in the design.

4.4.4 Land Use in the Reservoir Area

The results of a survey by INOS have been reviewed based on aerial photographs and field investigation. The breakdown of the land use is as follows:

Land Use	Area (ha)
Non-used mountains and hills	120
Cultivated land	100
Total	220

4.4.5 Hydrological Data

The discharge measurement of the Guare River has been conducted at Río Arriba (catchment area of 92 km^2) since 1978. However, the data contain many gaps, and full data exists for only four non-continuous years of 1978, 1889, 1991 and 1992.

Continuous data of river flow for approximately ten years are necessary for simulation. In this study, the river flow is estimated based on the observed values of the Ocumarito River at El Desecho that is located nearby and the condition is similar.

The discharge height of the Guare River at Río Arriba and the Ocumarito River at El Desecho is compared as follows, and the use of the data of the Ocumarito River is considered appropriate:

River and station	Catchment area	Data period	Average runoff depth
Guare at Río Arriba	92 km^2	1978, 89,91,92	448 mm
Ocumarito at El Desecho	123 km^2	1960-67	401 mm

4.4.6 Related Development Plans

In the Guare River basin, there is a plan to develop nickel mining in the west end of the basin. It is called "*Project of Loma de Hierro, Miranda and Aragua States*". The estimated reserves are 40 million tons, and exploitation will take place in five stages totaling 31 years.

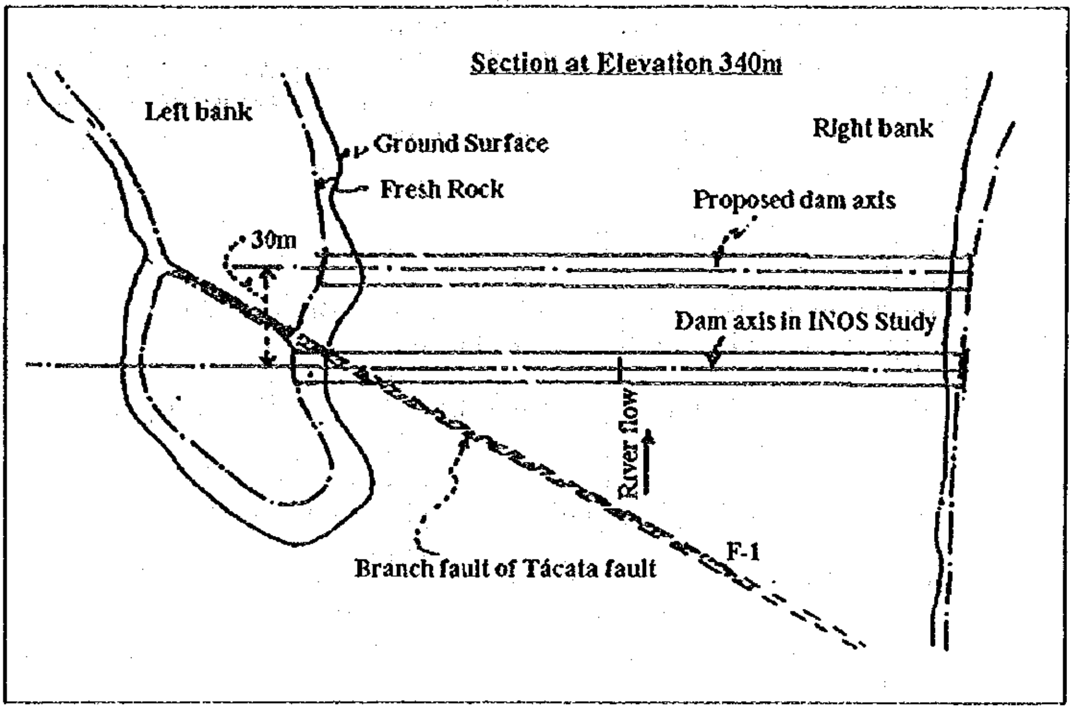
The plan is at the stage of environmental impact assessment with the Tuy River Basin Agency as the evaluator. In the present study, it has been considered that all wastewater and wastes would be treated properly and no negative effects are anticipated from the mining plan.

4.4.7 Determination of Dam Axis

The dam axis has been determined at 30 m downstream from the one proposed in the INOS Study. The reasons are as follows:

- A branch fault of Tácata fault runs along the former dam axis, and it should be avoided
- It is more economical to place the dam axis on the downstream side since water stoppage works for the narrow left bank ridge are reduced. Although the necessary space for the construction of a spillway should be maintained on the ridge.
- The elevation of the right bank ridge becomes low when the dam axis is on the downstream side, the shift of the axis of 30 m creates no problem

The sketch of the topography and geological condition at the proposed dam site is presented as follows:



4.4.8 Confirmation of H-A-V Curve

The curve for the relation of Height-Area-Volume for the proposed reservoir has been developed based on the 1/5,000 maps. The developed curve was compared to the one prepared in the INOS Study and there was a difference of ±1.5%.

The curve is presented in Fig.4.4-7.

4.4.9 Determination of Dam Type

A center core rockfill type dam has been proposed in the INOS Study. This study also selected the same type of the dam for the following reasons:

- The construction costs for the case of a rockfill type dam and a concrete gravity dam have been compared as follows and the rockfill dam is more economical being about a half the cost of the concrete gravity dam:

Item	Cost	Calculation
Rockfill dam		
Dam body	$ 24×10^6	$1.2\times10^6 m^3 \times \$20/m^3$
Spillway	$ 8×10^6	$30{,}000 m^3 \times \$250/m^3$
Total	$ 32×10^6	
Concrete gravity dam		
Dam body/spillway	$ 63×10^6	$250{,}000 m^3 \times \$250/m^3$

- The clayey material for the center core is considered to be available in the vicinity of the damsite, although only thin layers have been found inside the reservoir area.

- The drilling investigation made in the INOS Study did not identify a quarry site for rock material (size of rock of 0.5-1.0 m) and concrete aggregate. Although farther investigation is needed especially of sandstone and shale areas, not for metamorphic rocks, rock and aggregate are considered to be available in the vicinity.

4.4.10 Study on Water Diversion Method

The flow regulated by the reservoir will be used for domestic water supply. This study examines two means of water diversion and intake:

(1) Regulated flow is released into the Guare River just downstream of the dam and taken at Toma de Agua

(2) Water is diverted to Caujarito treatment plant of the Tuy III system

For the first option, the water is to be used in Tuy I and II systems where the water transmission and treatment is at currently capacity. On the other hand, Caujarito treatment plant has sufficient capacity. Accordingly in this study, the second option has been selected.

In the second option, the discharge from the Guare River downstream of Guare Dam decreases. This means that the water quality of the Tuy River downstream from the confluence with the Guare River is worsened. Accordingly, for this option, periodic releases of water is also considered.

4.4.11 Optimization of Development Scale

The optimum dam height has been determined considering topographical conditions, economic advantage, etc. as follows:

<u>Possible Maximum Dam Height</u>

The maximum crest elevation is approximately EL 355 m in accordance with the topography of the left bank ridge. A higher dam is technically possible, but it requires a higher cost in view of the topography of the area. The crest elevation of EL 355 m corresponds to a dam height of 70 m since the riverbed elevation is EL 285 m.

The possible maximum normal water level is thus determined at EL 351 m subtracting a freeboard of 4 m from the possible crest elevation of EL 355 m. The possible maximum gross storage capacity of the reservoir is 60×10^6 m^3 according to the H-A-V curve.

<u>Sedimentation Capacity</u>

Sedimentation capacity is determined at 6.6×10^6 m^3 on the basis of the following calculation:

Item	Value
Specific sediment discharge of the Guare River	360 $m^3/km^2/year$
Catchment area at the proposed damsite	183 km^2
Design sedimentation capacity for 100-year	$360 \times 183 \times 100 = 6.6 \times 10^6 m^3$

The volume of sediment discharge has been calculated considering the vegetation condition, geological condition, slope of the topography and verified by the observed value in Lagartijo Reservoir on the Lagartijo River, a right bank tributary of the Tuy River. The details of the estimation of the sediment production are described in the section titled "Estimation of Suspended Solid" in the Master Plan of this study.

<u>Possible Development Water by Reservoir Scale</u>

Annual average flow to be developed has been calculated by simulation of reservoir operation. Conditions of the calculations:

- The regulated flow is 95% assured water. This means the flow available for 95% of simulation period.
- Rainfall and evaporation from the reservoir are taken into account.
- A river maintenance flow of 0.38 m^3/s is used. The amount of the maintenance flow is obtained based on $0.21 m^3/s/100km^2$, the average flow during the driest month for the period 1960-67. In the following table, simulated values with and without the river maintenance flow are presented as a reference:

A result of reservoir operation simulation for the case of gross storage capacity of 40×10^6 m^3 is presented in Fig. 4.4-8. Calculation sheets are presented in Table 4.4-1.

The simulated values:

Max. reservoir capacity ($\times 10^6 m^3$)	20	25	30	35	40	50	60
With maintenance flow release							
Intake capacity (m^3/s)	1.12	1.35	1.55	1.71	1.85	1.93	1.99
Annual ave. intake ($10^6 m^3$)	33.6	40.4	46.7	51.4	55.4	57.9	59.8
Annual ave. intake (m^3/s)	1.07	1.28	1.48	1.63	1.76	1.84	1.90
Annual ave. spill ($10^6 m^3$)	26.0	20.0	14.5	10.3	6.7	4.6	2.9
Efficiency (%) *1	46	55	64	70	76	79	82
Without maintenance flow release							
Intake capacity (m^3/s)	1.56	1.80	2.01	2.17	2.28	2.34	2.40
Annual ave. intake ($10^6 m^3$)	46.8	54.0	60.4	65.2	68.4	70.2	72.1
Annual ave. intake (m^3/s)	1.48	1.71	1.92	2.07	2.17	2.23	2.29
Annual ave. spill ($10^6 m^3$)	25.1	18.7	13.0	8.8	6.0	4.4	2.7
Efficiency (%) *1	64	74	82	89	80	96	98

Note: *1: Efficiency is the ratio of annual average flow to the inflow to the reservoir

<u>Cost Curve</u>

The cost for the construction and maintenance of the dam and diversion and intake facilities have been considered.

(1) Guare Dam and Appurtenant Structures

Construction Cost

The construction cost of Guare Dam and appurtenant structures for the purpose of optimization study has been estimated as follows:

Gross capacity	Embankment Cost	Other cost *1	Total cost *2
$\times 10^6 m^3$	$ mil	$ mil	$ mil
20	15.7	4.1	24.7
25	18.5	4.1	28.2
30	20.4	4.1	30.5
35	22.7	4.1	33.5
40	24.8	4.1	36.2
50	40.7	5.2	45.9
60	61.7	5.8	67.5

Note: *1: include intake and spillway cost
*2: include 25% contingency

O&M Cost

Operation and maintenance cost is assumed at 2% of the construction cost.

Annualized Cost

Annualized cost has been obtained as the sum of annualized construction cost and annual operation and maintenance cost. Annualized construction cost has been calculated with a present worth of an annuity factor of 0.11 (project life of 50 years and an interest rate of 12%).

Gross capacity	Construction	O&M	Total
$\times 10^6 m^3$	$ mil	$ mil	$ mil
20	2.72	0.49	3.21
25	3.10	0.56	3.66
30	3.36	0.61	3.97
35	3.69	0.67	4.36
40	3.98	0.72	4.70
50	5.05	0.92	5.97
60	7.43	1.35	8.78

(2) Diversion Cost to Caujarito Treatment Plant

Construction Cost

The cost of the pumping station and a diversion pipeline for the use of optimization study has been estimated as follows:

Cpcty.	Intake	Pump	Pipeline *1				Others	Total
*1			dia	Steel	Install.	Cost *2	*3	*4
10^6m^3	m^3/s	$ mil	mm	$/m	$/m	$ mil	$ mil	$ mil
20	1.12	0.97	1,240	692	90	27.4	0.32	35.9
25	1.35	1.11	1,310	716	90	28.2	0.32	37.0
30	1.55	1.23	1,370	736	90	28.9	0.32	38.1
35	1.71	1.33	1,410	752	95	29.6	0.32	39.1
40	1.85	1.41	1,460	767	95	30.2	0.32	39.9
50	1.93	1.46	1,480	775	95	30.5	0.32	40.4
60	1.99	1.49	1,500	782	95	30.7	0.32	40.6

Note: *1: Gross storage capacity
*2 Pipeline length is 35 km
*3: Others includes direct cost for river crossing, considered constant
*4: Includes 25% contingency

O&M Cost

O&M cost has been estimated as power cost on the basis of Bs.8.47/kWh and Bs.1,185/kVA as follows:

Cpcty.	Intake	Operation	Maintenance	Total
*1		cost	cost	O&M cost
10^6m^3	m^3/s	$ mil	$ mil	$ mil
20	1.12	0.188	0.036	0.224
25	1.35	0.257	0.037	0.294
30	1.55	0.317	0.038	0.355
35	1.71	0.365	0.039	0.404
40	1.85	0.407	0.040	0.447
50	1.93	0.431	0.040	0.471
60	1.99	0.449	0.041	0.490

Note: *1: Effective storage capacity

Annualized Cost

Annualized cost has been obtained as the sum of annualized construction cost and annual operation and maintenance cost. Annualized construction cost has been calculated with a present worth of an annuity factor of 0.12 (project life of 15 years for pumps, 30 years for pipes and 50 years for civil structures and an interest rate of 12%).

Cpcty.	Construction	O&M	Total
10^6m^3	$ mil	$ mil	$ mil
20	4.31	0.22	4.53
25	4.44	0.29	4.73
30	4.57	0.36	4.93
35	4.69	0.40	5.09
40	4.79	0.45	5.24
50	4.85	0.47	5.32
60	4.87	0.49	5.36

Note: *1: Gross storage capacity

(3) Total Annualized Cost

The total annualized cost of the dam and the diversion to Caujarito is accordingly as follows:

Gross capacity of Guare Dam	Dam		Diversion		Total
	Construction	O&M	Construction	O&M	
$\times 10^6m^3$	$ mil	$ mil	$ mil	$ mil	$ mil
20	2.72	0.49	4.31	0.22	7.74
25	3.10	0.56	4.44	0.29	8.39
30	3.36	0.61	4.57	0.36	8.90
35	3.69	0.67	4.69	0.40	9.45
40	3.98	0.72	4.79	0.45	9.94
50	5.05	0.92	4.85	0.47	11.29
60	7.43	1.35	4.87	0.49	14.14

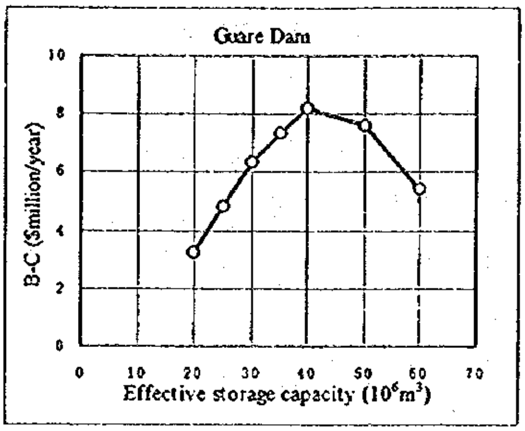
<u>Benefit-Cost Comparison of Alternative Development Cases</u>

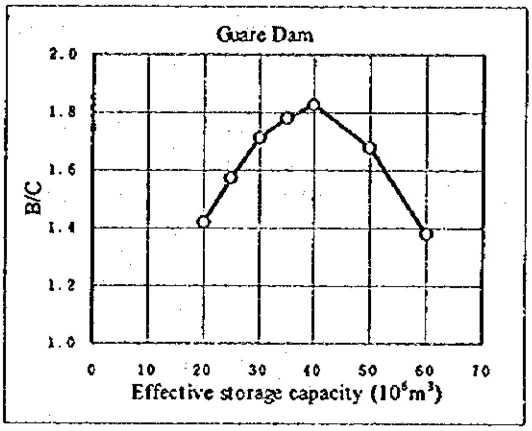
The following table and illustrations show the Annual Net Present Value (B-C), Benefit-Cost Ratio (B/C) and unit cost per cubic meters of water.

Effective storage capacity	Dam height	Ave. Annual Diverted Water		Annual Benefit (B)	Annual Cost (C)	B-C	B/C	Unit Cost
$\times 10^6m^3$	m	$\times 10^6m^3/yr$	m^3/s	$mil/yr	$mil/yr	$mil/yr		$/m^3$
20	49	33.6	1.07	11.0	7.74	3.26	1.42	0.230
25	52	40.4	1.28	13.2	8.39	4.83	1.58	0.208
30	56	46.7	1.48	15.3	8.90	6.36	1.72	0.191
35	59	51.4	1.63	16.8	9.45	7.36	1.78	0.184
40	61	55.4	1.76	18.1	9.94	8.19	1.82	0.179
50	66	57.9	1.84	18.9	11.29	7.65	1.68	0.195
60	70	59.8	1.90	19.6	14.14	5.42	1.38	0.236

Note: *1: Unit benefit is $0.327/m^3

The following illustration compares the Annual Net Present Value (B-C) and Benefit-Cost Ratio (B/C).





As illustrated above, both B-C and B/C are the maximum with the gross storage capacity of 40 $\times 10^6 m^3$. The gross storage capacity has been accordingly determined at 40 m^3/s considering the higher value of B-C and B/C.

4.4.12 Preliminary Design

Principal Features for Design

Principal features for design of Guare dam are the following:

Item	Value
Normal Water Level	EL 346.0 m
Low Water Level	EL 322.0 m
Riverbed Elevation	EL 285.0 m

Main Dam

Preliminary design for the main dam has been conducted and the major features have been determined. Plan and standard section of the dam are presented in Fig. 4.4-9 and 4.4-10, respectively.

(1) Dam Axis

At 30 downstream from the axis proposed by INOS as determined in Section 4.4.7.

(2) Dam Type

Rockfill type has been selected as discussed in Section 4.4.9.

(3) Crest Elevation

As a result of flood routing, Surcharge Water Level has been determined at EL 350.0 m, 4 m above the Normal High Water Level of EL 346.0 m. The crest elevation has been determined at EL 352.0 m adding a 2-m freeboard to the Surcharge Water Level.

(4) Typical Cross Section

Principal dimensions have been determined as follows:

- Crest elevation : EL 352 m
- Crest width : 10 m
- Upstream slope : 1 : 2.5
- Downstream slope : 1 : 2.25

Spillway

Preliminary design for the spillway has been conducted and the major features have been determined as follows: Plan and standard section of the dam are presented in Fig. 4.4-9 and 4.4-10, respectively.

- Design discharge : 600 m^3/s
- Type : Tunnel spillway
- Surcharge Water Level : EL 345 m
- Surcharge capacity : 7.9×10^6 m^3
- Overflow depth : 4 m
- Tunnel dimension : 8 m-diameter

Intake

Major features of the intake have been determined as follows:

- Domestic water : Intake tower, 3-span ϕ500 steel sluice
- Maintenance flow : Inclined sluice of 3-span ϕ150 steel sluice
  Capacity: 0.09 m^3/s

Foundation Treatment

The following foundation treatment has been proposed.

- Dam foundation : Curtain grouting; 2 m pitch zigzag
- Left bank ridge : Curtain grouting
- Right bank abutment : Rim grouting

Temporary Diversion Works

The following temporary diversion works has been proposed.

- Design flow : 350 m^3/s
- Tunnel : Standard horseshoe type
  i = 1/50, 6 m-diameter

Slope Protection for Left Bank Ridge

Slope protection works have been proposed from the dam axis to inlet of the spillway. Anchored shotcrete has been applied.

4.4.13 Cost Estimate

Construction cost has been estimated as follows (for detail, see Table 4.4-2).

Item	Cost (US$ million)
Construction of dam	21.61
Construction of spillway and intake	3.57
Pumping station and diversion pipe	27.76
(Sub-total)	52.94
Engineering and administration (15%)	7.94
Physical contingency (25%)	15.22
Total	76.10

4.5 Conclusion and Recommendation

4.5.1 Summary of the Study Results

Utilization plans for the Ocumarito River and Guare Dam have been studied and optimum scales for each plan have been determined in the previous sections of this chapter.

The following tables compare the efficiency of the plans by development scale, Annual Net Present Value (B-C), Benefit-Cost Ratio (B/C), and unit cost per cubic meter of water.

Utilization plan for Ocumarito River:

Diversion Capacity	Ave. Annual Diverted Water	Ave. Annual Diverted Water	Annual Benefit (B)	Annual Cost (C)	B-C	B/C	Unit Cost
m^3/s	mcm/yr	m^3/s	$mil/yr	$mil/yr	$mil/yr		$/$m^3$
without El Peñón							
0.5	5.13	0.16	1.68	1.31	0.37	1.28	0.255
1.0	7.80	0.25	2.55	1.81	0.74	1.41	0.232
2.0	10.20	0.32	3.34	2.33	1.01	1.43	0.228
3.0	10.56	0.33	3.45	2.80	0.65	1.23	0.265
4.0	10.63	0.33	3.48	3.04	0.44	1.14	0.286
5.0	10.63	0.33	3.48	3.36	0.12	1.03	0.316
with El Peñón of	30×10^6 m^3						
0	0.50	0.05	0.49	2.81	-2.32	0.17	1.873
0.5	6.63	0.21	2.17	4.12	-1.95	0.53	0.621
1.0	10.14	0.32	3.32	4.62	-1.30	0.72	0.456
2.0	13.86	0.44	4.53	5.14	-0.61	0.88	0.371
3.0	14.67	0.47	4.80	5.61	-0.81	0.86	0.382
4.0	14.96	0.47	4.89	5.85	-0.96	0.84	0.391
5.0	15.10	0.48	4.94	6.17	-1.23	0.80	0.409

Note: *1: Unit benefit is $0.327

Pumping to Tuy III pipeline plan:

Diversion Capacity	Ave. Annual Diverted Water	Ave. Annual Diverted Water	Annual Benefit (B)	Annual Cost (C)	B-C	B/C	Unit Cost
m^3/s	mcm/yr	m^3/s	$mil/yr	$mil/yr	$mil/yr		$/$m^3$
0.5	6.09	0.19	1.99	0.578	1.414	3.45	0.095
1.0	10.5	0.33	3.43	0.846	2.588	4.06	0.081
2.0	15.4	0.49	5.04	1.371	3.665	3.67	0.089
3.0	17.9	0.57	5.85	1.713	4.141	3.42	0.096
4.0	19.5	0.62	6.38	2.218	4.159	2.88	0.114
5.0	20.3	0.64	6.64	2.638	4.000	2.52	0.130

Guare Dam plan:

Effective storage capacity	Dam height	Ave. Annual Diverted Water		Annual Benefit (B)	Annual Cost (C)	B-C	B/C	Unit Cost
$\times10^6m^3$	m	$\times10^6m^3/yr$	m^3/s	\$mil/yr	\$mil/yr	\$mil/yr		$\$/m^3$
20	49	33.6	1.07	11.0	7.74	3.26	1.42	0.230
25	52	40.4	1.28	13.2	8.39	4.83	1.58	0.208
30	56	46.7	1.48	15.3	8.90	6.36	1.72	0.191
35	59	51.4	1.63	16.8	9.45	7.36	1.78	0.184
40	61	55.4	1.76	18.1	9.94	8.19	1.82	0.179
50	66	57.9	1.84	18.9	11.29	7.65	1.68	0.195
60	70	59.8	1.90	19.6	14.14	5.42	1.38	0.236

Note: *1: Unit benefit is $\$0.327/m^3$

4.5.2 Conclusion and Recommendation

<u>Utilization Plan of the Ocumarito River</u>

In the case of the Ocumarito-Lagartijo diversion plan without El Peñón Dam, the optimum development scale is a capacity of 2 m^3/s. In this case, an amount of 10.20×10^6 m^3 (an annual average of 0.32 m^3/s) of water will be developed with the unit construction cost of US$\$0.228/m^3$.

If the construction of El Peñón Dam is considered, an additional 3.66×10^6 m^3 (in an average of 0.12 m^3/s) is obtained with the annual construction cost of US\$2.81 million. This means that the construction of El Peñón Dam is US$\$0.768/m^3$.

On the other hand, the unit construction cost of the pumping plan to Tuy III pipeline is relatively low at US$\$0.130/m^3$. In this case, the annual developed water is 20.3×10^6 m^3 (an annual average of 0.64 m^3/s).

In conclusion, for the use of the Ocumarito River, the pumping plan with a capacity of 5 m^3/s is recommended.

However, it should be noted that in the case of Ocumarito-Lagartijo diversion, it could be used as an emergency route. Namely, it could be used if the Tuy III pipeline had a problem, water from Camatagua could be sent through this diversion. In the case of pumping plan to Tuy III pipeline, this emergency function could not be obtained.

It is recommended that the following hydrological observation is conducted for the detailed study in the future:

- Daily record of inflow and release at Ocumarito Dam
- Daily record of water released at Caicita

Guare Dam Plan

The optimum scale of the proposed Guare Dam has been determined at $40\times10^6 m^3$ of gross storage capacity with a dam height of 67 m. The annual developed water is $55.4\times10^6 m^3$ (equivalent to an average flow of 1.76 m^3/s). If maintenance flow is not taken into consideration, $68.4\times10^6 m^3$ (equivalent to an average flow of 2.17 m^3/s) is available, but it has been considered to prevent the deterioration of water quality of the Tuy River.

The unit construction is estimated at US\$0.179/m^3. This is competitive to US\$0.262/m^3 of the presently ongoing Taguaza-Taguacita interconnection.

It is recommended to conduct a study to examine the feasibility in more detailed sense. The study should include the possible option of water diversion from the proposed dam. The following hydrological observations should be initiated.

- Daily record of water level at the proposed Guare damsite
- Periodical discharge measurement to develop a H-Q curve