

No. 3

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)  
REPUBLIC OF ECUADOR  
ECUADORIAN INSTITUTE OF WATER RESOURCES (INERHI)

**FEASIBILITY STUDY  
ON  
TUMBABIRO IRRIGATION PROJECT**

**FINAL REPORT  
(MAIN REPORT)**

MARCH 1994

PACIFIC CONSULTANTS INTERNATIONAL  
NAIGAI ENGINEERING CO., LTD.

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FEASIBILITY STUDY ON TUMBABIRO IRRIGATION PROJECT

FINAL REPORT  
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**NAIGAI ENGINEERING CO., LTD.**

国際協力事業団

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## PREFACE

In response to a request from the Government of the Republic of Ecuador, the Government of Japan decided to conduct a feasibility study on the Tumbabiro Irrigation Project and entrusted the study to Japan International Cooperation Agency (JICA).

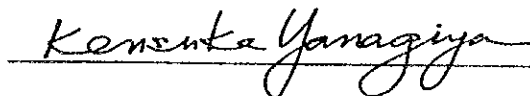
JICA sent to the Republic of Ecuador a study team headed by Mr. Masahito Yamanaka, Pacific Consultants International, three times from August 1992 to February 1994.

The team held discussions with the officials concerned of the Government of the Republic of Ecuador, and conducted the field survey at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Ecuador for their close cooperation extended to the team.

March, 1994



Kensuke Yanagiya

President

Japan International Cooperation Agency

March, 1994

Mr. Kensuke Yanagiya  
President,  
Japan International Cooperation Agency,  
Tokyo, Japan

Dear Mr. Yanagiya,

Letter of Transmittal

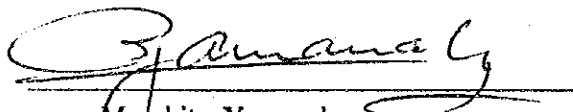
We are pleased to submit you the final report of the Feasibility Study on Tumbabiro Irrigation Project in Imbabura Province of the Republic of Ecuador. The report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency as well as the formulation of the above mentioned project. The comments made by the officials concerned of the Government of Ecuador during discussions on the draft report which were held in Quito City and Tokyo are also included in this report.

The project area has been playing an important role as food supply base and improvement of irrigation system of the area is urgently required. With the implementation of the Project, high economic return (EIRR = 22.9 %) and other related social impact on the regional economy can be expected. Furthermore, this project will become the model development for similar areas in Ecuador.

In view of the urgency of irrigation development in the area and of the need for socio-economic development of Ecuador as a whole, we recommend that the Government of Ecuador implement this Project as a top priority.

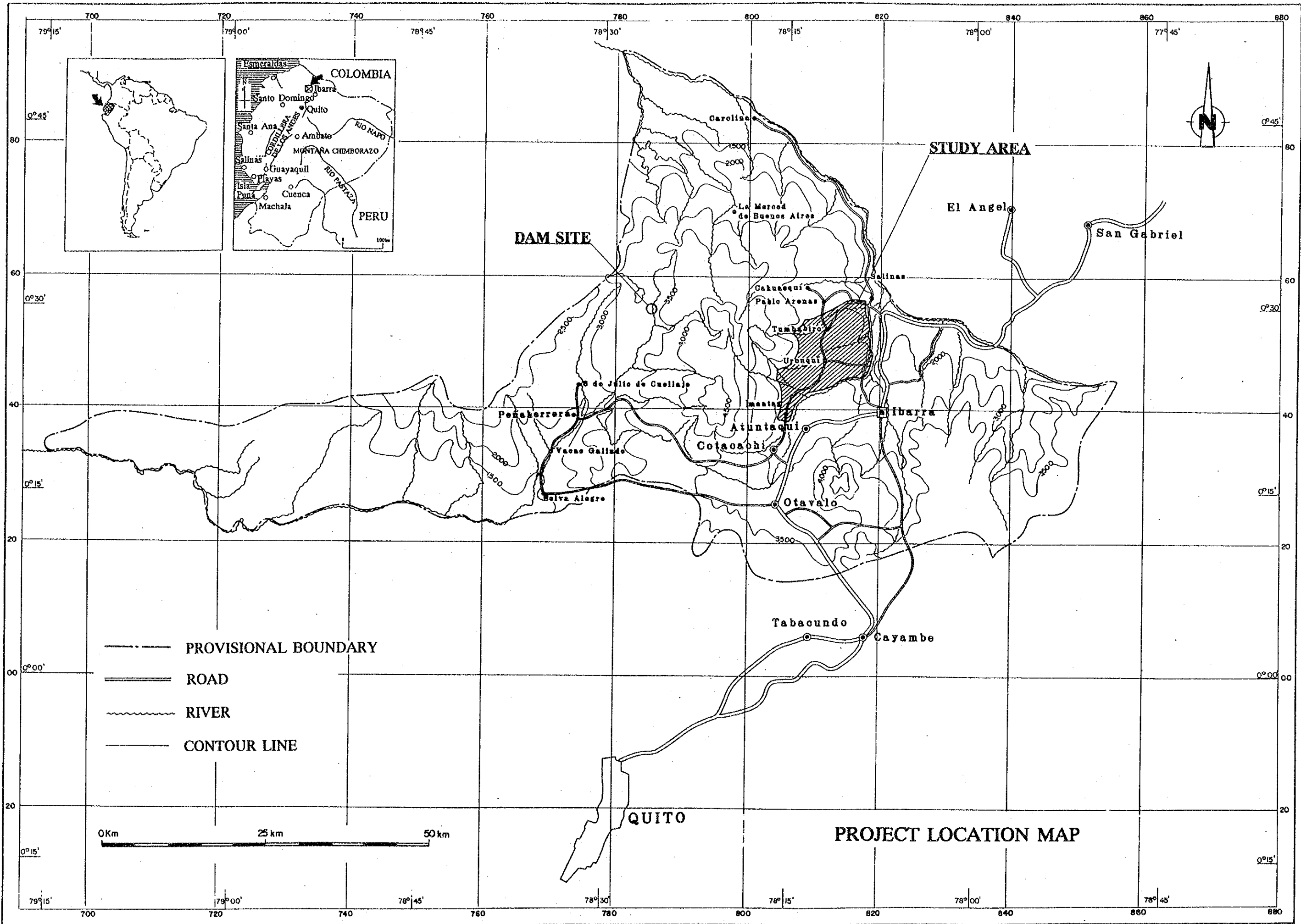
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Agriculture, Forestry and Fisheries and the Embassy of Japan in the Republic of Ecuador. We also wish to express our deep gratitude to the officials concerned of the Government of Ecuador for the close cooperation and assistance extended to us during our field study.

Very truly yours,

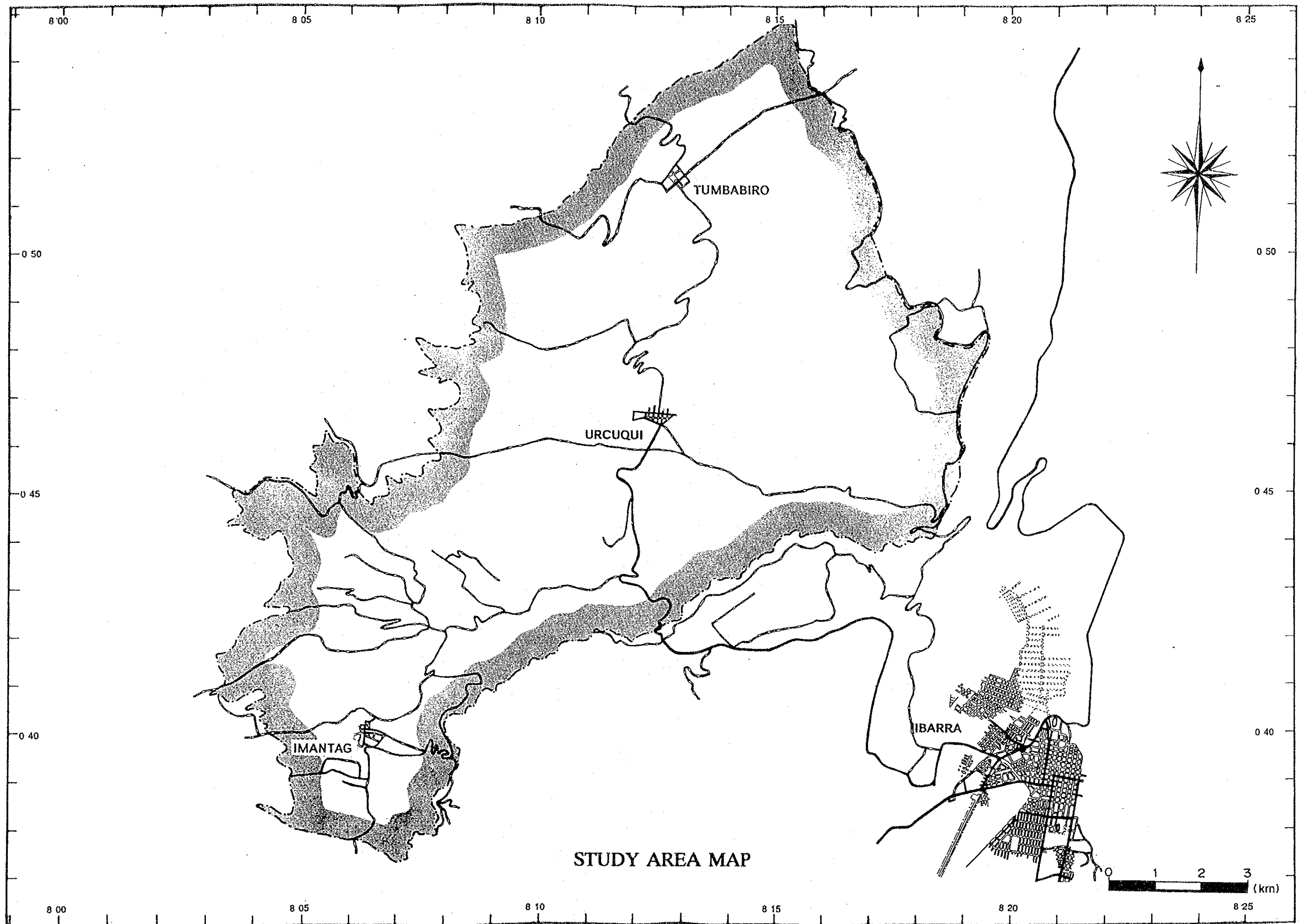


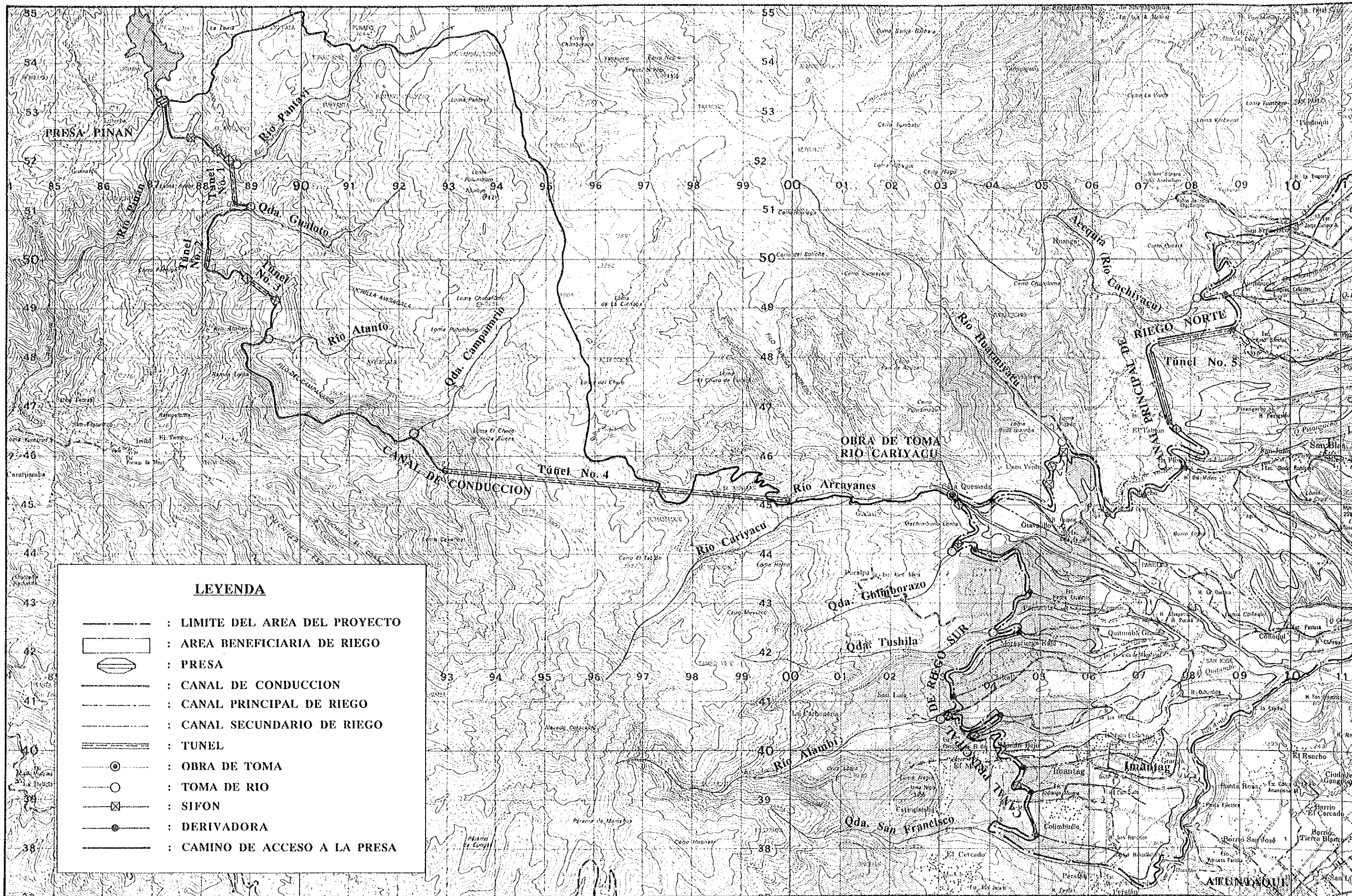
Masahito Yamanaka  
Team Leader  
Feasibility Study Team on Tumbabiro  
Irrigation Project  
Pacific Consultants International/  
Naigai Engineering Co., Ltd.





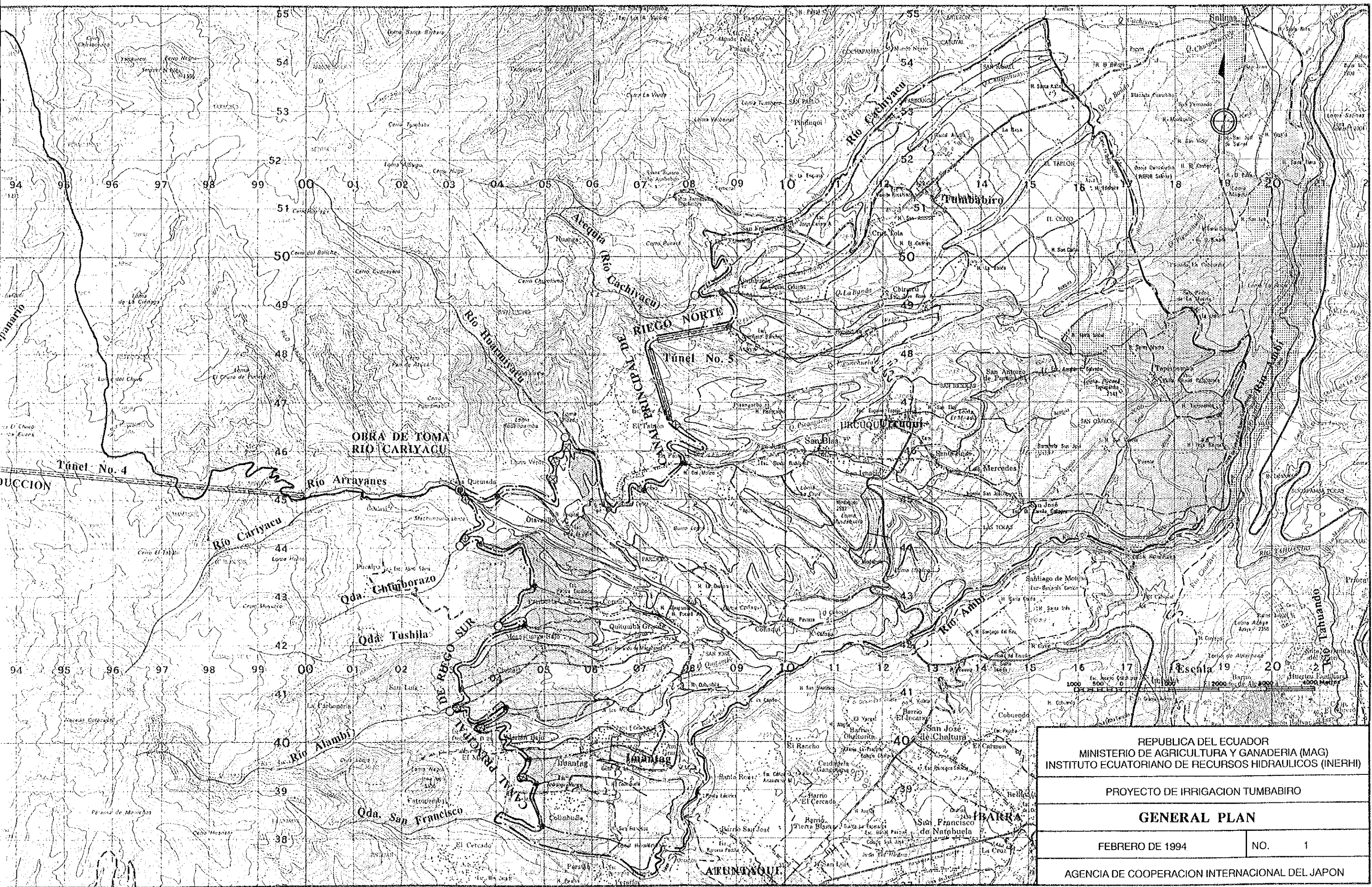






**LEYENDA**

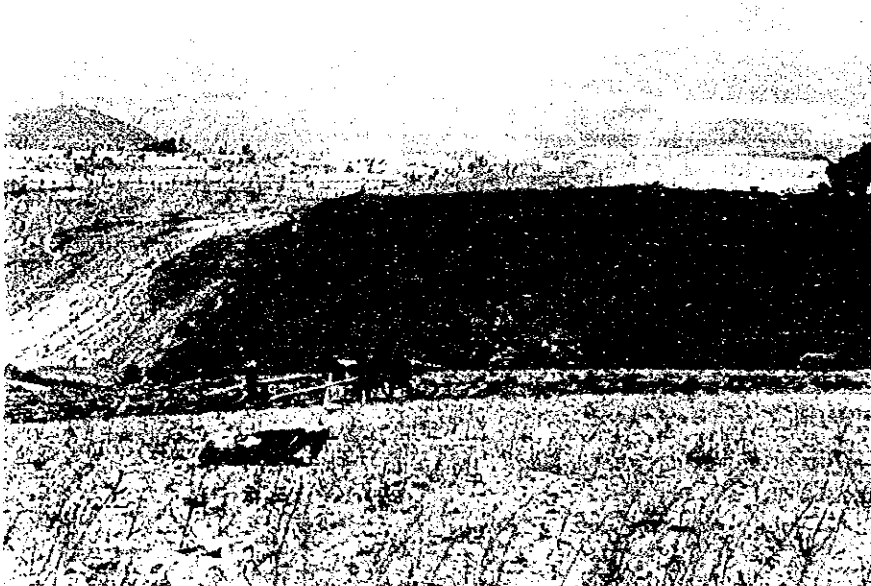
- : LIMITE DEL AREA DEL PROYECTO
- ▨ : AREA BENEFICIARIA DE RIEGO
- ⬭ : PRESA
- ==== : CANAL DE CONDUCCION
- : CANAL PRINCIPAL DE RIEGO
- : CANAL SECUNDARIO DE RIEGO
- ==== : TUNEL
- ⊙ : OBRA DE TOMA
- : TOMA DE RIO
- ⊠ : SIFON
- ⊙ : DERIVADORA
- : CAMINO DE ACCESO A LA PRESA



REPUBLICA DEL ECUADOR MINISTERIO DE AGRICULTURA Y GANADERIA (MAG) INSTITUTO ECUATORIANO DE RECURSOS HIDRAULICOS (INERHI)	
PROYECTO DE IRRIGACION TUMBABIRO	
<b>GENERAL PLAN</b>	
FEBRERO DE 1994	NO. 1
AGENCIA DE COOPERACION INTERNACIONAL DEL JAPON	



1.  
Study Area (Urcuquí)  
after harvesting of green  
peas



2.  
Study Area (Urcuquí)  
plowing by cattle



3.  
Study Area (Urcuquí)  
weeding



4.  
Proposed reservoir area  
(view from the left bank  
of the proposed dam)



5.  
Downstream section of  
Piñán River  
(view from the left bank  
of the proposed dam)



6.  
River bed at the proposed  
dam axis



7.  
Proposed barrow pit  
(view from the left bank  
of the proposed dam)



8.  
Confluence of Piñán and  
Pantaví Rivers



9.  
Proposed Cariyacu  
headworks site

## ***SUMMARY***





## SUMMARY

### 1. BACKGROUND AND OBJECTIVES OF THE STUDY

#### 1.1 Background of the Study

The Government of the Republic of Ecuador established in 1989 the National Development Plan (1989-1992), which targeted at the re-expansion of food crop production and the acceleration of agricultural export by expansion of crop production such as coffee, cacao and banana. The Plan also targeted at the expansion of agricultural production for domestic consumption.

Tumbabiro Area located in the northeastern part of Imbabura Province is characterized as the area of lower agricultural productivity compared with the surrounding areas because of insufficient irrigation water in spite of high potentiality of land for agricultural production.

In consideration of the above, the Government of the Republic of Ecuador planned to develop Tumbabiro Area by providing irrigation water as one of the main supply center of agricultural products and also to stabilize and improve the living conditions of the farmers in the area.

In this connection, the Government of the Republic of Ecuador requested to the Government of Japan in April 1990 for the technical cooperation for carrying out the feasibility study of the Tumbabiro Irrigation Project.

In response to the request, the Government of Japan dispatched to Ecuador the Preliminary Survey Mission through Japan International Cooperation Agency (hereinafter referred to as JICA) in April, 1992 and the Scope of Work (S/W) of the Study on the Project was concluded by both parties. Based on the above S/W, JICA dispatched the Study Team and conducted the Study on the Project.

#### 1.2 Objectives of the Study

The objectives of the Study are to conduct a feasibility study of the agricultural development project in Tumbabiro Area which mainly includes water resources

development plan and irrigation facilities improvement plan, and to implement technical transfer to Ecuadorian staff in connection with planning of irrigation scheme.

## **2. NATIONAL AND PROVINCIAL BACKGROUND**

### **2.1 Brief Description of the Country**

According to the census in 1990, Ecuador had a population of 9,648 thousands, and population annual growth rate during the past ten years (1980-1990) was 1.6%.

Agriculture was traditionally the basis of the national economy. Agricultural sector's share in the GDP has been decreasing since the oil production started in 1970. However, its sector still plays an important role in the national economy and an employment rate in the sector is still about 50% of the economically active population. The principal agricultural products are banana, coffee, cacao, rice, maize, soybean, cotton, vegetables, fruits, etc.

### **2.2 Brief Description of Imbabura Province**

The Imbabura Province involving the Study Area covers the northern part of Ecuador. Ibarra city, the capital city of the Province, is located approx. 140 km far from Quito city, the capital city of the country.

According to the census in 1990, the population of the Imbabura Province was 265,499 which was equivalent to 2.8% of the national population. Population density was 58.2 persons/km<sup>2</sup>. 129,174 persons (48.7%) live in urban area and 136,325 (51.3%) in rural area. The economically active population was 90,831, 33.3% of which were engaged in agricultural (the first industry) sector.

The economy of the Imbabura Province is based on agriculture, and it is actually supported by the agricultural production. Main crops in the Province are cereals such as maize, barely and wheat, covering approx. 60% of the total cultivated area. In addition to cereals, kidney bean, sugarcane and potato are mainly cultivated.

### **3. THE STUDY AREA**

#### **3.1 General Feature**

The Study Area is situated in the Imbabura Province which covers the northern part of the country, and located approx. 20 km northwest of the Ibarra City, the capital of the Province. The population in the Study Area was 12,055, the total number of household 1,491 and the average number of persons of one family 6.8 (Census, 1992).

#### **3.2 Natural Feature**

##### **(1) Study Area**

In general, the Study Area is classified as high land, the altitude of which is 1,700 – 2,540 m. As for its topography, deep valleys have been developed in northwest – southeast direction. Therefore, the Area is divided into some gentle ridges.

The average annual rainfall is 590 mm and the distribution of is characterized in the rainy (Oct. – Apr.) and dry (May – Sept.) seasons. Seventy seven (77)% of the annual rainfall are concentrated in the rainy season.

The monthly average temperature in the Study Area varies a little from 18.0 to 18.8°C through a year. The average temperatures of the monthly maximum and minimum temperatures are 23.3 – 24.9°C and 11.9 – 13.7°C, respectively. The daily change of temperature is within 9.6 – 12.0°C.

##### **(2) Water Resources Area**

The proposed dam site is located on the Piñán River at altitude of 3,000 m. The straight distance between the dam site and the Study Area is approx. 22 km. The source of the Piñán River is located at 12 km north of the proposed dam site and at El 3,300 m. It flows southward and joins with the Pantaví River at 1 km downstream of the proposed dam site, forming the Pitura River. The stream of the Piñán River is gentle (1/150) and wide at the upstream section of the proposed dam site, but steep (1/12) and narrow at the downstream section. The watershed of the river is gentle hill in general except for the boundary area being comparatively steep.

The outline of meteorology of the Water Resources Area estimated based on the observed data at the Apuela Gauging Station, etc is as follows:

Temperature:	Annual ave. of daily ave.:	12°C
	Annual ave. of daily max.:	18°C
	Annual ave. of daily min.:	7°C
Rainfall:	Annual ave.	: 1,800 – 2,000 mm
	Daily max.	: 120 mm
	Rainfall days	: 150 days/year

According to the existing geological data, the old basement rocks and volcanic rocks that are produced through volcanic activities and covering the old basement rocks are prevailing. The old basement rocks are composed of sandstone, limestone, Macuchi Formation and granodiorites which intrude into Macuchi Formation. The volcanic rocks are those of Pumamaqui, Yanahurcu, Cotacachi and Negro Puño.

### (3) Soil

All mother materials of soil in the Study Area are volcanic ash. The soil texture is mostly composed of loam and drainability is good. The soil pH is from neutral to weak alkaline because of high degree of base saturation. On the other hand, the contents of organic matter, nitrogen and phosphorous are low.

The results of the land classification of the Study Area based on the soil survey are as shown below:

Area by Land Class

Land class	1	2	3	4	5	6	TM	Total
Area (ha)	0	5,562	1,695	2,185	206	2,141	1,011	12,800
Ratio (%)	0	43	13	18	2	17	8	100

Note: TM = river, village, etc.

### 3.3 Agriculture

#### (1) Land Use

The area by respective present land use is shown below:

Area by Present Land Use

	Cultivated land	Pasture	Forest	Abandoned land	Urban etc.	Total
Area (ha)	7,373	2,396	443	2,553	35	12,800
Ratio (%)	57.6	18.7	3.5	19.9	0.3	100.0

The characteristics of present distribution of land by land use are summarized as follows:

- a. Cultivated lands are distributed in the comparatively flat areas;
- b. Natural pasture is distributed in the steep-sloped area. On the other hand, improved pasture is distributed in the comparatively flat area;
- c. Almost all the forest are the afforestation of Eucalyptus; and
- d. The abandoned lands that can not be used as agricultural land are distributed in the steep-sloped areas along the rivers.

#### (2) Agricultural Production

The present cropped area and agricultural production in the Study Area are as shown below. The maize, wheat and barley are the principal crops in the Study Area. The cropped area of their crops occupies almost 70% of its total. The Study Area has played an important role as the production area of the basic crops.

Present Cropped Area and Production

Crop	Cropped Area (ha)	Unit Yield (ton/ha)	Total Production (ton)
Maize	1,602	0.91	1,457.6
Wheat	1,148	1.53	1,757.1
Barley	1,028	0.85	873.4
Kidney bean	761	0.89	676.9
Potato	186	11.61	2,163.7
Sugarcane	106	45.40	4,802.3
Green peas	55	0.54	29.9
Fruit trees	111	19.65	2,181.2
Vegetables	40	30.62	1,224.6
<b>Total</b>	<b>5,037</b>	<b>-</b>	<b>-</b>

Note: Agacate and tomato are adopted as the represented fruit tree and vegetable, respectively.

**(3) Existing Cropping Pattern**

The existing cropping pattern of the main crops in the Study Area differs in accordance with whether the farm land is irrigated or not. The typical cropping patterns of respective farm lands are shown below:

Existing Cropping Pattern

Crop	J	F	M	A	M	J	J	A	S	O	N	D
<b>I. Rainfed</b>												
Maize												
Kidney Bean												
Wheat												
Barley												
<b>II. Irrigated</b>												
Maize												
Kidney Bean												
Potato												
Potato												

The fertilizer and chemicals are comparatively widely used. However, due to low use of improved seed, disease and pest of crops are common.

**(4) Land Tenure**

The present land tenure by farm size in the Study Area is as shown below. The average size of land holding is 8.6 ha. The area of land owned by the small-scale farmers (holding less than 3.0 ha of land) is only 6.8% of the total area, even though 72.3% of the farmers in the Study Area are categorized in the small-scale farmers.

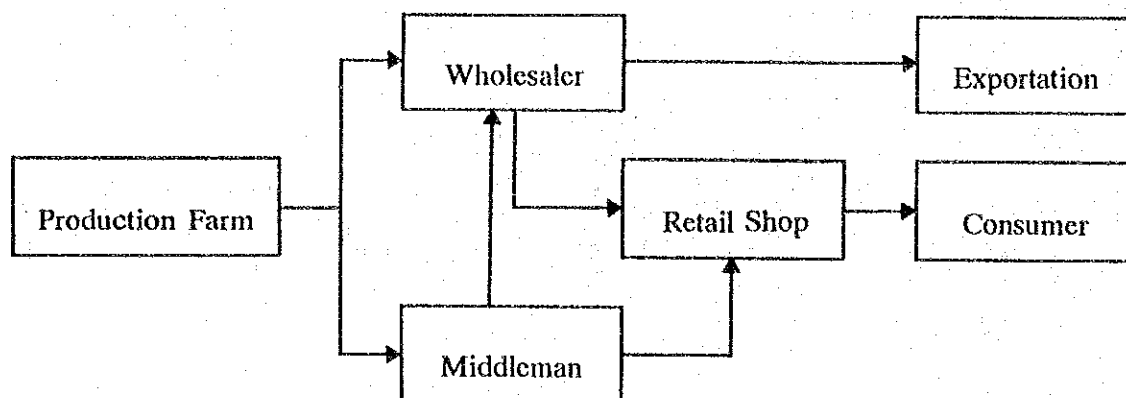
Present Land Tenure

Farm Size (ha)	Household		Owned Area		
	(No.)	(%)	(ha)	(%)	(ha/household)
Small-scale					
1.0 or less	781	52.4	315	2.5	0.4
1.1 – 3.0	297	19.9	553	4.3	1.9
Sub-total	1,078	72.3	868	6.8	0.8
Medium-scale					
3.1 – 10.0	280	18.8	1,529	11.9	5.5
Large-scale and Plantation					
10.1 or more	133	8.9	10,403	81.3	78.2
Total	1,491	100.0	12,800	100.0	8.6

**(5) Marketing System**

The marketing channel of farm products in the Study Area is illustrated below:

### Marketing Channel of Farm Products



The DPA--Imbabura executes agricultural administration and agricultural support services in close collaboration with the Provincial Agriculture and Livestock Council. In Cotacachi, these services are carried out by the ASA--Cotacachi, and in Ibarra through the Technical Department of DPA--Imbabura. The extension activities are carried out in conformity with the Agriculture and Livestock Technical Development Program (PROTECA).

#### **3.4 Existing Irrigation Facilities**

In the Study Area, there are 24 existing irrigation canals "acequia" (mainly earth lined). The water resources of these canals are mostly the rivers/streams flowing around the Study Area, the intakes of which are located at the upstream sections of these rivers/streams and the altitude of intakes is much higher than the farm land. Therefore, water is induced to the farm land by long--distance. Total length of the canals is approx. 240 km. The total area of the farm lands benefitted by these irrigation waters is 2,520 ha and number of persons who are paying the water charge is 1,730. Some of the large and medium--scale farmers are practicing sprinkler irrigation.

The operation and maintenance of the existing irrigation facilities are performed by the Water Use Union (Junta de Usuarios de Agua) organized by the beneficial farmers for respective canals. The canals are eroded at many places because of their gradient being steep and their lining being earth. Therefore, the canals are not maintained well.



## **4. THE PROJECT**

### **4.1 Project Formulation**

#### **(1) Problem Identification**

The Study Area has played the important role as one of the main production areas of cereals. However, the rainfed cultivation has become difficult due to the decrease of rainfall in recent years. At present, only 26% of the total farm land are irrigated in the Study Area and the amount of irrigation water is not enough. Furthermore, the expansion of the irrigation area is practically impossible due to the limited water resources around the Area.

The farm lands of the large-scale farmers and plantation farmers in the Study Area are equipped with irrigation facilities even though the amount of irrigation water is not sufficient in some of the farm lands. They can easily obtain the agricultural credit and their farming technique is generally high. Some of them have modernized irrigation facilities. In one word, the agricultural productivity of them is high. On the other hand, almost all the small and medium-scale farmers have no irrigation facilities. Even the farmers who have irrigation facilities are suffering from the water shortage problem. Therefore, the agricultural productivity of these farmers is very low.

Under these circumstances, the economy in the Area has retarded and many of the small and medium-scale farmers who have no irrigation facilities have temporarily worked away from home or abandoned agriculture.

Concerning the farming technology, the application of fertilizers, chemicals, etc is comparatively widely performed by small and medium-scale farmers. But it is very difficult for them to purchase the improved seeds and to receive the agricultural supporting services such as technical extension services. These are also other main causes of the low agricultural productivity in small and medium-scale farms.

The large-scale farmers are organizing the cooperatives (Centro Agricola) and buying agricultural inputs cheaper through the cooperatives. However, the small and medium-scale farmers are disadvantageous in respect of procurement of agricultural inputs, technical extension services, shipment of products, etc.

## **(2) Basic Development Concept**

The Project aims at the stability of the regional economy by the stable agricultural production through the stable supply of irrigation water by the improvement of water resources development facilities and irrigation facilities in order to solve one of the big impedimental causes against the development of the Study Area; that is, shortage of irrigation water.

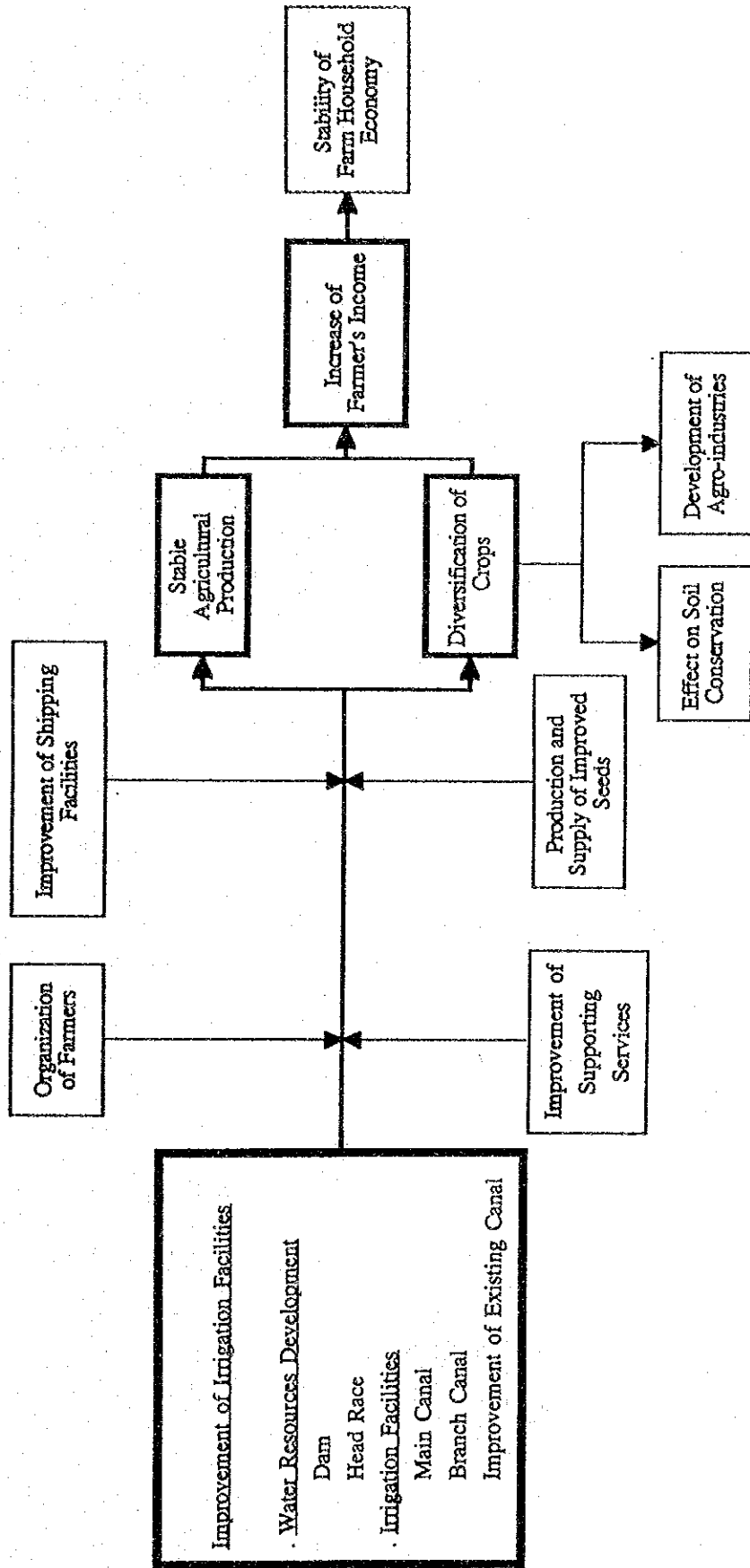
In order to maximize the effect of irrigation farming, the strengthening or improvement of the following matters which are the other causes of the agricultural low productivity in the small and medium-scale farms are also very important:

- the strengthening of agricultural supporting services such as technical extension services;
- the strengthening of organization of farmers;
- the improvement of shipping facilities of agricultural products; and
- the strengthening of production and supply of improved seeds

Through the improvement of irrigation and farming facilities, the diversification of crops, introduction of the crops suitable for the respective field conditions and rational cropping will become possible. Furthermore, the effective utilization of land resources and contribution to the conservation of soil will also become possible.

The basic development concept mentioned above is summarized below:

**Basic Development Concept**



### **(3) Land Use Plan**

In the Pre-F/S Report prepared by INERHI, it is recommended that land classes 1 – 4 be used as agricultural land, because of the constraint in land classification being mostly "slope". In the preparation of land use plan of the Project, it is also considered that the land of class 4 is to be utilized as agricultural land, in general, in addition to lands of classes 1 – 3. In addition, the present irrigation lands are included in the agricultural land, even though they are classified as class 6 due to their steep slope.

The land use plan is prepared by classifying the land characteristics in to 9 zones based on the results of land classification.

The objective development area in the Project is 9,527 ha in total by excluding the areas of Zones VI and VIII and urban area (3,273 ha in total) from the total Study Area of 12,800 ha. The objective irrigation area (total cropped area) is set as 8,574 ha, which is 90% of the objective development area.

### **(4) Irrigation Method**

In the Project Area, the furrow irrigation is practiced for many years by the irrigation farmers, even though the slope of their fields is comparatively steep and the fields are consolidated and equipped to the ones suitable for furrow irrigation.

In the Project, the furrow irrigation is also adopted in due consideration of the following:

- It is judged that the expected productivity will sufficiently be obtained for the proposed crops by furrow irrigation
- Furrow irrigation has well been practiced by the farmers in the Project Area

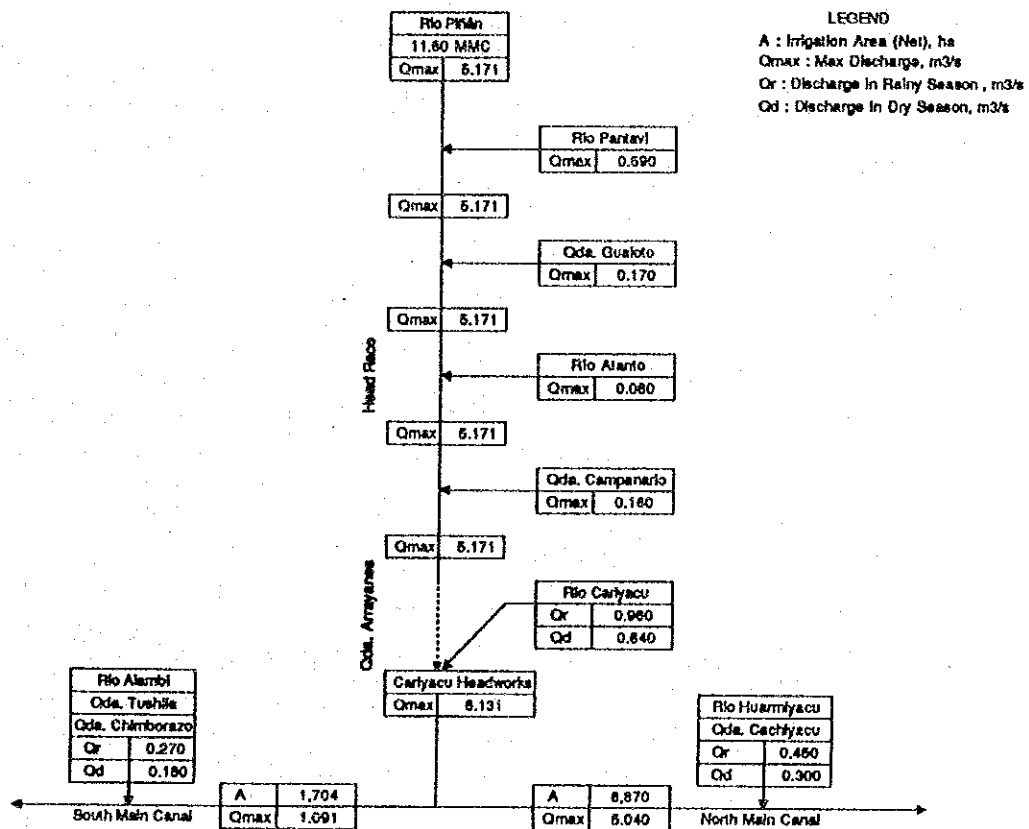
The monthly irrigation water requirements are estimated based on the FAO criteria and the result is shown below:

### Monthly Irrigation Water Requirements (Wrq)

Month	Wrq(mm/month)	Month	Wrq(mm/month)
Jan	107.2	Jul	177.4
Feb	119.8	Aug	110.8
Mar	49.2	Sep	46.4
Apr	11.6	Oct	34.0
May	21.6	Nov	137.2
Jun	181.4	Dec	214.0
Ave		110.9 mm/month (3.4 mm/day)	

Based on the above, the maximum gross irrigation water required is estimated to be 6.851 m<sup>3</sup>/s (December). Furthermore, the irrigation probability is set as 4/5 (80 %) which is widely adopted in Ecuador and other surrounding countries. The planned detailed irrigation canal network together with covering areas and water amounts for respective canals is shown below:

### Proposed irrigation Water Conveyance System



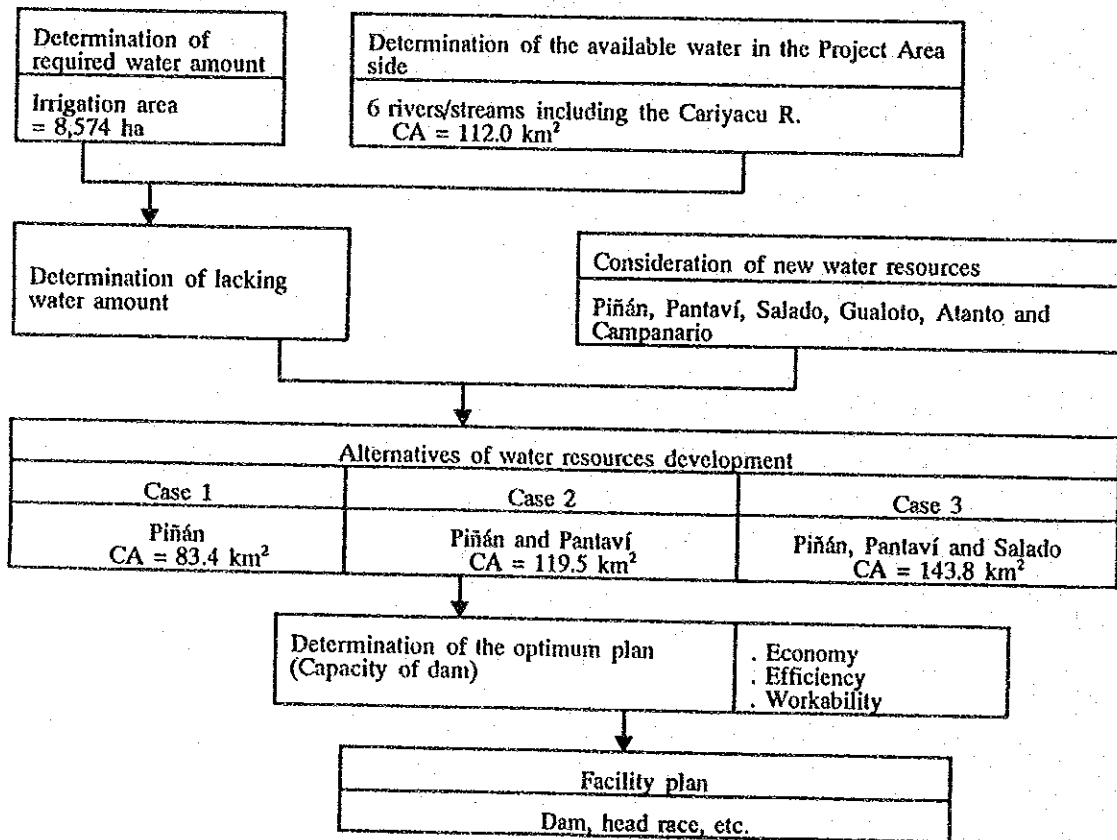
**(5) Water Resources Development Plan**

The proposed water resources development plan has been prepared in consideration of the development possibility and problems of the following two resources and mixed development of them.

- a. Reallocation of the existing available water resources at the Project Area side.
- b. New water resources development in order to supplement the shortage of required irrigation water.

The flow of the analysis is as shown below:

Flow Chart of Water Resources Development Plan



\* CA = Catchment Area

The new water resources development plan is studied based on the construction of a dam on the Piñán River which is the main water resources in the area. In this case, the following three cases have been considered:

- Case 1: A dam to store the discharge of the Piñán River and direct intake of the Pantaví River discharge
- Case 2: A dam to store the discharges of the Piñán and Pantaví Rivers
- Case 3: A dam to store the discharges of the Piñán, Pantaví and Salado Rivers

In all the cases, the discharges of the small rivers of Gualoto, Atanto and Campanario are utilized by directly intaking them to the Head Race, and 5% of the annual average discharge of all the rivers are planned to flow down without use as the maintenance flow of the river course.

As a result of the analysis, the required storage capacities of the dam for respective cases are as shown below:

<u>Case</u>	<u>Required Dam Effective Capacity</u>
1	11.22 x 10 <sup>6</sup> m <sup>3</sup>
2	11.54 x 10 <sup>6</sup> m <sup>3</sup>
3	10.55 x 10 <sup>6</sup> m <sup>3</sup>

The above fact means that it is not effective to store the discharge of the Pantaví River (Case 2) and that the storage capacity can be reduced by 0.67 x 10<sup>6</sup>m<sup>3</sup> by storing the discharge of the Salado River (Case 3). However, in the case of Case 3, the construction of a head race of 12 km long (including a tunnel of 2 km long) is required in order to convey the Salado River discharge to the Piñán River. The construction cost of the head race is much higher than the reduced construction cost of the dam in connection with the reduction of its storage capacity. Therefore, "Case 1", a dam to store the discharge of the Piñán River and direct intake of the discharges of the rivers of Pantaví, Gualoto, Atanto and Campanario, is judged to be the best.

## 4.2 Proposed Development Plan for Agriculture

### (1) Selection of Crops to be Introduced

The Project Area has been playing an important role as the production area of basic foods such as maize, kidney bean, potato, wheat and barley which are widely cultivated in the area. The Project aims at further strengthening this role in the future and also diversifying the crops by the increase of the irrigated farm field.

In the selection of the crops to be introduced with the completion of the irrigation facilities, the following matters have been considered:

a. Crops suitable for the natural conditions of the area

The altitude of the Project Area expands from 1,700 m to 2,540 m. Therefore, the suitability of crops for the altitude of the objective area is one of the important factors in the selection of crops to be newly introduced.

b. Crops which have high profitability

c. Crops useful for the protection of soil erosion on the sloped land and cropping system of them

The Project Area includes much sloped land and has high possibility of its soil erosion. The protection of soil erosion by means of mixed cropping (to reduce the period during bare land by cultivating fruit trees and pasture) is also important for the success of the Project.

d. Crops which have high marketability in and out of the country

In the selection of exportable crops, the marketability in other countries especially in the countries within the Andes Agreement has been considered.

e. Crops substitutable for imported foods

f. Crops cultivation technique of which corresponds to that of the farmers in the area or will be obtainable for the farmers through the technique extension services in the future



The crops selected for the Project in consideration of the above are as shown below:

Crops Introduced in the Project

	Domestic demand	Possibility for exportation	Import substitution	Possibility for agro-industry	Profit-ability	Experience *
<b>Main Crop</b>						
Maize(Seco)	⊙					A
Maize(Choclo)	⊙				○	A
Potato	⊙				○	A
Kidney bean	○	⊙			○	A
Green pea	○			○		A
Wheat	⊙		⊙			A
Barley	⊙		⊙			A
Sugarcane	⊙	○	○	⊙	○	A
<b>Vegetable</b>						
Tomato	⊙	○		⊙	⊙	A
Red pepper	○			⊙		A
Carot	○			○		A
Cabbage	○				○	A
Asparagus	○	○		⊙		B
Welsh onion	⊙				○	A
Cucumber	○	○		○	○	B
Cauliflower	○			○	○	B
Beet	○				○	A
Radish	○				⊙	A
Onion	⊙				○	A
<b>Fruit tree</b>						
Grape	⊙		○	⊙		B
Avocado	⊙	○			○	A
Babaco	○			○	⊙	A
Fig	○			○		A
Cherimoya	○				○	A
Tree tomato	⊙			○	⊙	A
Peach	⊙		○	⊙	⊙	B
Blackberry	○			⊙		A
Apple	⊙		○	⊙	⊙	B
<b>Pasture</b>						
Alfalfa	⊙			⊙	⊙	A

⊙ > ○

\*:Crops have cultivated in the area.

A = Cultivated by many farmers

B = Cultivated by only some farmers for test

**(2) Proposed Cropping Pattern**

The proposed cropping pattern of the selected crops has been set in due consideration of the effective use of rainfall in the area as shown below:

**Proposed Cropping Pattern**

E	F	M	A	M	J	J	A	S	O	N	D	
Kidney bean			Vegetables				Maize +					142 Ha
			Vegetables				Potato					142 Ha
			Kidney bean				Maize(Seco)					1,091 Ha
Kidney bean					Maize(Choclo)						545 Ha	
			Kidney bean				Potato					1,636 Ha
Wheat(Barley)							Kidney bean					1,498 Ha
			Vegetables				Vegetables					723 Ha
Fruits + Pastures												428 Ha
Fruits												1,018 Ha
Pastures												1,201 Ha
Sugarcane												150 Ha
<b>Total</b>												<b>8,574 Ha</b>

The proposed cultivation areas by crop have been set in consideration of the farm size in the area as mentioned below:

**1) Small-scale Farm (less than 3 ha)**

- Farm (less than 1 ha)

To cultivate self-consumptive crops in the first term and vegetables as cash crops in the second term

- Farm (1.1 – 3 ha)

The average cropped area for one farm is 1.7 ha, of which 0.25 ha are used for the cultivation of vegetables, 0.5 ha for fruit trees and remaining 0.95 ha for basic foods. The cultivation of fruit trees is to be performed by mixed cultivation with pasture in order to improve the profitability of land and to protect the soil erosion of land.

2) Medium-scale Farm (3.1 – 10 ha)

The average cropped area for one farm is 4.9 ha, of which 0.5 ha are used for the cultivation of vegetables, 1.0 ha for fruit trees and remaining 3.4 ha for basic foods. The cultivation method for fruit trees is the same in the case of Farm (1.1 – 3 ha).

3) Large-scale Farm (10.1 – 20 ha) and Plantation Farm (more than 20.1 ha)

The average cropped area for one farm is 70 ha and the total cropped area is 6,440 ha. The present sugarcane cropped area is to be maintained and the pasture area is to be reduced to 50% of the present area in consideration of the increase of its productivity due to the introduction of irrigation system to the area.

The remaining areas are to be divided into the following three categories by adopting the present Provincial areawise ratio for crops: Vegetables: 10%, Fruit trees: 20%, Basic foods: 70%

Furthermore, in the Project, maize and potato have been selected as basic foods for the area of lower than El 2,200 m and that of higher than El 2,200 m, respectively. The ratio of the areas is set as 50% each.

Proposed Cropwise Areas

Crop	Area (ha)	Crop	Area (ha)
Maize and Kidney Bean	142	Wheat	749
Maize (Seco)	1,091	Barley	749
Maize (Choclo)	545	Vegetable	1,730
Potato	1,778	Fruit Tree and Pasture	428
Kidney Bean	3,180	Fruit Tree	1,018
Green Peas	1,590	Pasture	1,201
		Sugarcane	150
		Total	14,354

**(3) Proposed Farm Production**

The proposed farm production based on the proposed land use and cropping pattern is as shown below:

Production of Farm Products

(Unit: ton)

Crops	Present	Proposed	Increase
Maize (dry)	1,458	3,660	2,202
Maize (choclo)	-	7,247	7,247
Potato	2,164	32,004	29,840
Kidney bean	677	8,714	8,037
Wheat	1,757	4,719	2,962
Tomato	-	44,115	44,115
Onion	-	18,165	18,165
Peach	-	12,321	12,321
Avocado	-	10,678	10,678
Apple	-	14,375	14,375
Alfalfa	-	191,295	191,295
Sugarcane	4,802	22,500	17,698

As shown in the above Table, the agricultural production will be greatly increase with the implementation of the Project compared with the present condition.

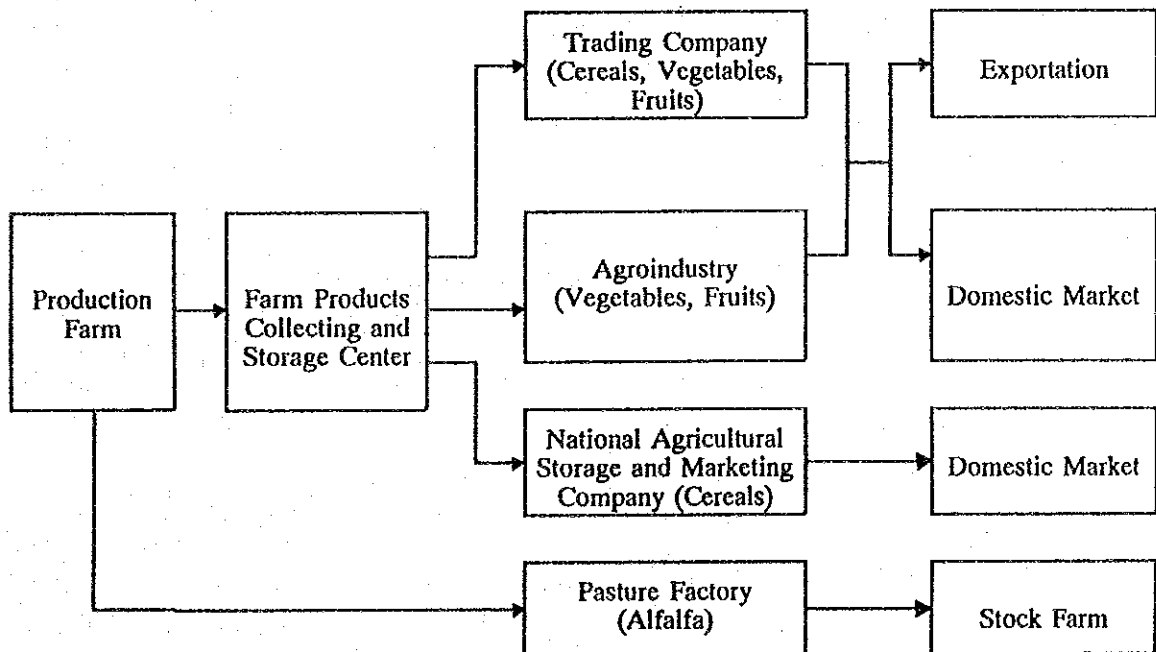
#### (4) Agricultural Supporting Plan

In order to secure farmers' income by averting a middleman in the present distribution system, the system shown below is proposed. It is proposed that the farm products collecting and storage centers are installed in Tumbabiro, Urcuqui and Imantag based on the organization of small and medium-scale farmers in respective areas mentioned below.

In order to achieve the aim of the Project, it is important that the agricultural support to the small and medium-scale farmers through the related institutions is carried out sufficiently. Therefore, strengthening of the agricultural supporting system, such as the production of seed (establishment of a seed production farm) and the extension services (expansion of the existing demonstration farm).

In order to obtain the agricultural supporting services from public institutions, the organization of the farmers is an essential condition. Therefore, an organization such as an association or cooperative of small and medium-scale farmers who have no organizations at present shall be established in each village.

Proposed Distribution and Marketing System



### 4.3 Infrastructure Facilities Planned

The main facilities planned in the Project are summarized below:

#### (1) **Plián Dam**

##### 1) **Dam**

. Dam type	:	Facing-type Rockfill Dam
. Height of Dam	:	48.0 m
. Crest Length	:	220.0 m
. Crest Width	:	10.0 m
. Volume of Dam	:	$350 \times 10^3 \text{ m}^3$
. Design Flood Discharge	:	$200 \text{ m}^3/\text{s}$
. Catchment Area	:	$83.4 \text{ km}^2$
. Normal Full Water Level	:	El 3,001.5 m
. Total Capacity	:	$13.1 \times 10^6 \text{ m}^3$
. Effective Capacity	:	$11.6 \times 10^6 \text{ m}^3$
. Reservoir Area	:	$870 \times 10^3 \text{ m}^2$
. Max. Intake Capacity	:	$5.171 \text{ m}^3/\text{s}$

#### (2) **Cariyacu Head Works**

. River Width	:	75 m
. Design Flood Discharge	:	$65.0 \text{ m}^3/\text{s}$
. Height of Fixed Weir	:	6.5 m
. Total Length of Weir	:	56.5 m
. Intake Gate	:	3.50 m x 3 spans
. Max. Intake Capacity	:	$6.131 \text{ m}^3/\text{s}$
. Sand Sluiceway Gate	:	3.00 m x 2 spans

#### (3) **Canals**

##### 1) **Head Race**

. Total Length	:	23.31 km including tunnels 8.89 km
. Max. Flow Capacity	:	$5.171 \text{ m}^3/\text{s}$
. Canal Type	:	Concrete flume

## 2) Main Canal

. Total Length	:	29.37 km including a tunnel 3.13 km
. Max. Flow Capacity	:	5.295 m <sup>3</sup> /s
. Canal Type	:	Concrete flume

## 3) Branch Canal

. Total Length	:	110.58 km
. Max. Flow Capacity	:	2.534 m <sup>3</sup> /s
. Canal Type	:	Concrete flume

# 5 PROJECT IMPLEMENTATION AND OPERATION & MAINTENANCE

## 5.1 Construction Schedule

The implementation period of the Project construction works is set as 90 months in total consisting of the detailed design phase of 18 months and the construction phase of 72 months. During the detailed design phase, the topographic survey and geological investigation of the sites proposed for the main structures, detailed design work, preparation of tender documents, etc. are to be performed.

During the construction phase, the acquisition of land for the proposed structures, tendering, construction works of the Project facilities, procurement of operation/maintenance equipment, etc. are to be conducted.

## General Construction Schedule

ITEM	1996				1997				1998				1999				2000				2001				2002				2003			
	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12
<b>I. Detailed Design Period</b>																																
1. Topographic Survey and Geological Investigation																																
2. Detailed Design and Prep. of Tender Documents																																
<b>II. Construction Period</b>																																
1. Land Acquisition																																
2. Tendering and Construction Contract																																
3. Preparatory Works and Access Road																																
4. Dam Construction																																
5. Head Race Construction																																
6. Tunnel C-4 Construction																																
7. Cariyacu Headworks Construction																																
8. Main Canal Construction																																
9. Secondary and Tertiary Canal Construction																																
10. Agriculture Assistance Facilities																																
11. Procurement of Operation and Maintenance Equipment																																
12. Construction Supervision																																

### 5.2 Project Implementation System

The Implementation Agency for the Project shall be INERHI. INERHI shall execute the detailed design of the Project facilities, tendering and tender evaluation, selection of the contractor, signing the contract, and supervision of the construction works with the assistance of the Consultants. The Consultants shall assist the Implementation Agency mainly for the technical matters included in the duties of the Implementation Agency. The construction works shall be performed on the contract basis with the successful contractor.

### 5.3 Project Cost

The Project cost consists of the construction cost, land acquisition cost, operation/maintenance equipment procurement cost, environment improvement cost, administration cost, advance survey cost, consulting services cost, and physical and economic contingencies.



The total Project Cost is estimated to be  $1,397 \times 10^9$  S/., the foreign component of which represents  $268 \times 10^9$  S/. (19.2%) and local component  $1,129 \times 10^9$  S/. (80.8%). However, the total Project Cost excluding economic contingency is  $271 \times 10^9$  S/. which consists of  $203 \times 10^9$  S/. (75.0%) for the foreign component and  $68 \times 10^9$  S/. (25.0%) for the local component.

### Project Cost

(Unit :  $10^6$  Sucre)

Description	L/C	F/C	Total
1. Construction Works	46,596	167,371	213,967
2. Land Acquisition	100	0	100
3. Procurement of O/M Equipment	0	1,104	1,104
4. Environment Improvement	4,279	0	4,279
5. Administration	802	0	802
6. Advance Survey	2,592	0	2,592
7. Consulting Services	7,038	16,215	23,253
Sub-total (1 - 7)	61,407	184,690	246,097
8. Physical Contingency (10%)	6,141	18,469	24,610
Sub-total (1 - 8)	67,547	203,159	270,706
9. Economic Contingency	1,061,307	65,007	1,126,313
Total (1 - 9)	1,128,854	268,166	1,397,020
9' (Economic Contingency)	8,828	65,007	73,834
Total (1 - 9')	76,375	268,166	344,541

Note: Economic contingency in ( ) shows the modified local currency portion based on the economic contingency rate of 1.7% per annum instead of 43.8% which has been obtained in adding the average exchange rate between US\$ and Sucre for the past 10 years.

#### **5.4 Operation and Maintenance**

The objective facilities to be operated and maintained in the Project are the Piñán Dam, Cariyacu Head Works, Head Race, Main, Branch and Tertiary Canals, and related facilities. These facilities excluding the Branch and Tertiary Canals shall be operated and maintained by INERHI. On the other hand, the Branch and Tertiary Canals are to be operated and maintained by the water users' associations which will be organized by the beneficiaries.

### **6. PROEJECT EVALUATION**

#### **6.1 Evaluation Basis**

The life of the Project is set as 60 years. The official exchange rate used for the evaluation is US\$1.00 = 1,883 Sucre as of July, 1993.

#### **6.2 Benefit of the Project**

Benefits of the Project generated by the Project implementation are consist of two categories of benefits; farm production and the operation/maintenance roads along the Main Canals.

##### **(1) Farm Production Benefit**

The goal of full development of the crop benefit is set at three years after completion of the Project facilities, and in the case of fruit, it is set at respective production years. Benefit from saving cost of transport is estimated in compliance with the amount of crop production.

The farm production benefit is constituted by incremental net farm production values brought by the provision of irrigation water and supporting services to the farmers. After completion of the Project facilities, the production plan based on the proposed cropping pattern is to be carried out, and the farm production benefit has been estimated with the confirmation by INERHI.

Farm production benefit based on the agricultural production plan is calculated as shown below:

### Farm Production Benefit (economic)

(Unit: 1,000 Sucre)

Item	With Project	Without Project	Increased Value
Gross Production Value	222,711,707	11,214,987	211,496,720
Production Cost	17,060,701	3,098,769	13,961,932
Net Production Value	205,651,006	8,116,218	197,534,788

### Farm Production Benefit (financial)

(Unit: 1,000 Sucre)

Item	With Project	Without Project	Increased Value
Gross Production Value	104,754,964	10,260,479	94,494,485
Production Cost	18,599,757	3,651,662	14,948,095
Net Production Value	86,155,207	6,608,817	79,546,390

## **(2) Other Benefits**

Other benefits can be defined as the anticipated effect of the O/M roads along the Main Canals.

### Anticipated Effect of the O/M Roads

(Unit: Sucre/Year)

Economic Value	Financial Value
15,080,000	20,845,000

## **6.3 Economic and Financial Evaluations**

The project justification is mainly appraised based on the calculation of economic internal rate of return (EIRR) and financial internal rate of return (FIRR).

The results of the evaluations are as follows:

$$\text{EIRR} = 22.9\%$$

$$\text{FIRR} = 14.5\%$$

The social discount rate of Ecuador is estimated at 14.25%. Consequently, the EIRR of 22.9% shows that the Project is economically feasible.

In order to justify the financial viability of the Project at a farm level, the model farmers of small and medium-scales in the Project Area have been selected and financial analysis of these farmers has been made.

#### Financial Analysis of Model Farmers

(Unit: 1,000 Sucre)

Farm Size	1 ha	3 ha	10 ha
Without project	-2,834	-1,475	2,275
With project	6,673	53,567	99,499
Surplus per ha	6,673	17,856	9,950

Taking the above result into consideration, the substantial improvement of the farm household economy in the Project Area can be expected as a result of the Project implementation. Furthermore, the high surplus per hectare shows the remarkable improvement can be expected in the small-scale farmers.

#### **6.4 Comprehensive Evaluation**

With the Project implementation, the improvement of agricultural productivity such as elevating of cropping intensity and increase of unit crop yield will be made possible. Moreover, the following secondary benefits such as generation of employment opportunities for construction works of the Project and agricultural production, and positive impact on the related sectors will also be anticipated:

- a. Increase of employment opportunities in the construction works of the Project.
- b. Increase of employment opportunities due to expansion of the planted area for

own farming. It is expected that the Project will generate the job opportunities of 969,101 man-year (80,758 man-month).

- c. Expansion of agricultural processing and distribution sectors with the increase in agricultural output and input. It is noted that the deal of about 37,400 tons will be expected due to the introduction of fruit production.
- d. Improvement and expansion of social foundation and promotion of vitalizing economy in Sierra (highland) region and also the Province of Imbabura through the improvement of living standards by stable agro-economy and increase in distribution volume of agro-related materials.
- e. Decrease of woman's household labor due to the distribution of irrigation water to each farm.
- f. Impact on agricultural production activities and stabilization of regional public welfare, and contribution to the national economy.
- g. Acceleration of other agricultural development projects in Ecuador.

The above consideration leads to the conclusion that the Project implementation is justified to be feasible from the economic and financial evaluations for which tangible benefits are employed. In addition, socio-economic effects are also fully expected. Accordingly, it is recommended that the Project be implemented in the early stage.

## **7. INITIAL ENVIRONMENTAL ASSESSMENT**

The social and natural environmental impacts in connection with the implementation of the Project have been assessed for respective areas; Water Resources Area (reservoir area, and dam and head race construction sites) and Project Area.

Since very few people live in the Water Resources Area, the implementation of the Project will have little impact on its dwellers as far as resettlement of the dwellers is concerned. The reservoir and surrounding area is covered mainly with natural pasture (paramo) and the submerged pasture area is very small compared with the total pasture land in the reservoir and surrounding area. There are no important animal species on which the Project implementation will give the influence. Consequently, it is judged that the dam construction will give little impact on the area. However, there are a path

of 1 - 2 m wide and small houses in the reservoir area. Thus it is necessary to consider the construction of their substitute.

The head race has to be constructed along the steep sloped mountainsides due to its topography. Most of the construction site belong to the woodland. Therefore, cutting of trees is unavoidable, but there are no important tree species. In order to construct the head race, the excavation of the steep sloped mountainsides is unavoidable. The cut surface of these mountainsides will still be stable even after the completion of the head race, judging from the cut slope stability along the existing canals in similar site.

The dam, head race and temporary construction roads are to be constructed within the Cotacachi-Cayapas Ecological Reservation and/or the Wild Life Protection Area. The construction of these facilities will be legally permissible if the contents of the agreement regarding the construction of the investigation road up to the dam site, judging from the fact that the construction of the above investigation road was permitted with the intention that the Project would be implemented.

Since the collapse and erosion of the cut slope are unavoidable during the construction works, it is necessary to minimize the negative impact on the environment by minimizing the cut of trees and excavation of the mountainside.

The Project Area is the existing farm land and will bring the positive effect like the increase of agricultural products with the implementation of the Project. And it is judged that the Project will not bring any remarkable negative effects on the environment in the Area.

As mentioned above, the social and natural impacts with the implementation of the Project on the environment in the Water Resources Area and the Project Area will be a little even not nil, and it is judged at this moment that the detailed environmental assessment will not be necessary. However, the detailed assessment may be required in the future when the national policy on the environment is changed.

## **8. RECOMMENDATIONS**

### **(1) Implementation of the Project**

It has been concluded that the Project will be feasible judging from both economic and financial view points. Therefore, it is recommended that the Project should be

implemented as soon as possible in consideration of such facts that the Project Area plays the important role as the food supply base to Quito, the capital city of the country and that great contribution to the activation of the area can be expected through the Project implementation.

It is also expected that the direction or method of the agricultural developments in Ecuador will be cleared through the implementation of the Project.

**(2) Present Water Right**

The Project is formulated with the assumption that the water rights of the rivers/streams presently owned by the large-scale farmers in the Project Area are to be canceled and rearranged to the new respective beneficiaries of the Project. Therefore, if this assumption is given up, the Project itself cannot be formulated. In this connection, it is necessary to clarify the cancellation of the present water rights by the documents between INERHI and the large-scale farmers prior to the commencement of the Project.

**(3) Land**

The main Project facilities such as a dam, head race and head works are to be constructed in the land owned by Hacienda El Hospital. Furthermore, some construction roads necessary for the construction works of the above facilities are also to be constructed in the above land.

Therefore, the Project construction works cannot be performed without the cooperation of Hacienda El Hospital. The use right or ownership of INERHI of the above construction sites should be clarified by the documents between INERHI and the Hacienda prior to the commencement of the Project.

In the Project Area, the Branch and Tertiary Canals pass through the private farm lands. Therefore, the use rights of these canals should be clarified by the documents between INERHI and the respective land owners.

**(4) Agricultural Credit to the Small-Scale Farmers**

Even though the big benefit will be born by the implementation of the Project, the introduction of fruit trees which requires the initial investment is planned in the Project even for the small-scale farmers. Therefore, for the successful implementation of the

Project, the agricultural credit to the small-scale farmers is badly necessary. In this connection, the mitigation of the credit conditions and magnification of credit amount of BNF to the small-scale farmers are strongly recommended.

**(5) Utilization of Surplus Water**

The Project is formulated in order to supply the irrigation water to the Project Area shown on the map. However, it is possible to discharge a part of the irrigation water led from the dam through the head race to the Cariyacu River when the rainfall in the Project Area side is more than the design rainfall. Therefore, this surplus irrigation water can be utilized in order to supplement the water shortage in the Salinus Project area. The implementation of the Project is very significant not only for the Project Area but also for the Salinus project area.

**(6) Geological Investigation**

The detailed geological investigations including boring are indispensable for the detailed design of the main Project facilities especially the dam and tunnels. Furthermore, the additional geological investigations will be required from time to time during the construction of these facilities.

Especially these investigations are very important for the tunnel construction works in order to grasp the geological changes which cannot be foreseen during the design stage. According to the result of such investigations, the construction method may be changed or modified. Furthermore, the permeability at the left bank of the dam should be carefully investigated.

**(7) Excavated Soil and Rock**

Much soil and rock are to be excavated in the construction of the dam and tunnels. Even in the construction of the canals, the excavated soil and rock will become huge because of the embankment for the canals being not allowed due to the steep topographic conditions at the construction sites. Therefore, in both the detailed design and construction works of the required facilities, much attention should be paid in order to reduce the excavated soil and rock in consideration of the conservation of the environment of the construction sites and their surrounding areas. Furthermore, it is recommended that monitoring of the effect of the excavated soil and rock is conducted and that the system that the countermeasures can be taken from time to time when necessary is established.



**(8) Hydrological Data**

The hydrological analyses have been conducted using the hydrological data for the limited period in both Water Resources Area and Study Area, and the results of these analyses are used as the basis of the design of the Project facilities in the Study. Therefore, it is very important that the collection of the hydrological data shall be continued, and that the results of hydrological analyses such as design discharge and flood discharge of the Pinan River shall be checked by adding the hydrological data newly collected in the detailed design of the required facilities.

**(9) Strengthening of Supporting Services**

The production and extension of the improved seeds and the strengthening of the technical extension services are important in order to make more effectively the irrigation farming which will be introduced by the Project and to improve the agricultural productivity. Furthermore, in order to achieve the high price exportation of the products, the strengthening of the operation of the Marketing Centers which will be installed by the Project is badly necessary especially for the small-scale farmers.



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## CONVERSION FACTOR

### LENGTH

cm	:	centimeter
m	:	meter
km	:	kilometer

### AREA, VOLUME AND WEIGHT

cm <sup>2</sup>	:	square centimeter
m <sup>2</sup>	:	square meter
km <sup>2</sup>	:	square kilometer
ha	:	hectare
l	:	liter
G	:	galón = 3.75 liter
m <sup>3</sup>	:	cubic meter
kg	:	kilogram
ton	:	ton
lb	:	pound = 453.6 g
qq	:	quintal = 100 lb = 45.36 kg

### CURRENCY

US\$	:	United States Dollar
S/	:	Sucre
¥	:	Japanese Yen

### OTHERS

m/s	:	meter per second
m <sup>3</sup> /s	:	cubic meter per second
ton/ha	:	ton per hectare
m <sup>3</sup> /km <sup>2</sup>	:	cubic meter per square kilometer
mm/día	:	millimeter per day
l/s	:	liter per second
°C	:	degrees in centigrade
EL	:	elevation
%	:	percent
No.	:	number

## **ABREVIATIONS**

ASA	Agencia de Servicios Agropecuarios
BNF	Banco Nacional del Fomento
CEPE	Corporación Estatal Petrolera Ecuatoriana
CONADE	Consejo Nacional de Desarrollo
DINAC	Dirección Nacional de Avalos y Catastros
DPA	Dirección Provincial Agropecuaria de Imbabura
EMELNORTE	Empresa Eléctrica del Norte
ENAC	Empresa Nacional de Almacenamiento y Comercialización
FODERUMA	Fondo de Desarrollo Rural Marginal
FONADE	Fondo Nacional de Desarrollo
FONAPRE	Fondo Nacional de Preinvestigación
IEOS	Instituto Ecuatoriano de Obras Sanitarias
IERAC	Instituto Ecuatoriano de Reforma Agraria y Colonización
IGM	Instituto Geográfico Militar
INAMHI	Instituto Nacional de Meteorología e Hidrología
INEC	Instituto Nacional de Estadística y Censos
INECEL	Instituto Ecuatoriano de Electrificación
INEMIN	Instituto Nacional de Energía y Minas
INEN	Instituto Ecuatoriano de Normalización
INERHI	Instituto Ecuatoriano de Recursos Hidráulicos
INIAP	Instituto Nacional de Investigaciones Agropecuarias
JUNAPLA	Junta Nacional de Planificación y Coordinación Económica
MAG	Ministerio de Agricultura y Ganadería
MOP	Ministerio de Obras Públicas
PROTECA	Programa de Desarrollo Tecnológico Agropecuario



***CHAPTER 1***

***INTRODUCTION***



## **CHAPTER 1: INTRODUCTION**

### **1.1 BACKGROUND OF THE STUDY**

The Government of the Republic of Ecuador established in 1989 the National Development Plan (1989-1992), which targeted at the re-expansion of food crop production and the acceleration of agricultural export by expansion of crop production such as coffee, cacao and banana. The Plan also targeted at the expansion of agricultural production for domestic consumption.

Tumbabiro Area located in the northeastern part of Imbabura Province is characterized as the area of lower agricultural productivity compared with the surrounding areas because of insufficient irrigation water in spite of high potentiality of land for agricultural production.

In consideration of the above, the Government of the Republic of Ecuador planned to develop Tumbabiro Area by providing irrigation water as one of the main supply center of agricultural products and also to stabilize and improve the living conditions of the farmers in the area.

In this connection, the Government of the Republic of Ecuador requested to the Government of Japan in April 1990 for the technical cooperation for carrying out the feasibility study of the Tumbabiro Irrigation Project.

In response to the request, the Government of Japan dispatched to Ecuador the Preliminary Survey Mission through Japan International Cooperation Agency (hereinafter referred to as JICA) in April 8 to 21, 1992 and the Scope of Work (S/W) of the Study on the Project was concluded by both parties.

Based on the above S/W, JICA dispatched the Study Team composed of Pacific Consultants International and Naigai Engineering Co., Ltd. and conducted the Study on the Project. The field surveys in Phase I and Phase II of the Study were carried out from August 17 to November 29, 1992 and from May 27 to August 24, 1993, respectively.

## **1.2 OBJECTIVES OF THE STUDY**

The objectives of the Study are to conduct a feasibility study of the agricultural development project in Tumbabiro Area which mainly includes water resources development plan and irrigation facilities improvement plan, and to implement technical transfer to Ecuadorian staff in connection with planning of irrigation scheme.

## **1.3 THE STUDY AREA**

The Study Area is the mountainous agricultural field expanding in the northeastern part of Imbabura Province, which covers Tumbabiro Area and its surrounding areas. The hecterage of the Study Area is determined to be 12,800 ha through the field survey and discussions with the Ecuadorian counterparts.

## **1.4 SCOPE OF THE STUDY**

### **1.4.1 Phase I**

#### **(1) Work 1 (in Ecuador)**

The site investigation of the Study Area was carried out and necessary data/information were collected in order to grasp the present conditions of the Area. Through the above, the problems against agricultural development of the Area including irrigation and farming system were picked up.

Geological investigation (boring and seismic survey) at the proposed dam and tunnel sites was conducted by the Study Team. Topographic survey of the areas for proposed dam, canals and other main facilities was also carried out by the Team.

#### **(2) Work 2 (in Japan)**

The data and information collected at the site were analyzed and the problems in connection with the agricultural development of the Study Area were clarified. Based on the above, the basic development concept was formed.

## 1.4.2 Phase II

### (1) Work 3 (in Ecuador)

Based on the results of the Phase I Study, detailed field investigation and collection of supplemental data/information were carried out. The basic development plan of the Project was formulated through the Study and discussions with the Ecuadorian counterparts.

Additional bore-hole investigation at the proposed dam site and route survey of the existing irrigation canals (acequia) in the Study Area were also conducted by the Study Team.

### (2) Work 4 (in Japan)

Based on the results of the Study in Work 1, 2 and 3, the irrigated agricultural development plan was formulated and evaluated. The project implementation plan was also prepared.

## 1.5 THE REPORTS

In connection with the Study, the Study Team has submitted the following reports to the Government of the Republic of Ecuador:

. Inception Report	:	10 copies (in Spanish)
. Progress Report (I)	:	10 copies (in Spanish)
. Interim Report	:	10 copies (in Spanish)
. Progress Report (II)	:	10 copies (in Spanish)
. Draft Final Report	:	
Main Report	:	10 copies (in Spanish)
Annex	:	10 copies (in Spanish)
. Final Report	:	
Main Report	:	20 copies (in Spanish and English)
Annex	:	20 copies (in Spanish)