No. 4

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

INSTITUTO COSTARRICENSE DE ELECTRICIDAD (ICE)

THE FEASIBILITY STUDY
ON
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT
IN
THE REPUBLIC OF COSTA RICA

FINAL REPORT

SUMMARY

MARCH 1996

ELECTRIC POWER DEVELOPMENT CO., LTD.
KOKUSAI KOGYO CO., LTD.
TOKYO, JAPAN

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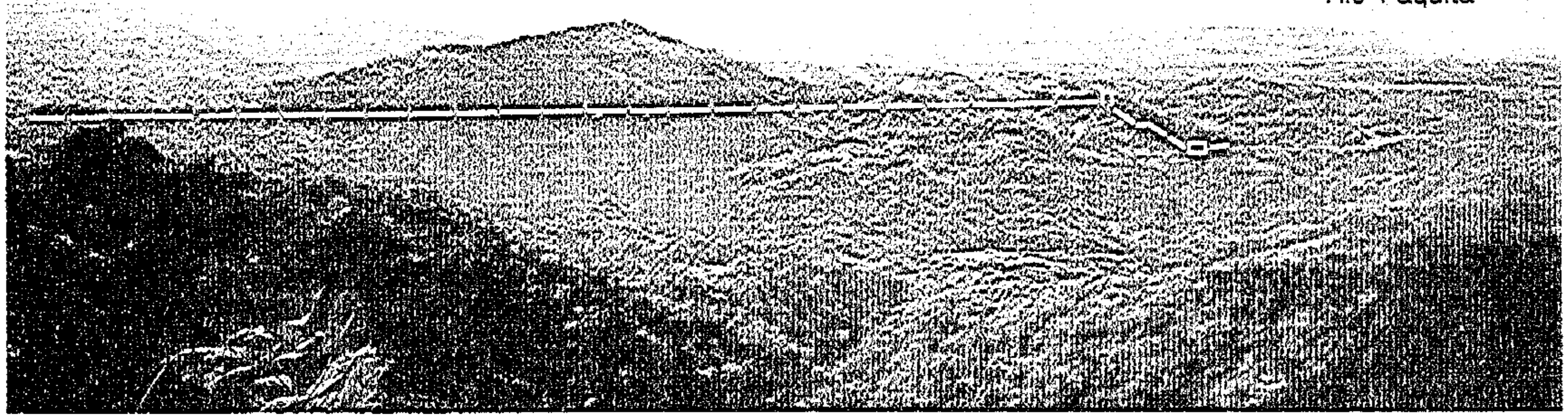
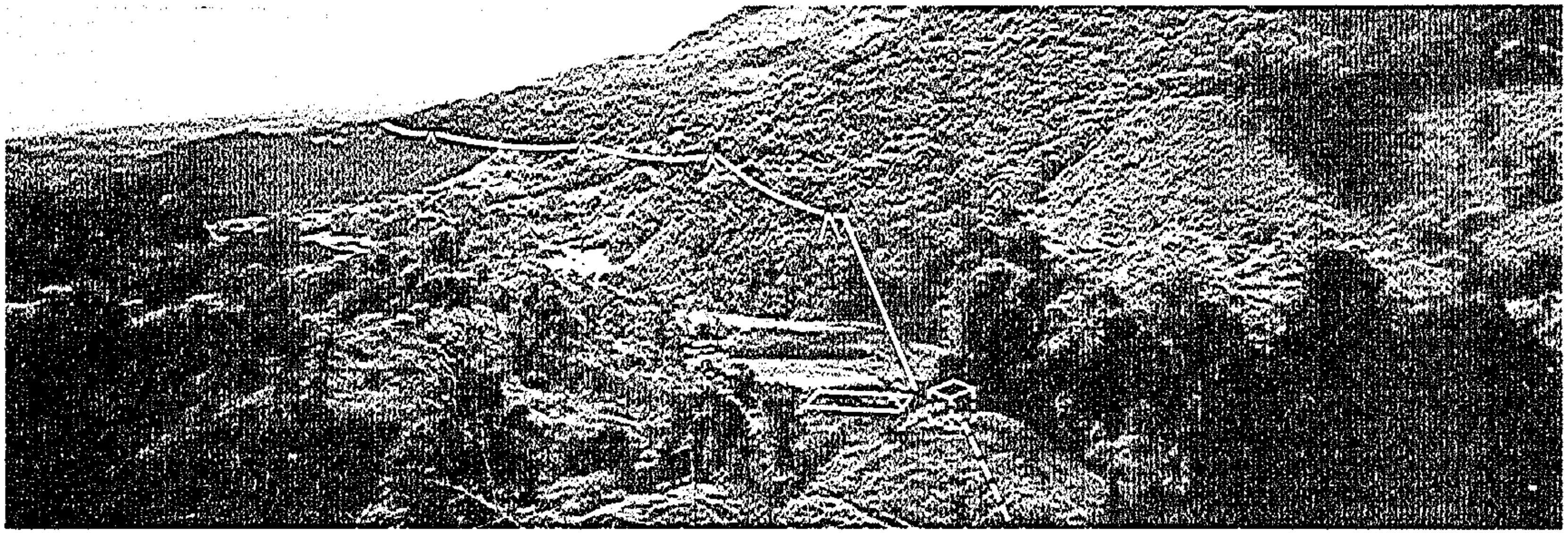
Project



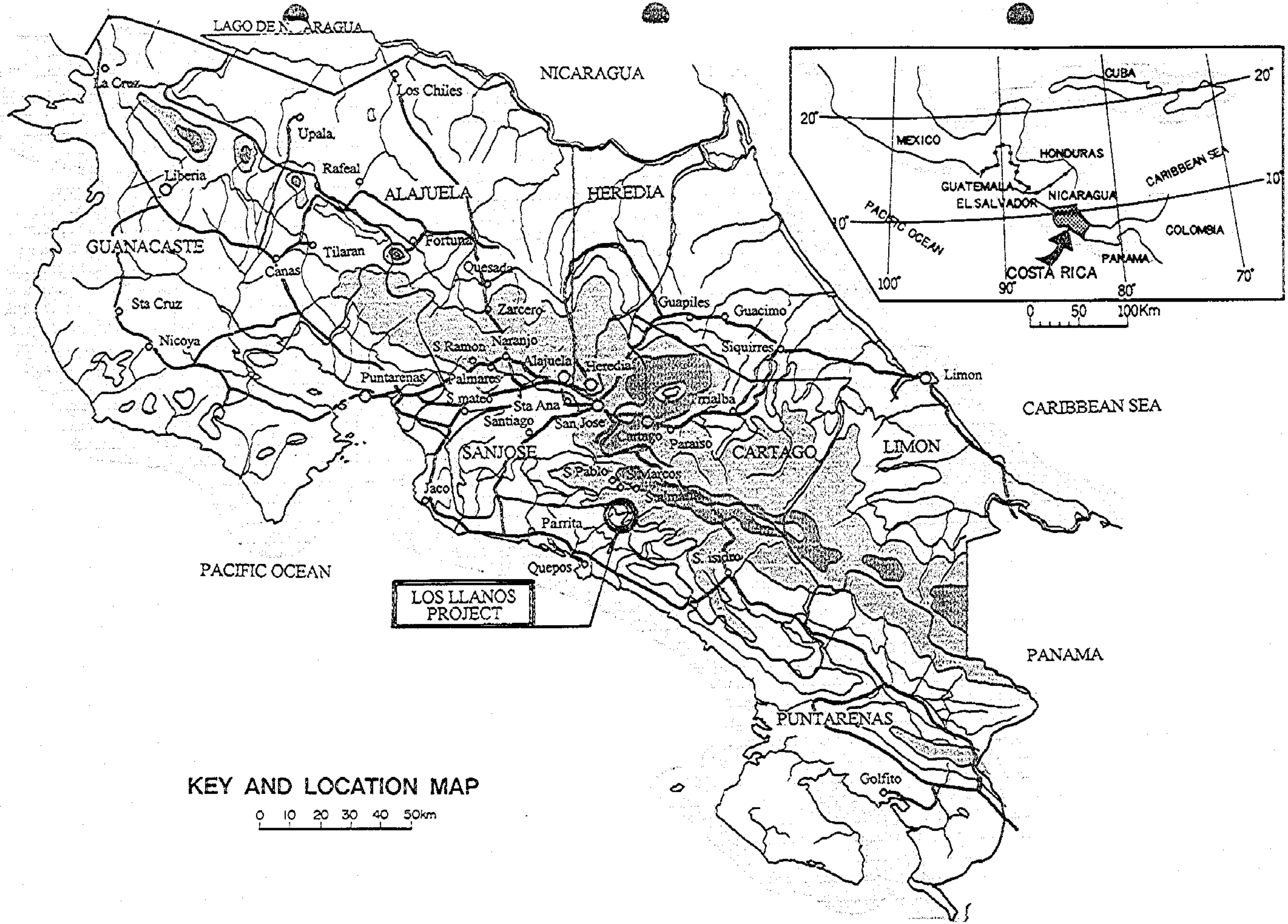
Power Tunnel Route View from the upper-reach of Paquita river



Los Llanos Powerhouse Site View from the peak of San Isidro mountain


Los Llanos Dam Site View from the upstream left bank


Los Llanos Dam Axis Adit No.1 at the right bank of EL. 445.22



KEY AND LOCATION MAP

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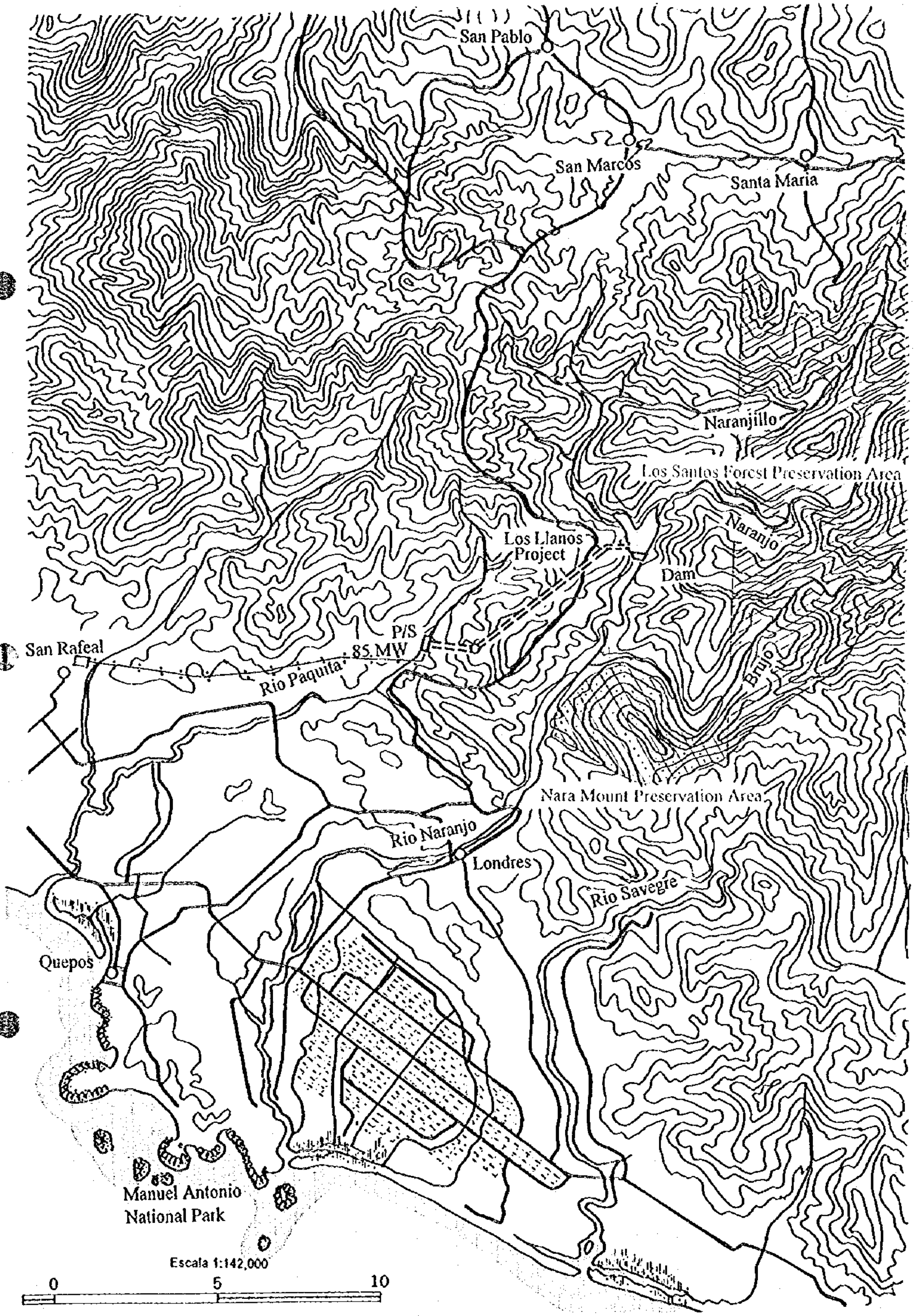
San Pablo
San Marcos
Santa Maria
Naranjillo
Los Santos Forest Preservation Area
Naranjo
Los Llanos
Project
Dam
P/S
85 MW
San Rafeal
Rio Paquita
Brujo
Nara Mount Preservation Area
Rio Naranjo
Londres
Rio Savegre
Quepos
Manuel Antonio
National Park
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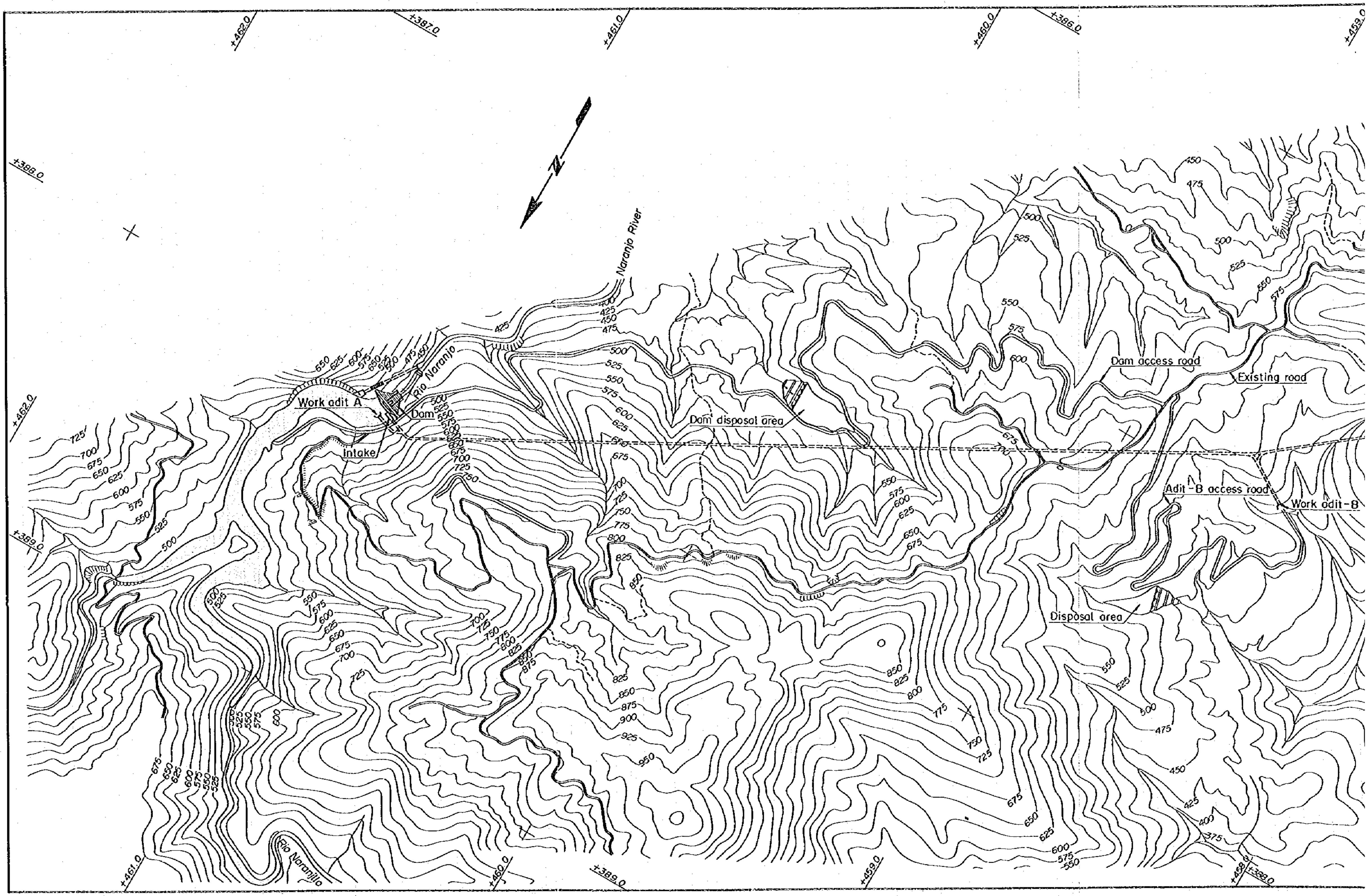

N
Naranjo River
Rio Naranjo
Work adit A
Dam
Intake
Dam disposal area
Dam access road
Existing road
Adit-B access road
Work adit-B
Disposal area
Rio Naranjillo
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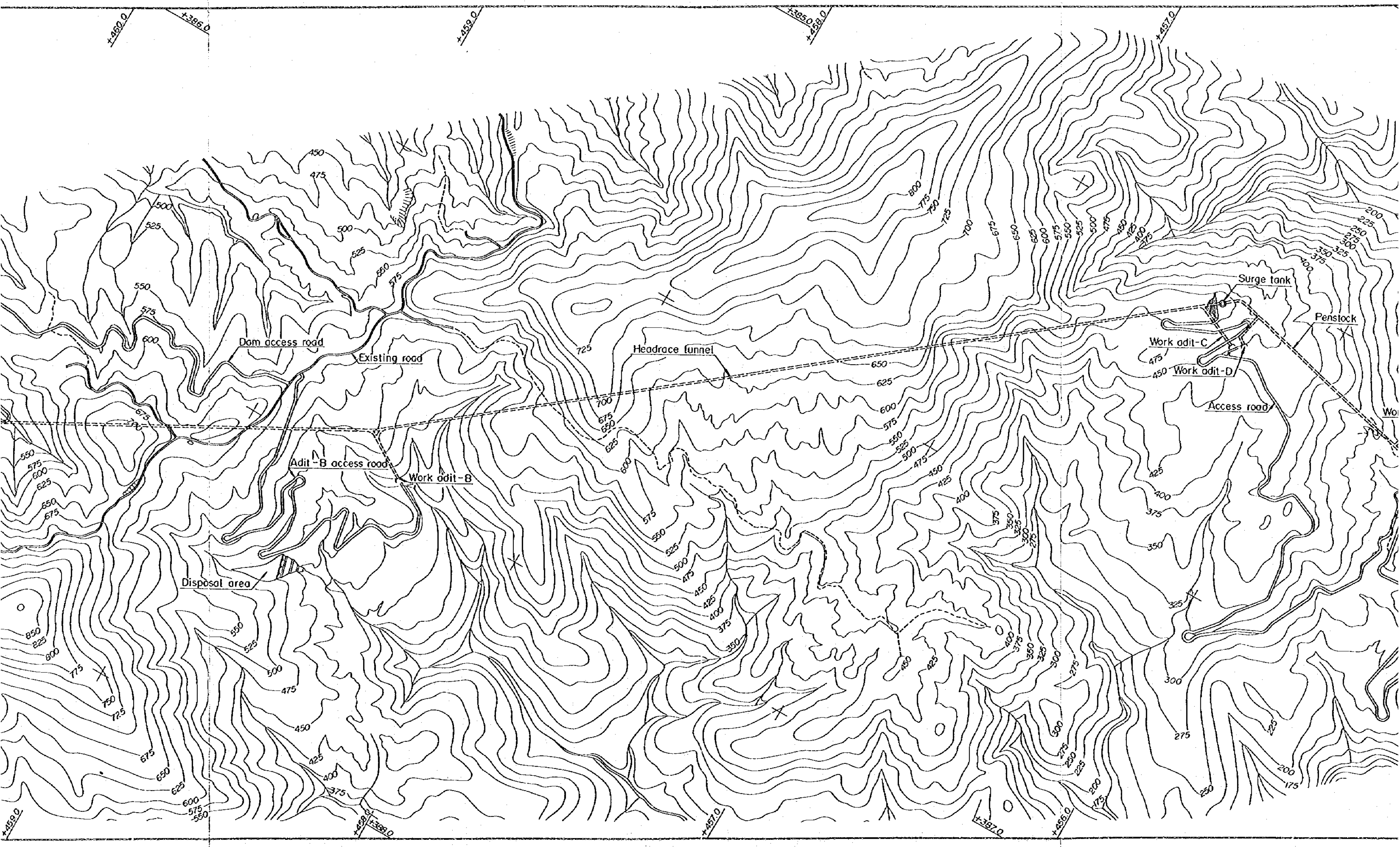
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Dam access road
Existing road
Headrace tunnel
Surge tank
Penstock
Work adit-C
Work adit-D
Access road
Adit-B access road
Work adit-B
Disposal area
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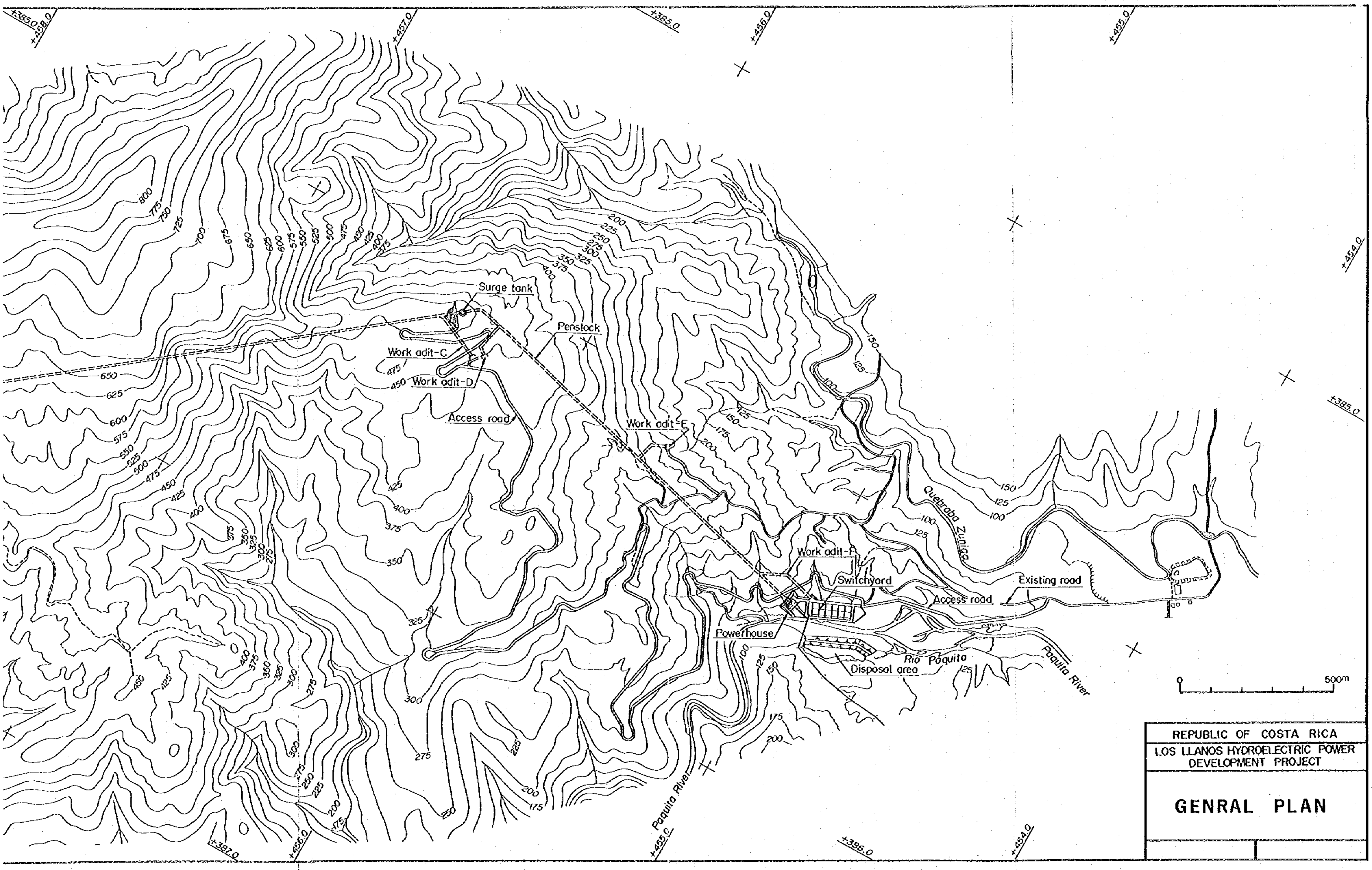

Surge tank
Penstock
Work adit-C
Work adit-D
Access road
Work adit-E
Work adit-F
Switchyard
Powerhouse
Existing road
Access road
Disposal area
Rio Paquita
Paquita River
Paquita River
Quebraba Zuniga
0
500m
REPUBLIC OF COSTA RICA
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT
GENRAL PLAN

Contents

Chapter 5 Demand Forecast and Power Supply Plan

Chapter 6 Meteorology and Hydrology

Chapter 9 Development Plan

Chapter 10 Power Transmission Plan and Power System Analysis

Chapter 12 Construction Planning and Cost Estimation

Summary

Summary

SUMMARY

This is a report on the results of the feasibility study conducted for the Los Llanos Hydroelectric Power Plant Project in the Republic of Costa Rica from 1994 to 1996 by Japan International Cooperation Agency (JICA), as technical assistance by the Japanese government. This report will be submitted to the government of Costa Rica and Instituto Costarricense de Electricidad (ICE) by JICA through the Ministry of Foreign Affairs of Japan. The feasibility study results are summarized as follows.

(1) The Project Characteristics

Los Llanos Hydroelectric Power Development Project consists of a power generation plan to construct a run-of-river type power plant using the head between the dam constructed at a point in the mid-stream part of the Naranjo River, with a 144 km^2 catchment area that can be regulated to meet the peak power demand, and diverted water using a 5.5 km waterway to the Paquita River, and a power transmission plan to transmit the power from the plant to a substation of the 500 kV Central America interconnecting transmission line.

This is a pluvial region with clearly distinguished wet and dry seasons providing an average annual rainfall of 5,500 mm. The total catchment area of the Naranjo River is 332 km^2. Its principle tributaries are the Naranjillo River in the upper streams and the Brujo River in the lower streams. Its average annual runoff is estimated to be about 35m^3/s - 40m/s. The project site is the confluence with the Naranjillo River and the average annual runoff is 15m^3/s. The guaranteed discharge (95%) is calculated to be 3.91m^3/s.

For the main stream, there are the Los Reyes, the Milagro, the Nara and the Los Llanos main stream development projects. Of these projects, this Los Llanos project is considered to present the highest generation efficiency. It is, therefore, the most promising hydro-electric power development project at the national master plan stage.

Coffee growers live upstream from the project site and live stock farmers live in the hills downstream. There are, however, no residents in the expected submergence area near the project site. There are also no roads or public buildings for which compensation would be required in the area. African palm is grown in the brackish-water area in the inner area and at the mouth of the river which also has mangrove groves. The river water is used (max. 1.8m^3/s) to cultivate this palm during the dry season, and these are the only water rights existing for the Naranjo River.

The project is thought to help and not damage the growth of the mangroves. As for the palm, there will be several days in a year when the current water intake cannot be secured, thereby causing production decrease. This will be subject to compensation.

Power demand in the Republic of Costa Rica has increased rapidly in recent years. In 1993 it increased by 7.4%. However, Costa Rica does not produce fossil fuel which is economical and thus mainly relies on hydro-power generation. Considering these conditions and the physical aspects of the development project, the commissioning of this project is expected to be in about 2005.

However, when the power demand projection is considered, it is seen that 2005 is not early enough. It is, therefore, desirable that the Los Llanos Hydro-electric Power Plant be commissioned as soon as possible.

(2) Climate and Hydrology

Runoff gauging stations and meteorological stations are located in the basin and in the area surrounding this project. The Londres runoff gauging station is the oldest of these and is reliable. The correlation between the observed values at the Londres runoff gauging station and the daily discharge observation at the dam site is very high. Therefore, the calculation is based on a 23-year discharge at Londres. Regarding the flood volume, the PMP (probable maximum precipitation) was derived from the meteorological value, and from the rainfall intensity and time distribution maximum flood was calculated by discharge calculation. The PMF (probable maximum flood) at the dam site was 1,590 m^3/s.

Sediment flowing down the river is divided into suspended load and bed load, and is correlated to the river discharge. Although the supplement rate differs depending on the reservoir capacity, the projected sedimentation load was calculated for 50 years and the dam's estimated sedimentation face height was set at 497 m.

(3) Geology, Material and Earthquake

The bed rock which represents the geology of this area is sedimentary rock from between the Mesozoic era Jurassic period to the Tertiary Eocene epoch, and hardened sediment of the Quaternary age end which partly covers it. For the dam, the foundation is sufficiently solid and hard conglomerate is distributed. The power plant site is on the left bank of the Paquita River, located near the border of conglomerate distributed in the waterway route and the lower marl.

Regarding the concrete aggregate, there is sufficient riverbed sand gravel near the power plant. However, crushed stone derived from raw ore sandstone from upstream, is planned to be used at the dam site. The epicenters of the earthquakes which occurred from 1990 to 1994 within a 1,000 km diameter of the project site are concentrated along the Pacific Ocean coast. The results of statistical probabilistic analysis of these earthquake data and the existing earthquake data were fully studied and the design lateral seismic factor of the project site was set at 0.15.

(4) Power/Energy Demand and Supply

In 1993, the per capita energy demand in Costa Rica Was 1,370 kWh, similar to other developing countries. In the developing countries, a macro method using the correlation with the economic growth to formulate the demand projection is applied in many cases. Being very close, there is almost no difference between this value and the growth rate projected by ICE. Therefore, the demand and supply balance plan produced by ICE was employed.

In Costa Rica, power is provided mostly by hydro with thermal supplementation. Therefore, power supply depends on the river flow and changes in that flow serve to greatly affect the system. Therefore, when studying the balance, considering the firm output of hydro, the daily load factor was 66%.

When this project is commissioned in 2005, it is expected that it will contribute greatly to Costa Rica's power demand and supply and to the overall economic development of the area.

(5) Transmission Plan

Costa Rica's power transmission system is constructed of 230kV and 138kV transmission lines. In about 2000 - 2003, a 500kV Central American interconnecting transmission line (SIEPAC) is planned to be materialized and commissioned. In the neighboring Pirris Hydroelectric Power Project also, the voltage will be decreased to 230kV from the 500kV substation (San Rafael) of SIEPAC and interconnected to San Jose, the capital.

Considering transmission energy, including those of future projects, and lowering its effect on the interconnecting line at outages, this project will be connected at San Rafael Substation by one 230 kV circuit. The transmission route is about 22 km long and is economical, running from the power plant, crossing the Paquita River, running through the mountains at the right bank to the foot of the mountain to reach the plains to the San Rafael Substation.

(6) **Environment and Compensation**

Environmental impact must be considered, based on the laws of the country. Costa Rica, however, has no guidelines at this time.

In this study, the initial environmental examination (IEE) was conducted following JICA guidelines, which is based on the environmental consideration method for development study/plan establishing in international organizations such as the World Bank and United Nations Environmental Plan, and bilateral assistance organizations.
In this study, environmental impact assessment (EIA) was conducted on environmental items which were judged to be more necessary.

In the entire Brujo River area, which is a tributary in the northeast part of Naranjo River basin and not directly involved in this project, is a forest conservation area. Besides that, however, there are no conservation areas. Coffee is grown and stock farms are run in the hills in the upper reaches and the mid-stream area involved in this development project. None, however, will be affected by the project such as being submerged and are not directly connected with the main stream of the river.

At the river mouth, a part of the right bank is designated as the Manual Antonio National Park and a resort area along the coastline including the Quepos Reef is located next to the park. An alluvial fan is formed on the left bank from the lower reaches to the river mouth, and palms are grown here. At the outside, a sandbar is formed on the shoreline and mangroves lie in the brackish-water in-between.

(7) **Optimum Development Project Outline**

The outline of the Los Llanos hydro-electric power development project is as follows. The installed capacity is 85 MW. The annual guaranteed energy of this hydro-electric power plant is calculated to be 107 GWh. When compared with a diesel thermal power plant, this equals 22,800 tons/oil consumption.

(8) Construction Process and Cost

The construction period for this project is expected to be 4 years considering the weather, topography, construction scale, construction material, structure location and preparation works. Considering the supply and demand balance, it is necessary to prepare for the construction following the rough schedule below if the project is to be commissioned in 2005.

Duration		Item
Apr. 1996 - Sep. 1997		Further Investigation Works
Jun. 1996 - Dec. 1997		Request of ICE to MIDEPLAN
Sep. 1996 - Aug. 1998	(2.0 years)	Detailed Design
Jun. 1998 - Dec. 1999	(1.5 years)	Finance Formalities
Jan. 2000 - Dec. 2000	(1.0 year)	Approval of Congress
Mar. 2001 - Dec. 2001	(0.8 year)	Bidding of Contract
Jan. 2001 - Dec. 2004	(4.0 years)	Construction

The construction cost for this project is calculated on the assumption that the design, construction, materials and products of currently expected technical standards will be applied. The geological conditions and topographical characteristics and construction scale were also considered in the calculation.

The construction cost of this project was calculated in both domestic and foreign currencies. Access roads, camping facilities, environmental protection measures, power transmission line, switchyard, engineering fees, management cost and interest during the construction period are included. It does not, however, include inflation costs. This calculation was made in January, 1995. (Exchange rate: US$1 = 168 Colones).
The construction cost is US$151,763 and the power generation end construction cost is US$0.04/kWh.

(9) Economic and Financial Evaluation

In making the economic evaluation, the alternative facility approach method was used to estimate and assess the economic cost for the project and the alternative thermal power plant. The flow chart for the benefits and cost based on the economic cost of the project is shown in Table 14-4. Economic internal rate of return (EIRR), net present value (B-C), and benefit and cost ratio (B/C) are as follows.

Economic internal rate of return (EIRR)	:	20.2%
Net present value (B-C)	:	US$42,389,000
Benefit/cost ratio (B/C)	:	1.43

It is deemed that regarding the economic viability of this project, the construction and operation of this project is far more economical than constructing an alternative thermal power plant which would offer an equivalent service. This superiority will be maintained until the social discount rate which reflects the opportunity cost of capital reaches 20.2%. In financial evaluation, the financial internal rate of return was calculated as 12.4%. It can be concluded that this is a financially sound power generation project, even at the current electricity rate.

This evaluation is subject to condition that Pirris Hydropower Project will have been completed before commissioning of Los Llanos Project.

Los Llanos Hydroelectric Power Project

Item	Unit	Contents
River		Naranjo River
Catchment Area	km^2	143.7
Annual Inflow	10^6m^3	471.8
Design Flood	m^3/s	1,600
Project Feature		Run-of-River Type
Maximum Discharge	m^3/s	27
Maximum Effective Head	m	359.4
Installed Capacity	MW	85
Reservoir		Daily Regulation (5 hours)
High Water Level	m	477.4
Low Water Level	m	470.0
Effective Storage Capacity	10^3m^3	653
Surface Area	10^3m^2	100
Dam		Concrete Gravity
Height x Crest Length	m x m	62.4 x 114
Dam Volume	10^3m	89,200
Headrace		
Inner Diameter x Length	m x m	3.1 x 5,540
Surge Tank		
Inner Diameter x Height	m x m	8.0 x 57.3
Penstock		
Inner Diameter x Length	m x m	3.10 ~ 2.02 x 1,540 x 1 line 1.25 x 26 x 2 lines
Powerhouse		Steel Reinforced Concrete, Open type
Width x Length	m x m	19 x 37
Turbine (Vertical Shaft Francis)	MW x Units	43.7 x 2
Generator (3-phase AC)	MVA x Units	50.0 x 2
Switchyard	kV	230
Width x Length	m x m	40.0 x 120
2 Circuit Line	kV	230
Power Generation		
Annual Total Energy	GWh	389
Firm Energy	GWh	107

Conclusion and Recommendation

Conclusion and Recommendation

CONCLUSION AND RECOMMENDATION

Los Llanos Hydroelectric Power Project is located at the mid-stream part of the Naranjo River which flows into the Pacific Ocean, 50 km south of San Jose in the Republic of Costa Rica. The study team conducted a feasibility study on the power generation and the related transmission line projects. Through these studies, it is concluded that this project is technically, economically and environmentally feasible. The content of this conclusion follows.

CONCLUSION

(1) As of January, 1995, the total generating capacity of electric facilities in the Republic of Costa Rica was 1,098 MW, of which 83% is by hydro. On the other hand, of the hydropower potential which can be economically developed, only 8% has been developed. The project aims to effectively utilize hydro-power resources, an important energy resource, within Costa Rica and supply ample and stable electric power.

(2) Costa Rica's power demand has increased steadily each year. It is projected that the annual growth rate from 1995 to 2005 will be 7.6%. The peak demand in 2004 is projected to be 1550 MW, and new facilities for more than 400 MW will be required.

(3) Considering the power demand projection, detailed design, time required for funding and the construction period, it was determined that this project should be commissioned into the nationwide electric power system in 2005.

(4) The Naranjo River development plan suggested in the master plan was restudied, and the appropriate layout considering development time, development scale, discharge and gross head was selected. The geological and topographical conditions and conditions based on environmental impact assessment were compared and studied, and the most economically viable development plan was selected.

(5) The construction cost was estimated on the assumption that design, construction, materials and products will be of the technical standards as of January, 1995. The topographical and area conditions of the project site and construction scale were considered in the work cost, and import duties and interest during construction were included. The construction cost including domestic and foreign currencies is US$152 million.

(6) The economic viability of this project is deemed superior to alternative thermal power facilities. The construction cost per kWh is US$0.04 and is an economical energy source

compared to other countries. The cost and income of this project was estimated and the economic internal rate of return discounted to the present value became 20.2%, showing that it is a feasible project considering the national economy, subject to condition that Pirris Hydropower Project will have been completed before commissioning of Los Llanos Project.

(7) A concrete gravity-type dam will be employed considering the topography, geology, construction cost and operational ease. The most appropriate and economical ground-type power plant will be used considering the topographical and geological conditions. Functionally and economically superior Francis turbines which provide excellent efficiency and maximum energy generation will be used. There are no problems likely to hinder the construction of this project and the project is technically feasible.

(8) There are no residents within the planned reservoir area. There are no roads or public buildings for which compensation would be required. However, palm is grown in an area where the water flow will be reduced. The only irrigation facility on the Naranjo River exists at that location. The maximum irrigation water volume is $1.8m^3/s$ and river water is used for cultivation. Production will be decreased and appropriate compensation is added to the construction cost.

(9) Environmental aspect to be noted within the project area is that mangroves are cultivated in the brackish-water at the mouth of the river. The mangrove growth and the sandbar growth along the shoreline is deeply related and the plan must not shut out suspended sand during the flood period. As this project's dam only regulates and does not store (hold sand), it will not decline the sandbar at the river mouth. An appropriate amount of environmental measures cost is added to the construction cost.

(10) It was assessed that this project will provide only minimal affect on the surrounding natural and social environment, and will contribute greatly to the stable supply of electricity and to the development of the society in the area.

RECOMMENDATIONS

Los Llanos Hydroclectric Power Development Project is technically, economically and environmentally feasible. The Project is justified to be commissioned in 2005 according to the Power Development Plan of Costa Rica, therefore, it is recommended that the project be implemented.

It is necessary to implement the following matters in order to realize the Project.

(1) To make preparations required for construction such as detailed design and composition of bid documents.

(2) The additional investigations mentioned in Chapter 15 "Further Investigations" should be carried out, to be reflected in the detailed design.

(3) For the commissioning of the Project in the year 2005, it is necessary to arrange for construction funds; to invite tenders and select the contractor at the beginning of 2000 and to start the main work during the dry season. Main schedule until commissioning and required time is shown below:

Required period				Item
Sep/1996	-	Aug/1998	(2.0 years)	Detailed design
Jun/1998	-	Dec/1999	(1.5 years)	Finance formalities
Jan/2000	-	Dec/2000	(1.0 year)	Approval of Congress
Mar/2001	-	Dec/2001	(0.8 year)	Bidding of Contract
Jan/2001	-	Dec/2004	(4.0 years)	Construction

(4) Relocation of roads to be affected by implementation of the Project, compensation for land, houses, etc. to be affected must be done for the smooth implementation of the Project. It is also necessary to continue the study and monitoring of expected environmentally affected items.

Chapter 1 Introduction

1.1 Antecedents and Background

Placing political focus on the development of domestic energy, in 1949 the Government of Costa Rica established ICE (Instituto Costarricense de Electricidad) toward that end. Today, ICE electric power generation facilities (1,023.5 MW) account for 93.2% of Costa Rica's total capacity, supplying 80% of the nation's total demands in cooperation with the CNFL (National Power and Light Company). Regarding the composition of the energy sources, of a total installed capacity of 1,098 MW, thermal power produces 255 MW, representing 28% including geothermal power. Hydropower produces 788 MW, accounting for 72%. From the viewpoint of actual electric power generated each year, almost all is dependent on hydropower, indicating Costa Rica's heavy precipitation. While hydropower potential which can be developed economically are estimated at approximately 9,000 MW, the portion developed thus far is very small, at about 8%. However, over the past five years the average increase in electricity demands shows an annual increase of 6.5% a year with an increment ratio of 7.4% in 1993. Under these circumstances, Costa Rica has engaged strongly in the development of its hydropower resources as the main domestic energy source. Notwithstanding these efforts however, 54% of Costa Rica's total energy still remains dependent on import. As it is estimated that demands for oil and electricity will be 1.6 times and 3.0 times more than today's respectively, great hopes are now placed on hydropower development.
(Electricity and Sustainable Development in Costa Rica: ICE 1994)

The ICE is presently attempting to execute electric power development projects which are mainly hydropower projects. 4 projects out of 13 hydropower development plans that were at the stage of Master Plan in 1990 have been extracted in cooperation with LGL, a Canadian consultant. The Government of Costa Rica requested Japan to carry out a Feasibility Study (F/S) of the Los Llanos Project, being the most promising of the described projects. The Japan International Cooperation Agency (JICA) agreed to carry out this study, with ICE as their counterpart and the relevant agreement was signed by both parties in March, 1994.

1.2 Contents of Study

Objectives of Study

The objectives of this study are to carry out a study in Costa Rica and domestic work concerning the Los Llanos Hydroelectric Power Development Project to produce, with environmental evaluation taken into consideration, a development plan that is technically feasible, economical, financially sound, and to prepare a Feasibility Study Report accordingly. In conjunction with these activities, to also attempt technical transfer to the Costa Rican counterpart through this study.

Object Area and Scope of Work

The hydropower development site of this study is located at Long. 84° 3" W, Lat. 9° 33" N. It is situated in the middle reaches of the Naranjo River, 50 km south of the capital city of San Jose. Here, a dam is to be constructed from which water will be conducted westward through a headrace tunnel to a power station to be located in the middle of the Paquita River in a bid to generate power by utilizing the head between these points. Related transmission line will be constructed to San Rafael, located 22 km west from the power plant. The areas to be influenced by this project, i.e., the entire area of the basin of the Naranjo River and the Paquita River and the area from the river mouths up to the Pacific coastline, have been designated as the subject area for this study.

Work Contents

The study was classified into Preliminary Investigation Stage, Detailed Stage and Feasibility Grade Stage in accordance with the accuracy of study, and the following studies were conducted.

(1) Preliminary Investigation Stage

(a) Collection and review of existing data and study reports.
(b) Field survey and present situation survey of the project area.
(c) Compare the comparable alternative plans to select the optimum development plan based on the existing data.
(d) Entrust the FUNDEVI with the initial environmental examination (IEE) to accurately and efficiently extract those items liable to be gravely and/or adversely affected by the development, while considering the contents of the development.

(e) Review all relevant information such as ICE's peak demands, electricity consumption characteristics etc. and analyze the same in accordance with the power expansion program.

(f) Prepare study plans and technical specifications with regard to the Detailed Study.

(2) Detailed Stage

Geographical measuring, geological survey and material testing, and hydrological and meteorological survey were conducted and environmental influence assessment (EIA) and compensation survey were begun.

(a) Geographical Survey

1) Aerial photography and mapping at 1:5000 scale
2) Installation of survey piles and bench marks
3) Ground survey (dam, powerhouse) at 1:1000 scale

(b) Geological Survey and Material Testing

1) Geological reconnaissance (main structures, reservoir, quarry site and others)
2) Core boring, permeability test (dam, waterway, powerhouse, quarry site)
3) Seismic prospecting (same as above)
4) Work adit excavation (dam site)
5) Test pit excavation (for construction materials)
6) In-situ test, laboratory test
7) Historical earthquake study

(c) Hydrological and Meteorological Survey

1) River flow
2) Survey of high water (flood), and low water (firm discharge) levels
3) Observation and analysis of hydrological and meteorological data
4) Analysis of sediment discharge and sedimentation by observation of floating sand, etc.
5) Establishment of hydrological and meteorological observation stations

(d) **Environmenta Impact Assessment (EIA)**

1) Preparation of EIA items with regard to the natural, social and economic environments determined by the initial environmental assessment.
2) Continuation of natural environmental survey (water quality, fluctuation of irrigation water flow, ecological system of the flora and fauna)

(e) **Compensation Survey**

1) Survey of compensatory items (houses and buildings, standing trees, land, rights and titles etc.)
2) Survey of moving compensation (public buildings)

1.3 Reports

The following reports/documents have been submitted to ICE:

(1) Inception Report (Sept.1, 1994)
(2) Questionnaire
(3) Contract for Aerial Photography and Survey
(4) Contract for Initial Environmental Examination
(5) Progress Report (Nov. 30, 1994)
(6) Progress Report Annex (Mar. 10, 1995)
(7) IEE Final Report - FUNDEVI (Dec. 1994)
(8) Final Result - Topographic Mapping (Mar. 1995)
(9) Interim Report (Sept. 1995)
(10) Draft Final Report (Jan. 1996)
(11) Memorandum of Discussion (No.1 - No.8)

<u>Existing Report</u>

The outline of the Project is described in "Los Llanos Hydroelectric Power Project Description" compiled by ICE in June 1991. Afterward ICE elaborated a master plan "Plan Maestro de la Cuenca Hidrografia Rio Naranjo", in cooperation with Canadian consulting group LGL. And the Project has been confirmed as having the first priority within the hydroelectric power development projects in Costa Rica.

Based on these reports, the JICA study team examined the appropriateness; carried out comparative study; and implemented additional investigation work, study and tests. These data, as well as additional study conducted by ICE are compiled in Appendix. Also included in Appendix is a list of the data and information relevant to the project as obtained from ICE and/or other organizations.

1.4 Study in Costa Rica

JICA mission visited Costa Rica during the following period.

(1) 1st Mission: August 29 to October 27, 1994
(2) 2nd Mission: November 13, 1994 to January 26, 1995
(3) 3rd Mission: February 12 to March 13, 1995
(4) 4th Mission: May 17 to June 6, 1995
(5) 5th Mission: July 1 to August 14, 1995
(6) 6th Mission: November 26 to December 13, 1995
(7) 7th Mission: January 30 to February 13, 1996

1.5 Acceptance of Trainees

ICE requested JICA to accept one trainee for each fiscal year, i.e., two in all. Accordingly, two engineers visited Japan: One in January 1995 and the other in September 1995.

Chapter 2 General Description of the Republic of Costa Rica

2.1 Geography

The Republic of Costa Rica is located in Central America, between Lat. 8° to 11° 14" N. and between Long. 82° 32" and 85° 58" W. The country is bordered by the Republic of Nicaragua to the north and the Republic of Panama to the east. Costa Rica faces the Caribbean Sea to the northeast and the Pacific to the southwest. The total land area is 51,000 km^2. Geographically, Costa Rica is a long, narrow country, the narrowest section being 119 km across and 274 km at the widest. The majority of the land is mountainous. The highest peak is Mt. Chrripo Grande at 3,819 m. However, the land is generally covered by tropical forest and is, therefore, abundant in vegetation. 25% of the land is designated as National Parks and/or Forest Preserves where development is restricted.

The project area is located in the basin of the Naranjo River which runs southward from the Dota, the central mass of mountains, and includes the Paquita River which flows parallel to the west. Originating in hilly country in the southern part of San Marcos, the Naranjo River runs westward across the southern slopes of the hilly Dota district to run rapidly southward from the Dam site. Of the total 43 km length up to the river mouth, the lower reaches of 15 km are flat alluvial fans where coco palms are cultivated. On the other hand, the Paquita River shows similar conditions as a rapid stream in that it is only 100 m above sea level at the power station site which is 17 km from the river mouth, rising to 1,300 m above sea level at a point 7 km upstream from that area.

2.2 Climate

Costa Rica has a partial tropical forest/savanna climate, but is greatly influenced greatly by the topography and altitude. The temperature does differ between the dry season (December through April) and the rainy season (May through November), although it is a minimal difference as the year round mean temperature is between 20 - 30°C.

Precipitation ranges from 30 to 120 mm per month even in February, the time of the least rainfall. The 5,500 mm annual average precipitation in the Naranjo River valley is regarded as one of the heaviest in the world.

2.3 Population

Population in Costa Rica amounts to some 3.2 million, and the density is 62 persons/km^2.

2.4 Economy

The GNP of Costa Rica is US$6.2 billion. The GNP per capita is approximately US$2,000. Agriculture and cattle represent the major industries. Manufacturing accounts for 19% of the GDP indicating that Costa Rica is the most industrialized of the five Central American countries.

Costa Rica's balance of trade constantly shows a deficit and in light of this, the government now stresses the development of the Export Processing Industry District and Tourism. Approximately 700,000 tourists visited Costa Rica in 1993.

2.5 Energy Resources

Due to its undulating topography and heavy precipitation, Costa Rica enjoys an abundance of hydropower resources, although only 8.2% of these have been developed. No fossil deposits which are possible to develop economically exist, and all is imported. As to the geothermal resources, some 1,200MW have been studies including Miravalles site (110MW). Vol. Tenorio site (90MW) has also been found no promising.

Investigations have been made on geothermal and certain promising areas have been confirmed and priority has been placed on development at the Miravalles site. Power generation with an output of 55 MW was started in 1994 and the second phase development which is scheduled to be completed in September 1996, is now under way. Geothermal resources in the Miravalles area are estimated to be 250 MW. According to a national investigation of Costa Rica's geothermal resources, the entire national geothermal resources are estimated to be 1200 MW, including Miravalles. Tenorio Volcano (90 MW) was selected as a candidate site of geothermal resources. This was based on investigations at a reconnaissance level using funds provided by the Italian Government via the United Nations. The investigation covered an area of 25,000 square kilometers (Guanacaste Volcanic Mountain Range, Central Volcanic Mountain Range, and Talamanca Mountain Range) which was perceived to provide high potential as a geothermal resource zone.

2.6 Transport and Communication

Roads play an important role in Costa Rica. Costa Rica has 35,541 km of roads, of which 7,341 km (20.7%) are national highways and 28,192 km (79.3%) being local roads. Besides, Juan Santa Maria International Airport in San Jose, and Moin Port on the Atlantic coast have been increasing its importance.

As of the end of 1994, there were approximately 500,000 regular telephone lines, so as to attend rapid increases in the number of subscribers.

Chapter 3 General Description of the Project Area

3.1 Location and Access

The project site is located about 50 km from San Jose, the capital city. The upper stream belongs to San Jose Province and the lower reaches belong to Puntarenas Province. There are two access routes available to the site. The dam site in the upper stream can be reached by going southward on Highway No. 4 from San Jose and arriving at San Pablo and San Marcos. Another route is via Highway No. 2 (the Pan-American Highway) and passing through Santa Maria and San Marcos. To travel to the powerhouse in the lower reaches, there is also a route via Highway No. 11 westward from San Jose and going southward from Orotina and along the Pacific coast through Jaco Beach to Quepos. However, regardless of the route taken, it is 140 km from San Jose to Quepos and takes three hours by car in all cases.

It would be convenient to set up bases in San Marcos and Quepos to approach the dam site and the power plant site respectively. These towns are connected by gravel roads which are partially public roads, and by ICE's survey roads. There are flat gravel roads from Quepos along the Rio Noranjo and the water level and flow observatories in Londres can be easily reached even in the rainy season. An access route to the power plant is provided by a road running through the mountainous areas that form the watersheds to the Rio Paquita. It takes about an hour from Quepos. Steep survey roads in the mountainous areas have to be used to travel from the power plant to the dam site, and there are places which even a four-wheel drive vehicle would be hard pressed to traverse in the rainy season. It takes two hours by car between these points.

3.2 Natural Conditions

These areas belong to the Temperate Rainy Climate Zone (Clima templado lluvioso) and the Tropical Rain Climate Zone (Clima tropical lluvioso). The mountain regions are covered by forests. There are no special conservation districts in the Rio Naranjo valley except for forest preserves established in the northeastern region. The topography of the areas up from the dam site is rugged. Settlers now use this area as private land for coffee plantations. The coffee bushes are initially planted on the steep slopes but must be transplanted elsewhere as the land becomes impoverished. Due to this, totally stripped land is found throughout the region. It is assumed that this is because the trading centers for coffee beans are located outside the Rio Naranjo valley and tend to concentrate in this, the Los Santos region.

A part of the right bank of the mouth of the Rio Naranjo is conserved as the Manuel Antonio National Park. This is a resort area which includes the famed submerged rocks and coastline of Quepos. On the left bank of the river mouth are flatlands which are quite different from the terrain of the right bank due to the influences of the Rio Savegre being stronger than those of the Rio Naranjo. Here, the traditional cultivation of African palms is very popular. There are also mangrove trees in the swampland between the coastline and the palm plantations.

The Rio Naranjo that runs southward from the dam site changes course westward to bypass this flatland and then turns southward again to flow into the Pacific Ocean. Therefore, this waterway route was selected in the power generation plan to attain a head over a short distance by discharging water into the Rio Paquita that runs down straight in the west.

3.3 Social Environment

There are no large cities within the project area, although small villages, mainly home to cattle breeders, are scattered throughout the highlands along the river, except for Londres Village which is located at the point where the Rio Naranjo runs slowly into the flatlands. The base towns of San Marcos and Quepos are both outside the river basin, and both have public facilities. Both have a market and hotel etc., aside from public facilities such as schools, a hospital, churches, police stations, post offices, and town halls.

It is noteworthy that there is a local airport in Quepos which provides easy access from/to San Jose, the capital city. The coastline, which is well provided with hotels and restaurants, is well established as a tourist area as well being as a national park. Many tourists visit this area.

3.4 Environmental Protection

Today, various measures are promoted by each country as well as at the international level against global environmental problems. These include global warming, reduction of tropical forest, accelerating desertification and acid rain. There are deep concerns regarding the influences of individual development projects on the neighboring natural and social environments. Although a hydro power development is considered environmentally friendly, it is now required that the project plan provides adequate environmental protection measures to ensure that it co-exists with the natural and social environments of the developing area. Such environmental measures should, in principle, be provided according to the laws and regulations of the country concerned. However as no guidelines have been established in Costa Rica at this time, environmental assessment must be made with the complete study at the initial stage of the plan as much as possible to ensure its result is reflected in the plan.

In this study, the initial environmental examination (IEE) is carried out according to JICA guidelines. These guidelines are equivalent to the environmental protection measures concerning the development study/plan, currently established by various international organizations including the World Bank and the UN Environmental Plan Committee and also by bilateral aid organizations such as USAID and ODA. The environmental impact assessment (EIA) regarding the environmental concern which is required further in this study is then carried out. The data collection and on-site survey for this study are carried out in cooperation with ICE. Work related to IEE and EIA is consigned to a local firm. The study, prediction and assessment of environmental effect are conducted by the Study Team based on the results of this study. The goal for the environmental protection and the measures to prevent or reduce environmental influences are proposed accordingly.

Chapter 4 Present State of Electric Power Industry

4.1 Present State of Power Supply Facilities

As of January, 1995, Costa Rican's total installed capacity was 1,177.8 MW, of which 1,103.5 MW is held by ICE, leaving the remainder with the other power companies to own individually. Table 4-1 shows the installed capacity by company and by generation method. 74.1% of the total installation is hydroelectric with the remaining 25.9% being thermal electric, including the 55 MW Miravalles Geothermal Power Plant.

4.2 Transmission Systems

The transmission systems are interconnected from Peñas Blanca (Costa Rica/Nicaragua boarder) in the north to Paso Canoas (Costa Rica/Panama border) in the south. Line voltages of 230 kV and 138 kV are employed. The transmission lines stretch 1,583.9 km (880 km of 230 kV and 703.9 km of 138 kV) overall. Fig. 4-2 is a map of the Electric Power System in Costa Rica. Table 4-2 shows the major transmission lines in operation.

4.3 Distribution System

As of December, 1994, the power demand met by the entire group of power companies was 4,204 GWh. The electrification rate was 93% with a total length of distribution lines of 20,794 km. The following table is a break-down:

Company	Length (km)	No. of Application	Consumption of Energy (GWh)
ICE	12,002	332,892	1,562
CNFL	2,107	317,904	1,988
ESPH	262	34,410	158
JASEC	818	46,670	230
COOPE GUANACASTE	2,381	26,614	94
COOPE LESCA	1,832	31,134	119
COOPE SANTOS	1,177	20,256	42
COOPE ALFARO	215	3,848	11
Total	20,794	813,727	4,204

4.4 Present State of Power Demand

Domestic power consumption in 1994 was 4,204 GWh as is broken down as follows:

Residential	1,915 GWh	(45.6%)
General	888 GWh	(21.1%)
Manufacturing	1,284 GWh	(30.5%)
Public	117 GWh	(2.8%)
Total	4,204 GWh	(100.0%)

The Costa Rican power market is expanding steadily, and the annual average growth rate of power consumption from 1985 to 1994 is rather high at 5.8%.

As of 1994, the electrification rate in Costa Rica was 92.7%, a relatively high rate for a Central American countries.

4.5 Electricity Tariff

The average tariff rates charged by ICE and the other power companies in practice as of February, 1995 are:

Residential		12.00 c/kWh
General		19.20 c/kWh
Industrial	(large firms)	14.80 c/kWh
	(small firms)	17.20 c/kWh
Construction		27.50 c/kWh
Public		4.60 c/kWh

Chapter 5 Demand Forecast and Power Supply Plan

5.1 Power Demand Forecast

As described in Chapter 4, The Costa Rican power demandgrew at a high mean annual rate of 5.8% during the period 1985 to 1994. Table 5-1 shows the record of the growth of GDP and power demand in Costa Rica, from 1980 to 1994. This is expected to continue.

5.1.1 Power Demand Forecast by ICE

ICE is conducting its own demand forecast to formulate a power development plan which will respond to future demand increases. This forecast is based on the numbers of subscribers and the power consumption records of the subscribers classified into sectors (residence, industry and general), to estimate the future demand between 1995 and 2015. Table 5-1 shows the power demand forecast by ICE.

5.1.2 Demand Forecast by Study Team

(1) Method of Demand Forecast

The macroscopic method used here was to evaluate the power demand by focusing on the correlation between the per capita electric energy consumption and the economic growth rate, as published by EPDC in its document, "Method of Long Range Demand Forecast Of Energy For Developing Countries From The Worldwide Standpoint", EPDC, Sep. 1985.

5.1.3 Comparison of Demand Forecast Results

Generally, the result of the JICA shows no substantial difference from the value (base) estimated by ICE. There is also almost no difference seen in the vicinity of 2005, when the Los Llanos Power Plant is scheduled to start operation, and the two forecasts agree quite well.

5.2 Power Supply Plan

5.2.1 Power Supply Plan by ICE

The power development plan formulated by ICE for the period from 1995 to 2015 is shown in Table 5-4. In this development plan, an optimum power development program called LOGOS (Logiciel du Gestion Optimal du System Electrique) is used.

5.2.2 Power Development Plan

The power development plan, was studied by basically referring to the electric power development plan of ICE. As Result of the Study if the power demand grows as it is estimated, Los Llanos Hydroelectric Power Plant will be indispensable from a viewpoint of the power (kW) and energy (kWh) balance. It should be pointed out that the commissioning of Los Llanos Hydropower Plant will only be realized in 2005 or later, considering the practical construction schedule. In the event that the commissioning of Los Llanos Hydropower Plant is delayed beyond year 2005, the kW and kWh balance will become quite stringent.

5.3 Optimum Electric Power Development Plan

The study showed that the Los Llanos Power Plant should start operation in 2005. (See Table 5-8) The results of this study coinside with the results of the ICE study using LOGOS.

In the long-term development plan up to 2015, however, ICE plan was slightly modified to include 64MW base thermal power generation in 2007. Regarding the other plan contents, the same study results were acquired as in the ICE development plan.

Chapter 6 Meteorology and Hydrology

6.1 Outline of Meteorology and Hydrology

The Project area is situated in an area with two seasons--a dry season between December and March, and a rainy season between April and November. Precipitation in February (the month with the least precipitation throughout a year) is approximately 30-120 mm. In October, the peak of the rainy season, it reaches 600-1,000 mm. The difference is caused by trade winds, which blow in from the Pacific Ocean during the rainy season and hit the mountainsides of the area (orographic regions). However, torrential rain and flood in the area are caused when hurricanes come in from the Atlantic Ocean (nonorographic regions). Precipitation in the basin of the Naranjo River averages approximately 5,500 mm/year, one of the highest in the world.

Temperatures fluctuate little throughout the year. The daily average temperature in the flatlands is 25-27°C. The change of temperatures in the course of a day is approximately 10-12°C. Located in a high-rain area, the relative humidity reaches an average of 70% during the dry season, and 80 to 90% during the rainy season.

6.2 Inflow at the Project Dam Site

Catchment area at the dam site, located in the mid-stream of Naranjo River, is 147.0km^2. Daily inflow data at Los Llanos dam site have been accumulated since February 1993. However, since the observation period has been relatively short, the inflow for the Los Llanos Project was determined by correlating additional data accumulated at Londres Runoff gauging station, located approximately 15 km downstream from the project dam site.

As a result, the correlation coefficient of the daily inflow between the two was a high value of 0.95.

The inflow for a 23-year period (May 1971 through April 1994) was calculated according to an equation obtained from the data above. Measured values from February 1993 forward were also used.

The following is a summary of the results:

Annual average inflow:	15 m^3/s
Maximum monthly average inflow (average of October over 23-year period):	27 m^3/s
Minimum monthly average inflow (average of March over 23-year period):	4.3 m^3/s
95% firm discharge:	3.91 m^3/s

6.3 Inflow Calculation at Other Sites

In this study, it is necessary to obtain inflow data at several locations apart from the planned dam site, mainly for the use in evaluating environmental impact.

Calculation has been done based on the data collected at Londres Runoff gauging station, and according to the area rate, considering the precipitation distribution.

(1) Lower Naranjo River Irrigation-Water Intake Site

	Before Completion	After Completion
Annual average inflow:	28 m^3/s	14 m^3/s
Maximum monthly average inflow (average for October over a 23-year period):	58 m^3/s	32 m^3/s
Minimum monthly average inflow (average for March over a 23-year period):	5.8 m^3/s	1.6 m^3/s

(2) Naranjo River Estuary Site

	Before Completion	After Completion
Annual average inflow:	37 m^3/s	22 m^3/s
Maximum monthly average inflow (average for October over a 23-year period):	75 m^3/s	49 m^3/s
Minimum monthly average inflow (average for March over a 23-year period):	7.6 m^3/s	3.3 m^3/s

(3) Paquita River Power Station Site

The planned Power Station site is located to the upper stream of Paquita river, adjacent northwest of Naranjo river. Catchment area of Paquita river is 179km², and that at Power Station site is 24.5km².

	Before Completion	After Completion
Annual average inflow:	3.7 m^3/s	1.8 m^3/s
Maximum monthly average inflow (average for October over a 23-year period):	7.5 m^3/s	3.3 m^3/s
Minimum monthly average inflow (average for March over a 23-year period):	0.8 m^3/s	5.0 m^3/s

6.4 Flood Analysis

Probable maximum flood (PMF) is utilized for the dam design flood discharge.

Torrential rain peculiar to the area of the project site is related to hurricanes. Therefore, for calculation of PMP, precipitation should be treated as nonorographic precipitation.

As a result, PMF at the project dam site was calculated as 1,590 m^3/s. This figure equals approximately the probable flood volume in 10,000 years (1,540 m^3/s), as described earlier.

PMF at the project dam site: 1,600 m^3/s

6.5 Sedimentation

The Project makes it difficult for sand to accumulate in the dam, both from the structural and operational aspects, since the total capacity of the reservoir is rather small (approximately 1.5 million m^3). Therefore, the crest peak of the spillway gate is lower than the available water level, thus allowing excess sand to be discharged together with floodwater through the gate.

In addition, the water level of the main regulatory pool varies greatly during the course of a day, which often results in creating something like river conditions within the reservoir. Therefore, a flushing effect can be always expected.

In this study, the amount of sedimentation in the reservoir will be estimated according to the results of observation and analysis conducted by ICE.

As a result, it has been proven that there is no permanent sedimentation when using the basic plan (as discussed in the main report on trap efficiency).

Chapter 7 Geology and Construction Materials

(1) Outlines of Geology and Topography of Project Area

The project area, topographically, is in its maturity and is situated in a mountainous area having steep slopes and sharply eroded valleys and gullies, while geologically, it is in a region where sedimentary rocks from the Jurassic Period of the Mesozoic Era to the Eocene Epoch of the Paleogene Period are distributed.

The basement rocks of this area are mainly conglomerate, partially sandstone, and extremely locally, marlstone among sedimentary rocks, the strikes and dips of their bedding planes indicating NW-SE and NE characters, while as a whole, very prominent folding and/or faulting structures are not seen in this area. These basement rocks are directly overplain at parts by Quaternary deposits, but from the viewpoint of engineering geology, there is nothing in particular to be mentioned concerning distribution of these Quaternary deposits.

(2) Geology and Engineering Geology of Main Civil Structure Sites

Three sites (upstream, midstream, and downstream) on the Naranjo River had been made candidates as damsites in this project area from before, and the result obtained in this Feasibility Study was that the downstream site would be the most advantageous. Hereinafter, the term "damsite" will mean the "downstream damsite."

The basement rock at the damsite is made up as a whole by conglomerate which is massive, hard, and dense. From the standpoint of rock mechanical properties, it has adequate properties as the foundation rock for a concrete gravity dam of 60m height class, while it has also been revealed that there are hardly any problems hydrogeologically (See Figs. 7-2 and 7-5).

With respect to the reservoir area also, it has been made clear that there are no problems topographically and geologically regarding watertightness and stability of the slopes around the reservoir (See Fig. 7-2).

The intake site is located on a fairly steep slope at the right-bank side of the Naranjo River, but it appears that the slope is stable topographically. There is a great possibility that the basement rock comprises conglomerate, but according to the results of investigations so far, conditions engineering geology-wise to be problems in particular have not been revealed (See Fig. 7-2).

For the headrace tunnel, a route passing under the mountain body comprising the watershed between the Naranjo River and the Paquita River has been proposed as a result of the present study. It has been revealed by investigations up to the present that mainly conglomerate and partially sandstone are distributed in the area along this route, that three lineaments intersect the route according to aerial photo interpretation, that faults such as to cause a great change in the geological structure of basement rocks have not been found, etc.

Seen from the standpoint of engineering geology, this tunnel may encounter weathered rock at parts in sections of tunnel cover depth less than 100m and minor faults at some places, but the possibility is great that most sections will pass through sound basement rock, and it is thought there will not be very many serious problems (See Fig. 7-9).

The surgetank site, topographically, is located on a ridge line, and since there is no outcropping of basement rocks in the surroundings, the geological properties at this site have not yet been ascertained, but the possibility is great that the basement rock is conglomerate. Although detailed geological data are not available as of the present, it appears that topographically and geologically there are no harmful defects at this site for construction of a surgetank (See Figs. 7-8 and 7-9).

Initially, the route of the penstock was planned above ground and surveys were carried out with that in mind. As a result, it was found that the basement rocks of the route mainly consisted of conglomerate, that weathering was fairly severe at the surface portion of that conglomerate and, therefore, that it would be necessary for foundations of supports for the penstock to be made considerably deep. Meanwhile, since this conglomerate is of very good rock character deep underground, making the penstock an underground type (tunnel type) was studied. In the end, the conclusion drawn was that it would be most advantageous from both the aspects of civil works construction technology and cost for the penstock of the Project to be made a tunnel type, and it is thought that conclusion is reasonable both geology-wise and engineering geology-wise (See Figs. 7-8, 7-9, 7-10 and 7-12).

The powerhouse site is located on the left-bank side of the Paquita River, where the surface of river terraces formed along the river abut the mountain slope. It has been found that terrace deposits of maximum thickness 7 to 8m overlie the basement rock conglomerate. For the powerhouse foundation rock, the abovementioned terrace deposits should be excavated and removed (See Figs. 7-13 and 7-14).

According to the above, it may be concluded that the topographical, geological, and engineering geological conditions of the main civil structure sites, so far as revealed up to now, will pose no serious problems in construction of the various civil structures proposed in the present Feasibility Study.

(3) **Engineering Geological Evaluation concerning Construction Materials**

Since a concrete gravity dam is proposed for this Project, the most important matter concerning construction materials is securing a supply area for concrete aggregates.

ICE had carried out investigations of river sand-gravel of the Paquita River near the powerhouse site and basement rocks at the damsite and the surroundings of the reservoir area as prospective sites for collecting concrete aggregates. It was made clear upon evaluating the results of investigations at the various sites mentioned above in the present Feasibility Study that the Quebrada Azul site at the upstream side of the reservoir area is promising.

Sandstone of hard and dense rock character is distributed at the Quebrada Azul site and, quality-wise, it is quite satisfactory as aggregate for concrete. However, this site is approximately 3km from the dam site going along the river channel and slightly distant, so that the necessity for additional investigations to be made hereafter at a place close to the damsite may be pointed out. (See Fig. 7-15)

Chapter 8 Seismicity

Costa Rica, which is situated on the Circum-Pacific Seismic Belt, has experienced countless earthquake disasters in the past. The maximum magnitude of earthquakes occurring within the project area (90km) since 1990 has been 7.3. Classifying the modes of earthquakes according to plate earthquakes occurring at the boundaries of plate sinking and inland earthquakes occurring at inland earthquake faults, it can be seen that all of the earthquakes in the area have been plate boundary earthquakes.

The group of plates existing in the area around Costa Rica has relative movement velocities which are comparatively high and which are reported to be about approximately 9cm/yr. Consequently, the relative displacement in 100 years is 9m, and it is thought that since the plates cannot withstand such relative displacements, extremely great earhquakes occur at plate boundaries on the order of every 100 or 200 years. Accordingly, it may be judged that it will be possible to rationally predict and evaluate great earthquakes occurring at plate boundaries by looking at historical earthquake data.

On the other hand, regarding displacement speeds of active faults distributed inland, in most cases they are about several meters in 1,000 years even with very fast ones, and it is considered that near-field earthquakes causing damage occur on the order of once in thousands of years or tens of thousands of years. Hence, it is difficult to properly evaluate inland near-field earthquakes by stochastic earthquake risk evaluations. Furthermore, near-field earthquakes occurring inland are generally of smaller scale than great earthquakes at plate boundaries, and magnitudes are considered to be around 7.

Maximum accelerations at the Los Llanos site were stochastically estimated in this chapter using four formulae based on historical earthquakes. The results are given in Table 8-7.

The values of maximum accelerations estimated will be different depending on the ground conditions applied, and with regard to the Los Llanos site, since the seismicity of Costa Rica is basically high, a value which would encompass the results obtained this time, that is, 300 gal, was assumed. This value, from the standpoint of stochastic analysis results, corresponds roughly to a return period of 10,000 years.

Design Horizontal Seismic Coefficient of Ground at Project Site

Regarding the relationship between horizontal maximum acceleration of earthquake motion and design horizontal seismic coefficient, it is calculated by an equation devised so that the sizes of stresses in the ground and structures excited by earthquake motion will be equivalent for cases of handling dynamically (dynamic analysis) and statically (static analysis using design seismic coefficient). The results are given below.

Dam Type	Design Horizontal Seismic Coefficient
Fill Dam	0.15
Gravity Dam	0.15
Arch Dam	0.30

Chapter 9 Development Plan

9.1 Optimum Development Plan

The previous study regarding a development plan on the Naranjo River confirmed as follows.

- General layout of Los Llanos hydroelectric project is as shown in Fig. 9-13.
- 62 m high gate type concrete gravity dam is constructed at the downstream axis with effective storage of 653 x 10^3 m^3 allowing daily regulation as shown in Fig. 9-14.
- Peak running time is 5 hours.
- Maximum discharge is 27 m^3/s as shown in Fig. 9-15.
- Power plant with 2 units of 42.5 MW is built on the left bank of the Paquita River.
- Compensation is estimated in the project cost in order to make up a poor African palm harvest owing to the decreased water caused by the project.

The projected outline for optimum development plan is as follows.

High Water Level	EL. 477.4 m
Low Water Level	EL. 470.0 m
Effective Storage Capacity	653 x 10^3 m^3
Tail Water Level	EL. 84.0 m
Gross Head	389.7 m
Effective Head	359.4 m
Maximum Discharge	27 m^3/s
Installed Capacity	85 MW
Firm Power Output	82.7 MW
Annual Available Energy	389 GWh
Firm Energy	107 GWh
Secondary Energy	282 GWh

Main Facilities

Dam	Concrete Gravity Type	62.4 m x 114 m
Headrace		3.1 m x 5,540 m
Surge Tank		8.0 m x 58 m
Penstock	Tunnel Type	3.10 m - 1.25 x 1,570 m
Powerhouse	Open Type	
	Francis Turbine	

Chapter 10 Power Transmission Plan and Power System Analysis

10.1 Outline of Power Transmission System

The power transmission system of Costa Rica is a 230 kV system interconnected to that of Nicaragua and Panama. The system exchanges power on a mutual basis with certain neighboring countries. The domestic power transmission system consists of 230 kV and 138 kV transmission lines. As of January 1995, the total lengths were 880 km and 704 km respectively.

However, there is a plan to form a large 500 kV power transmission system (SIEPAC) interconnecting five central American countries and Panama. This system is projected to come on line somewhere between the years 2000 and 2003.

Fig. 10-1 shows the 230 kV and 138 kV power transmission system (scheduled for 2015) in Costa Rica.

10.2 Power Transmission Line Route

The power generated at the Los Llanos Power Plant to the metropolitan area of San Jose, the largest load center in Costa Rica.

(Alternative Route A)
One is an almost straight route crossing the Paquita River at the power house and traversing the mountain areas.

(Alternative Route B)
Although the shortest, it traverses a mountain area. The other is a route running to the right of the Paquita River to the plains and to San Rafael (Parrita) and running parallel to SIEPAC is also conceivable.

(Alternative Route C)
Another possible route is one that, after arrival at the plains, would traverse the palm plantations, and run along National Highway 239 to San Rafael (Parrita).

Fig. 10-3 shows the Alternative of Transmission Line Route.

Comparison of the three alternative routes (A, B and C) is shown below.

	Route A	Route B	Route C
Transmission line length	◎(20 km)	○(22 km)	△(25 km)
Traversing mountain area	△	○	◎
Transmission line intersection	○	◎	△
Traversing palm plantation	◎	○	△
Material transportation	△	○	◎
Maintenance convenience	△	○	◎
Construction cost (relative to Route B)	△ 1.5	◎ 1.0	○ 1.0
Minimized felling of natural and afforestation trees	△	◎	△
Short distance	◎	○	△
Overall evaluation	○	◎	△

On the basis of the overall study of the three routes, A, B and C, including the technical and economical evaluations, Route B was selected as the route for the projected transmission line. Route B is approximately 22 km.

10.3 Study and Analysis of ICE System

The thermal capacity, voltage, short circuit current capacity and the safety level of the transmission line, as of 2005 when the Los Llanos Power Plant starts operation, were studied.

10.3.1 Power Flow Calculation

There is no need for reactive power phase modifying equipment, and there is no problem in power flow.

10.3.2 Short Circuit Capacity

- Los Llanos Power Plant 230 kV bus : 6.8 kA (2,700 MVA)
- San Rafael (Parrita) Substation 230 kV bus : 8.6 kA (3,400 MVA)

The 3-phase short circuit current at the respective points is as above.

The short circuit current is within 31.5 kA as specified by IEC, and therefore free from special problems.

10.3.3 Stability

The system is stable in the case.

10.4 Conclusion

The double circuit, 230 kV plan is recommended for the transmission electric power of Los Llanos Project based on this study. The power transmission line parameters of this plan are as presented below.

Transmission voltage	:	230 kV
Number of circuits	:	2
Total length	:	Approximately 22 km
Conductor type/size	:	ACSR, 1 x 954 MCM

Chapter 11 Feasibility Design

Feasibility design includes the civil engineering design of the temporary and permanent structures, and the power generation facilities and outdoor switchyard which involve the electric machine design.

(1) Design of Dam and Waterway

Based on the optimum development plan described in Chapter 9, a concrete arch dam and concrete gravity dam were compared selecting each dam axis in the lower dam site area. Result of the comparison, it was judged that the concrete gravity dam is suitable. Regarding the headrace tunnel, the most economical tunnel inner diameter is examined and the location and number of the work adits were studied in consideration of the construction methods and work period.

(2) Powerhouse and Outdoor Switchyard

In the development planning stage, the upstream end on the flatland in the river terracing on the left bank of the Paquita River was selected as the powerhouse location. However, the foundation site contains marlstone. As the penstock is embedded in the tunnel, the powerhouse location was re-examined because it can be situated regardless of the topographic conditions. Consequently, the location is shifted to upstream where the foundation is conglomerate, thereby also shortening the penstock.

Regarding the power generation facility, the types of turbines and numbers of machine units are examined. The employment of 2 Francis turbines is determined based upon discussions with ICE since this combination provides the best operation merits as well as the highest output and generated power. Based on these basic specifications, the powerhouse building dimensions are determined to accommodate the turbines, generator, auxiliary machinery and switchboard chamber. The most economical and safest location enabling a turbine center elevation of EL 79.5m is selected. Regarding the outdoor switchyard, when banked, the left bank of the Paquita River would provide a wide site next to the powerhouse. Therefore, the main transformer is installed to the powerhouse side and connected to the powerhouse by bus cable.

Chapter 12 Construction Planning and Cost Estimation

The project schedule was examined to start operation in 2005 based on the ICE power development plan. (See Chapter 5.)

The construction cost is estimated assuming the following conditions;

(1) Of the civil works, the access road and camping facilities are to be completed by ICE.

(2) Other civil works and the installation of the hydraulic equipment and electro-mechanical equipment (transmission line included) are carried out by the contractor(s).

12.1 Construction Schedule

3.5 years are estimated for the construction, assuming that the works are carried out efficiently by employing the optimum machines for a construction of this scale and layout, and that the access road and construction power (transmission line) are provided prior to the main construction. The entire construction schedule is planned considering the ordering, manufacture and installation of electromechanical equipment. It is ensured that operation will start as scheduled.

12.2 Cost Estimation

The unit construction costs are estimated based on labor wages and equipment/ material price as of January, 1995 and the unit construction costs are compared with those of similar project(s) currently being developed in Costa Rica. It is also referred to the realistic figures in the domestic and international markets. The applied local/foreign currency exchange rate is US$1 = 168 colones. All cost is indicated in US dollars.

Summary of Construction Cost

(Unit: million US$)

Item	FC	LC	Total
1. Civil works	34.6	28.9	63.5
2. Hydraulic Equipment	7.4	1.6	9.0
3. Electromechanical Equipment	24.2	3.1	27.3
4. Transmission Line	3.2	1.0	4.2
5. Direct Cost (1+2+3+4)	(69.4)	(34.6)	(104.0)
6. Project Control Cost	2.1	17.1	19.2
7. Compensation Cost	0.0	0.7	0.7
8. Contingency	7.2	6.3	13.5
9. Indirect Cost	9.3	24.1	33.4
10. Total Cost (5+9)	(78.7)	(58.6)	(137.3)
11. Interest during Construction	14.4	0.0	14.4
12. Grand Total	93.1	58.6	151.7

Chapter 13 Environment

(1) Environmental Protection

The planned area is close to the Dota Forestry Reserve but is not included in the Reserve. A national park which is subject to protection and a mangrove swamp are situated side by side at the planned river mouth of the Naranjo River. Also, the Quepos mangrove swamp into which water from the Paquita River partially flows, is situated near that river s mouth. Environmental protection must, therefore, be considered in the facility design and in its operation.

(2) Hydrology

When this Project is realized, there will be a max. $27m^3$/sec water flow from the Los Llanos dam site to the neighboring Paquita River through the underground channel. The Los Llanos dam is located immediately downstream where the Naranjillo River (effluent of the Naranjo River) joins. According to the flow prediction based on the record of the Naranjo River for the past 23 years, the lowest monthly average flow at the river mouth is indicated in March at $1.7m^3$/sec. Max. $27m^3$/sec water is increased at the Paquita River. The midstream area of the Paquita River has a history of flooding due to heavy rainfall during hurricanes. In this Project, certain environmental measures are provided for flood control, for instance, flow to the Paquita River is stopped during heavy rainfalls.

Significant topographic change due to erosion and sedimentation is recognized along the banks of this river. The major factors for this erosion and sedimentation are not the river itself, but rather it is due to hydraulic interaction between the ocean and the lagoon, and the large physical energy of the ocean. It is, therefore, an urgent issue for Costa Rica s national land security related organs to provide the necessary measures before the Project is started.

Regarding the water quality of the two rivers, the water is clean, although turbidity does increase in response to the flow increase during the wet season. Also, in this Project, the reservoir is small and the water replacement time short. There is, therefore, no risk of water pollution such as eutrophication in the reservoir water.

According to the study regarding the groundwater level change in the Naranjo River basin, the groundwater level is shallow even in the dry seasons. No significant drop in the water level is recognized. Also, the brine level at the beach is not significant.

Although the Project reduces the river flow in the dry seasons, serious impact on both the biological environment and local industries can be reduced by retaining a min. 1.7m^3/sec in a short period together with monitoring the environment.

(3) Topography and Geology

There is almost no topography or geology in the planned area deemed valuable for academic research and which case would, therefore, require special protection.

(4) Soil

Although the soil distributed in the planned area is dense, erosion occurs easily due to its high permeability. It is, therefore, necessary to provide adequate measures for slope protection and turbidity prevention.

(5) Aquatic Life Forms

Although a variety of aquatic life forms are recognized in the Naranjo and Paquita Rivers, they are not particularly valuable or rare species.

According to the study subject to mangrove protection near the Naranjo River mouth, the Project does not affect the fresh water, feed supplies or the water flow. As a topographic protection measure, a modification of the dam facility is planned to supply sediment from upstream.

Also, there is no serious impact on the life forms in the river mouth or on the shallow beach since the brackish water zone at the river mouth is protected.

Savegre Beach south of the Naranjo River mouth is known for marine turtles. Any environmental impact on these turtles is mainly caused by the development of marine tourism and ocean pollution. This Project, however, is not directly engaged in these problems.

(6) Terrestrial Life Forms

A variety of flora and fauna are distributed in this area. There are some precious plants at the reservoir and dam sites. However, the planned flooding area is small. Also, approx.35% of the entire area (10ha) is river terrace. Therefore, no precious gregarious plant group is submerged. Regarding the precious varieties, however, it is necessary to research their distribution along with the project execution and re-locate or propagate them as required.

There is also a distribution of some precious animals. Although their habitat will be made slightly smaller due to the land dedication to the facilities and restriction to the construction area, as these animals are migratory there will be no serious impact on them over the long term.

(7) Scenic and Recreation Areas

Although the planned area is located in a mountainous area, it provides no special scenic views. Also, the reservoir and dam facilities are not visible from the roads used by local residents. The planned site is not used for recreational purposes.

(8) Noise and Vibration

The planned area is located in a mountainous area where there are no noise or vibration sources. The temporary noise and vibration resulting from the construction does not seriously affect the wild life. Although the human population is extremely low, night construction should be carefully considered due to the noise and vibration involved. It is necessary to plan measures for the residents in the early stages together with the measures for compensation for their relocation.

(9) Population

The planned area contains a number of small villages although less than 100 people are directly affected by the Project. With the total population of the major villages along the Naranjo River basin being approx. 28,000 people, less than 1% are physically affected, as in the case of relocation. It is necessary to discuss relocation of the residents thoroughly and provide compensation accordingly.

(10) Industries and Economy

Most of the planned sites are located in a mountainous area. Small livestock farms are operated on the cleared slopes. The industries in this area are varied depending on their location being upstream, midstream or downstream. The main industry upstream is livestock farming on cleared land although the numbers of coffee plantations have increased in this area recently. At the midstream area, livestock farming on the plains is the main industry. Primary industries such as large palm plantations, and rice and flower production are the major industries in the downstream area. Service industries such as tourism are located at both midstream and downstream.

The only industrial site affected by this Project is a very small farm at the planned powerhouse site, where a farmer presently raises livestock and grows achote. The owner is compensated since the land is acquired for the Project. The main industry in this area is palm plantations. However, this Project does not seriously affect that industry.

(11) Income and Unemployment

The basic income source for the residents in the planned area is small scale farming (individual) or earning wages as farmhands from working on the large farms. Also, many residents earn cash outside their villages. This is one of the poorest areas in Costa Rica. According to a recent study, it is necessary to establish the local infrastructures and an industrial base to improve the financial conditions of the residents by providing employment therefrom.

It is necessary, therefore, to position this Project as a local prosperity promotion program which provides job opportunities to the local residents in the construction, together with medical facilities and infrastructures as the additional value accompanying the Project.

(12) Land Use

A total land area of 56.6ha must be acquired for this Project. This land consists of forest, meadowland and wasteland. The meadowland is currently used for livestock farming. Although the land owners are compensated, the required land is only a small portion of the meadowland area and does not affect local land usage. The Project also does not affect the palm plantations or rice production at the downstream areas.

(13) Public Facilities and Services

A very small school is presently located at the planned concrete yard. Although the existing road is expanded and used as the work road, it is necessary to fully discuss with the school management and owners of the land where the new road is to be built, and to relocate the school or acquire land for its relocation. Regarding the road development due to the construction, it is necessary to establish a stable transportation system in this area and with the neighboring areas.

The medical facilities for the construction workers and the education facilities for their family can improve the living environment for the local people when these facilities are released to the local community at the end of construction. This can be discussed with the local government.

(14) River Use

In the dry season, the river water is used for irrigation by some palm plantations located in the Naranjo River downstream area. When the Project is completed, the monthly average flow in March (dry season) reaches its lowest level of $1.7m^3$/sec at the Naranjo River mouth. This flow is important in retaining the brackish zone and providing a natural environment in the river mouth area including the mangrove swamps. The flow at the irrigation intake site is an average of $0.67m^3$/sec on a 23-year basis. Since the max. intake is $1.8m^3$/sec., intake shortage is expected although the shortage period in dry season varies each year. It is necessary to compensate the shortage each year depending on the palm harvest record as well as by the monitoring records. It is also necessary to discuss an efficient water utilization plan and the partial application of groundwater with the palm plantation owners and provide an optimum water plan in this area.

A shrimp farm is situated next to the mangrove swamp at the Naranjo River mouth. According to the brine data for this pond, there is no change in the relation between the Naranjo River flow change and the brine level change in the pond. The brine level is retained at the specified value regardless of a flow drop of the Naranjo River.

The Naranjo River is used for small scale tourism between its midstream area and river mouth, as well as for bathing and fishing at a limited area in the midstream area. Although the flow drops due to the Project, the season for river level descent is extended. The location for recreational use may also be moved.

(15) Ocean Use

Mainly rod-and-line fishing is done in the ocean where the planned river water flows in. Shrimping is carried on along the shores of Savegre. A national park is located on the beach between the Paquita and Naranjo Rivers, where the flow direction changed. Fishing is prohibited at the Naranjo River mouth and in the mangrove swamp in Quepos to 29km off- shore. No serious impact is expected since the brackish area at the river mouth is retained even in the dry season regardless of a flow drop in the Naranjo River. The natural environment of the mangrove swamp along the Naranjo River mouth is protected, the flow along Savegre moves to the north, and the only fishing in this area is off-shore fishing. Although the flow increase of the Paquita River expands the present fresh water dispersion range slightly, it does not interrupt the fishing vessels entering and leaving Damas Lagoon.

(16) Tourism and Recreation

The Manuel Antonio National Park is the main tourist site in this area. The major tourist attractions are calm seas, scenic views, bathing and animals/plants in the park. This Project reduces the mud content in the Naranjo River flowing to the Park. There is no serious impact on tourism resources.

(17) Cultural Assets

There are no cultural assets in the planned area.

(18) Public Sanitation

As a run-off reservoir is installed in this Project, no disease can result from water stay. Establishment of a local medical facility is expected by this Project.

(19) Comprehensive Viewpoint

Considering the factors described above, this Project can be achieved with no serious impact to the natural, social and economical environments for the local community.
The total compensation cost for this Project is estimated at 38,132 x 10^6 colones.

Chapter 14 Economic and Financial Evaluation

14.1 Economic Evaluation

(1) Method of Evaluation

The "alternative facility approach method" is adopted in the Project. As the Project is designed to be a peak load power generation plant, a peak load thermal power generating facility is assumed as alternative facility. The alternative facility should have a capacity to render the equivalent service to the Project (in effective dependable capacity and annual available energy).

Construction cost, operation and maintenance cost, etc. are to be calculated as the cost, while these costs for the alternative project are taken as the benefit of the Project, and economic evaluation is to be made, by calculating Net Present Value (B-C), Benefit/Cost Ratio (B/C) and Economic Internal Rate of Return (EIRR).

(2) Economic Cost of the Project

Cost of the Project will include initial investment, operation and maintenance, renovation and compensation for palm plantation. The economic cost is calculated by excluding the transfer items from the financial cost, and the standard conversion factor was applied.

(3) Economic Benefit of the Project

The alternative facility approach method is adopted for economic evaluation of the Project. Here thermal generating facility which can render the equivalent service (both in effective dependable capacity and annual available energy) to the Project is assumed. And the required cost, such as initial investment, operation and maintenance, and renovation, for the thermal power generation is regarded as the benefit for the Project.

(4) Economic Evaluation of the Project

As a result of evaluation, it has been revealed that the Project is feasible with any index. (See Table 14-4)

- Net Present Value (B-C) : US$42,389,000
- Benefit/Cost Ratio (B/C) : 1.43
- Economic Internal Rate of Return (EIRR) : 20.2%

It should be pointed out that transmission line scheme contemplated in the Project is formulated on the condition that Pirris Hydropower Project will have been completed before commissioning of Los Llanos Project. Therefore, the result of this evaluation is also subject to the precondition.

14.2 Financial Evaluation

(1) Method of Financial Evaluation

In a financial evaluation of an electric power project, it is usual to obtain Financial Internal Rate of Return (FIRR) by "discount cash flow method" reckoning construction cost, operation and maintenance cost, renovation cost, etc., as cost factors, while sale of electric energy produced by the project is to be reckoned as benefit. Evaluation point will be the entrance of San Rafael (Parrita) Substation.

(2) Financial Cost and Benefit of the Project

Financial costs of the Project are the initial investment at market prices, renovation cost, and operation and maintenance cost.

The financial benefit of the Project is the electricity sale revenue. The revenue is calculated based on ICE's average bulk sale tariff of 0.059 US$/kWh as of January 1995.

(3) Financial Evaluation of the Project

Financial Internal Rate of Return (FIRR) has been calculated based on the financial benefit (=income from the sale of electric power) shown in Table 14-6.

- FIRR : 12.4%

Chapter 15 Further Investigations

To proceed from the detailed design stage to the implementation stage in this Project, it is necessary to further examine the topography and geology of the sites where the major civil engineering structures are installed as described in the Feasibility Study.

This chapter describes the studies to be added or continued including the topographic study, geological study, material survey, hydrologic study for downstream, environmental impact, and compensation.

15.1 Topographic Study

(1) Construction Road Route Survey:

Supplement to existing 1:5,000 scale topography map

(2) Aggregate Acquisition Site & Temporary Facility Sites:

1:1,000 Scale Topographic Survey

(3) Headrace Longitudinal Survey (Concavo Pass Point):

Approx. 250m downstream from Work Adit B

15.2 Geological/Material Study

To proceed this Project to the detailed design stage, the additional geological survey/construction shown in Table 15-1 is required for each planned site, and the route and construction material acquisition sites.

Further accurate geotechnical data is required regarding the waterproofing treatment for the foundation rockbed at the dam site (downstream site). It is necessary to confirm the dynamic characteristics of the rockbed from its surface to the structure foundation depth at the intake site.

Regarding the headrace tunnel route, it is necessary to examine the dynamic characteristics of the rockbed and the hydrographic conditions in the tunnel where the tunnel rock cover is max. 50m.

Regarding the surge tank site and penstock route, it is vital to ensure that the dynamic characteristics of the rockbed and hydrographic conditions around the civil engineering structures where the tunnel rock cover is max. 100m.
It is also necessary to ensure the concrete aggregate mine near the dam site.

15.3 Hydrologic and Meteorologic Study

15.3.1 Meteorologic Study

It is necessary to continue meteorological observations since the entire observation network required for the implementation design and construction plan is now completed. The network includes the Napoles Observation Station, newly installed for this Project study.

15.3.2 Flow Observation

It is necessary to continue flow observations since the entire observation network required for the future construction plan and operation plan is now completed. The network includes the run-off gauging station at Paquita River powerhouse site, newly installed for this Project study.

15.3.3 Site Observation

It is necessary to continue site observations at the Naranjo River downstream basin for environmental assessment in the future. It is recommended that observations be made twice monthly from December through March in the dry season, and once monthly for the remainder of the year.

15.4 Environmental Study and Compensation

15.4.1 Impact On Social Environment

An increase in the number of tourists is especially expected at the downstream area of this Project. Therefore, the study is carried out regarding immigration to mainly Quepos and employment opportunities. The study is also carried out regarding items such as the future water use plan of which the impact on the social environment is large since the water flow is divided into the Paquita River.

15.4.2 Public Health Study

Studies and surveys are conducted regarding harmful insects and plants that mediate disease, and the health of the local residents. The result is reflected in the power development project to prevent public health problems in the local community.