JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF PUBLIC WORKS, TRANSPORT AND HOUSING (SOPTRAVI)
MINISTRY OF INTERNATIONAL COOPERATION (SETCO)
NATIONAL EMERGENCY COMMITTEE (COPECO)
NATIONAL SERVICE AUTHORITY FOR WATER SUPPLY AND SEWERAGE (SANAA)
MIINISTRY OF NATURAL RESOURCES AND ENVIRONMENT (SERNA)
MUNICIPALITY OF THE CENTRAL DISTRICT (AMDC)

THE STUDY

ON FLOOD CONTROL AND LANDSLIDE PREVENTION IN TEGUCIGALPA METROPOLITAN AREA OF THE REPUBLIC OF HONDURAS

FINAL REPORT

SUMMARY

MAY 2002

PACIFIC CONSULTANTS INTERNATIONAL
NIKKEN CONSULTANTS, INC.

Foreign Currency Exchange Rates Applied in the Study

Currency	Exchange Rate/USD
Honduran Lempiras (Lps)	15.84
Japanese Yen (JPY)	122.44

(Rate as of November 1, 2001)

PREFACE

In response to a request from the Government of the Republic of Honduras, the Government of Japan decided to conduct the Study on Flood Control and Landslide Prevention in Tegucigalpa Metropolitan Area of the Republic of Honduras and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Mitsuo Miura of Pacific Consultants International (PCI) and composed of staff member of PCI and NIKKEN Consultants,Inc. to Honduras, two times between January 2001 and December 2001. In addition, JICA set up an advisory committee headed by Mr. Katsushige Masukura, Japan Construction Information Center, between January 2001 and May 2002, which examined the Study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of the Republic of Honduras, and conducted field surveys in the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

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

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

May, 2002

川上隆朗

Takao Kawakami
President
Japan International Cooperation Agency

THE STUDY ON FLOOD CONTROL AND LANDSLIDE PREVENTION IN TEGUCIGALPA METROPOLITAN AREA OF THE REPUBLIC OF HONDURAS

May, 2002

Mr. Takao Kawakami
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit you the final report entitled "The Study on Flood Control and Landslide Prevention in Tegucigalpa Metropolitan Area of the Republic of Honduras". This report has been prepared by the Study Team in accordance with the contracts signed on18 January 2001, 25 January 2002 and 1 May 2002 between the Japan International Cooperation Agency and the Joint Study Team of Pacific Consultants International and NIKKEN Consultants,Inc.

The report examines the existing conditions related to flood and landslide in Tegucigalpa metropolitan area, proposes a master plan for the disaster mitigation and presents results of the feasibility study for priority projects, which was identified in the master plan.

The report consists of the Summary, Main Report, Supporting Report, Data Book, GIS Operation Manual and Maps. The Summary summarizes the results of all studies. The Main Report contains the existing conditions, the proposed master plan, the results of the feasibility study, and conclusions and recommendations. The Supporting Report includes technical details of contents of the Master Plan. The Data Book contains basic data used in the Study. The GIS Operation Manual includes explanations and handlings of database constructed in this Study. The Maps contains principal maps.

All members of the Study Team wish to express grateful acknowledgement to the Japan International Cooperation Agency (JICA), JICA Advisory Committee, Ministry of Foreign Affairs, Ministry of Land, Infrastructure and Transport, Embassy of Japan in the Republic of Honduras, and other donors, and also to Honduran officials and individuals for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the promotion of the disaster mitigation of Tegucigalpa metropolitan area, and that friendly relations of both countries will be promoted further by this occasion.

Yours faithfully,

三浦 光夫

Mitsuo Miura
Team Leader

EXECUTIVE SUMMARY

FLOOD/LANDSLIDE DAMAGE MITIGATION MASTER PLAN

1. EXISTING PROBLEMS AND TARGETS OF THE MASTER PLAN

The study revealed that 30% of the Target Area for Disaster Prevention is occupied by flood or landslide hazardous area and 15% of the total population live in those dangerous areas. The target of the Master Plan is to minimize the damage and avoid any loss of human lives by flood and landslide even with a hurricane of the Mitch scale. In order to attain this goal, a master plan composed of non-structural measures and structural measures was formulated.

2. MASTER PLAN PROJECTS

The Master Plan has been planned to achieve the targets by the projects in Table 1.

Table 1 Mater Plan Projects

	Flood Damage Mitigation	Landslide Damage Mitigation	Common
Structural Measures	Choluteca River Improvement (target: 15-year flood) Pescado Lake Outlet Improvement	Berrinche Reparto Bambu	-
Non-structural Measures	Watershed Management Land Use Plan/ Land Use Regulation Structural Code Application Forecasting/Warning/Evacuation	Land Use Plan/ Land Use Regulation Forecasting/Warning/Evacuation	Education/Enlightenment/Training (including preparation and publication of hazard maps) Disaster Management Information System

3. FACILITY PLANNING OF STRUCTURAL MEASURES

Major facility planning for the master plan structural projects is as shown in Table 2.

Table 2 Summary of Facility Planning for Mater Plan Projects

Projects	Components	Descriptions
Flood Damage Mitigation	Choluteca River Improvement	Excavation: L=7km, 750,000 m^3 River Widening: L=200 m (Including Counter Fill, Horizontal Boring, Concrete Shaft) Revetment: L=9 km Dike: L=3 km Bridge Reconstruction: 1 bridge
	Pescado Lake Outlet Improvement	Slope Trimming, Gabion
Landslide Damage Mitigation	Berrinche	Soil Removal, Surface Drainage, Sub-surface Drainage, Drainage Well
	Reparto	Soil Removal, Surface Drainage, Sub-surface Drainage, Drainage Well
	Bambu	Surface Drainage

4. *PROJECT COSTS*

The project costs for the proposed master plan are as shown in Table 3.

Table 3 Project Costs of Proposed Master Plan

Name of Projects	Project Costs (1,000 USD)
Flood Damage Mitigation	52,437
Landslide Damage Mitigation	8,308
Common	3,166
Total	63,911

5. *FINANCIAL PLAN*

The financial plan was made referring the loan conditions of BID and assuming the project period between 2002 and 2015. The maximum annual disbursement amount is USD 37.46 million in 2006 and the maximum annual repayment is USD 2.91 million in 2027.

6. *ORGANIZATION PLAN*

The organization plan for the implementation of the master plan projects were proposed.

- Overall Coordination: Coordination Committee
- Flood Control Structural Measures: AMDC (SOPTRAVI)
- Landslide Prevention Structural Measures: AMDC (SERNA, SOPTRAVI)
- Watershed Management: AMDC (SANAA,SERNA,COHDEFOR)
- Land Use Plan/Land Use Regulation/Structural Code : AMDC (COPECO,CODEM)
- Education/Enlightenment/Training: CODEM (COPECO)
- Preparation and Publication of Hazard Maps: CODEM (COPECO,SOPTRAVI,SERNA)
- Forecasting/Warning/Evacuation: COPECO,CODEM (SERNA,SMN)

7. *SELECTION OF PRIORITY PROJECT*

By comparing the master plan projects in terms of urgency, significance, schedule, economical, aspects, a part of the river improvement, all of the landslide prevention projects, forecasting/warning/evacuation, education/enlightenment/training, and disaster management information system were selected as the priority projects.

8. *EVALUATION OF MASTER PLAN AND RECOMMENDATION*

The proposed Master Plan was judged to be feasible from the viewpoints of economic(EIRR=10.49%), financial, managerial, technical, environmental and social aspects. The Study recommended that the related Honduran organizations should coordinate closely to implement the master plan in order to create a safe capital against natural disasters.

FEASIBILITY STUDY ON THE PRIORITY PROJECT

1. CONTENTS OF THE PRIORITY PROJECTS

The contents of the priority projects for the feasibility study are as follows:

(1) CHOLUTECA RIVER IMPROVEMENT

Excavation	:	750,000	m^3
River Widening	:	200	m
(including counter fill, horizontal boring, concrete shaft)			
Revetment	:	3	km
Dike	:	1	km

(2) PESCADO LAKE OUTLET IMPROVEMENT

Slope Trimming	:	9,000	m^3
Gabion	:	630	m^3

(3) BERRINCHE LANDSLIDE PREVENTION

Drainage Well	:	8	places
Water Collection Boring	:	4,000	m
Drainage Boring	:	370	m
Drainage Channel	:	1,840	m
Soil Removal	:	184,000	m^3

(4) REPARTO LANDSLIDE PREVENTION

Drainage Well	:	1	place
Water Collection Boring	:	500	m
Drainage Boring	:	230	m
Drainage Channel	:	2,330	m
Soil Removal	:	40,000	m^3

(5) BAMBU LANDSLIDE PREVENTION

Gabion	:	690	m^3
Drainage Channel	:	260	m

(6) FORECASTING/WARNING/EVACUATION

Rainfall/Water Level Gauging Station (for Flood Damage Mitigation)	:	3	places
Rainfall Gauging Station (for Landslide Damage Mitigation)	:	4	places

(7) EDUCATION/ENLIGHTENMENT/TRAINING

Education/enlightenment/training program for disaster management administrators, educators and public.

(8) DISASTER MANAGEMENT INFORMATION SYSTEM

Data base of hazard map information, flood/landslide forecasting and warning information, emergency disaster information, and optical fiber cable system through which the responsible organizations are connected to the data base.

2. *PROJECT COSTS AND FINANCIAL PLAN*

The total project cost is estimated at USD 36 million. The breakdown is shown in Table4.

Table 4 Project Costs

Item	Amount (thousand USD)
Direct Construction Cost	25,020
Engineering Service Cost	3,615
Contingency	6,332
Compensation Cost	473
Administration Cost	1,251
Grand Total	36,691

From the table above, compensation cost and administration cost are not covered by foreign loan or grant. Therefor, the total project cost subject to loan or grant is USD 35.0 million. Remaining USD 1.7 million should be prepared by Honduran government.

3. *PROJECT EVALUATION*

The EIRR=13.44% and the total project cost is USD 37 million, thus the project is economically and financially feasible.

Ten houses are to be relocated for the implementation of Reparto landslide prevention works but those houses are located in the dangerous area. Thus, it was judged that the house relocation compensation is possible because relocation would give them safer place to live.

Environmental Impact Assessment was made and influenced factors were selected and it was judged that all items could be dealt with by mitigation measures in the implementation stage.

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ABBREVIATIONS

AMDC	: Municipality of the Central District
COPECO	: National Emergency Committee
CODEM-DC	: Municipality emergency committee of central district
COHDEFOR	: Honduran Corporation of Forest Development
DECA	: Directorate of Environmental Evaluation and Control
EIA	: Environmental Impact Assessment
F/S	: Feasibility Study
GDP	: Gross Domestic Product
IDB	: Inter-American Development Bank
JICA	: Japan International Cooperation Agency
M/P	: Master Plan
SANAA	: National Service Authority for Water Supply and Sewerage
SERNA	: Ministry of Natural Resources and Environment
SETCO	: Ministry of International Cooperation
SOPTRAVI	: Ministry of Public Works, Transport and Housing
UNDP	: United Nations Development Program
USAID	: United States Agency for International Development
USGS	: United States Geological Service

Chapter 1
Introduction

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Tegucigalpa, the capital city of Honduras, already challenged by unfavorable natural conditions in terms of flood and landslide, has become more vulnerable against natural disasters because of uncontrolled urban development.

In October 1998, Hurricane Mitch lashed across the whole of Central America, leaving Honduras as the country most devastated by the attack. In the aftermath, over 13,000 casualties were reported across the country, and in Tegucigalpa alone, one thousand people were either dead or missing.

After Hurricane Mitch, a large number of foreign countries and international organizations provided the country with various assistance. The Honduran Government has been working hard to recover from the damage wreaked by the hurricane even until now. Sadly, serious disaster problems remain. The mal capacity of the Choluteca River in Tegucigalpa has not been improved at all. Nothing has been done about the landslide areas and many houses are still at high risk.

However, it is impossible nor appropriate to solve all the flood and landslide problems in Tegucigalpa with only structural measures such as river improvement or landslide prevention works, because of budget constraints and other limitations. Consequently, an integrated disaster prevention master plan composed of structural and non-structural measures is urgently needed.

1.2 OBJECTIVES OF THE STUDY

The objectives of the Study are:

(1) To formulate a master plan for flood damage mitigation and landslide damage mitigation in the Tegucigalpa Metropolitan Area of the Republic of Honduras,

(2) To conduct a feasibility study on the urgent and priority project(s), and

(3) To transfer technology to the counterpart personnel of participating agencies such as Ministry of Public Works, Transport and Housing (SOPTRAVI), Ministry of International Cooperation (SETCO), National Emergency Committee (COPECO), National Service Authority for Water Supply and Sewerage (SANAA), Ministry of Natural Resources and Environment (SERNA) and Municipality of the Central District (AMDC) in the course of the Study.

1.3 STUDY AREA

The Study Area covers the Choluteca River basin upstream from point A as shown in *Figure 1.1*. The Target Area for Disaster Prevention covers the Tegucigalpa Metropolitan Area as shown in *Figure 1.2*.

1.4 STUDY ORGANIZATION

The Study was conducted under the following organizational scheme:

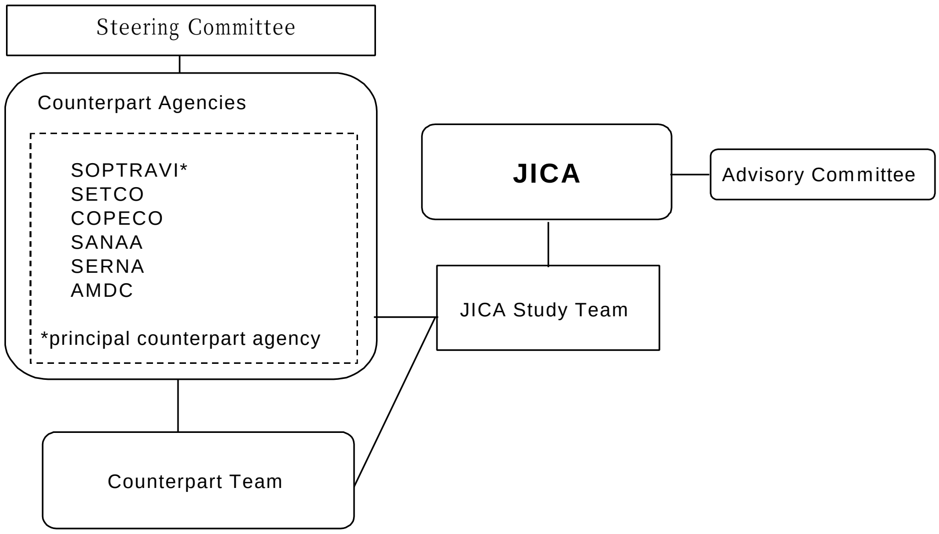

Figure 1.3 Study Organization

The Study Team is composed of the following sixteen (16) members:

Name	Task
- Mr. Mitsuo MIURA	- Team Leader/Disaster Prevention Planning
- Dr. Kozo TAKAHASHI	- Landslide Prevention
- Mr. Takuro TERASHIMA	- Flood Control
- Dr. Chaisak SRIPADUNGTHAM	- Hydrology/Hydraulics
- Mr. Kaoru NAKAZATO	- Landslide Topography/Geology
- Mr. Hiroshi TANAKA	- Land Use Planning
- Dr. Valerio GUTIERREZ	- Watershed Management
- Mr. Kazuhiro ISHIZUKA	- Geodetic Survey
- Mr. Kouji OOIKE	- GIS (1)
- Mr. Takahiro GOTO	- Facilities Design/Cost Estimate
- Mr. Ryo MATSUMARU	- Socioeconomy/Project Evaluation
- Dr. Somasundaram JAYAMOHAN	- Environment
- Mr. Yoshiaki KANEKO	- Organization/Institution
- Mr. Hideo SAKURABA	- Interpreter
- Mr. Yoshitaka ISHIKAWA	- Interpreter
- Mr. Kenji MORITA	- Study Coordination/GIS (2)

The Advisory Committee consists of three (3) members as follows:

- Mr. Katsushige MASUKURA	- Chairman of the Committee
- Mr. Hidetomi OI	- Committee Member
- Mr. Yasuo ISHII	- Committee Member

The government of Honduras has organized a counterpart team consisting of the following members:

Name	Organization
- Mr. Martin Perez	- SOPTRAVI
- Ms. Rosa Maria Bonilla	- SOPTRAVI
- Mr. Gustavo Suazo	- SOPTRAVI
- Mr. Marcio Fiqueroa	- SOPTRAVI
- Mr. Rafael Alduvin	- SETCO
- Mr. Mario Aguilera	- COPECO
- Ms. Martha Flores	- COPECO
- Mr. Rodolfo Ochoa	- SANAA
- Ms. Miriam Narvaez	- SANAA
- Ms. Gladis Rojas	- SANAA
- Mr. Adrian E. Oviedo	- SERNA
- Mr. Hector Fonseca	- AMDC
- Mr. Carlos Gutierrez	- AMDC

The Steering Committee was established with the following members:

Name	Organization
- Ms. Yasmina Deras	- SOPTRAVI
- Ms. Juana Elisa Granados	- SOPTRAVI
- Ms. Nora Derez Suazo	- SOPTRAVI
- Mr. Martin Perez	- SOPTRAVI
- Mr. Yolanda Madrid	- SETCO
- Mr. Hugo Arevalo	- COPECO
- Mr. Marcio Rodriguez	- SANAA
- Mr. Kenneth Rivera	- SERNA
- Mr. Mario Castañeda	- SERNA
- Mr. Rafael Trimino	- AMDC

1.5 STUDY SCHEDULE

The time schedule of the Study is shown in *Figure 1.4* together with the staffing schedule.

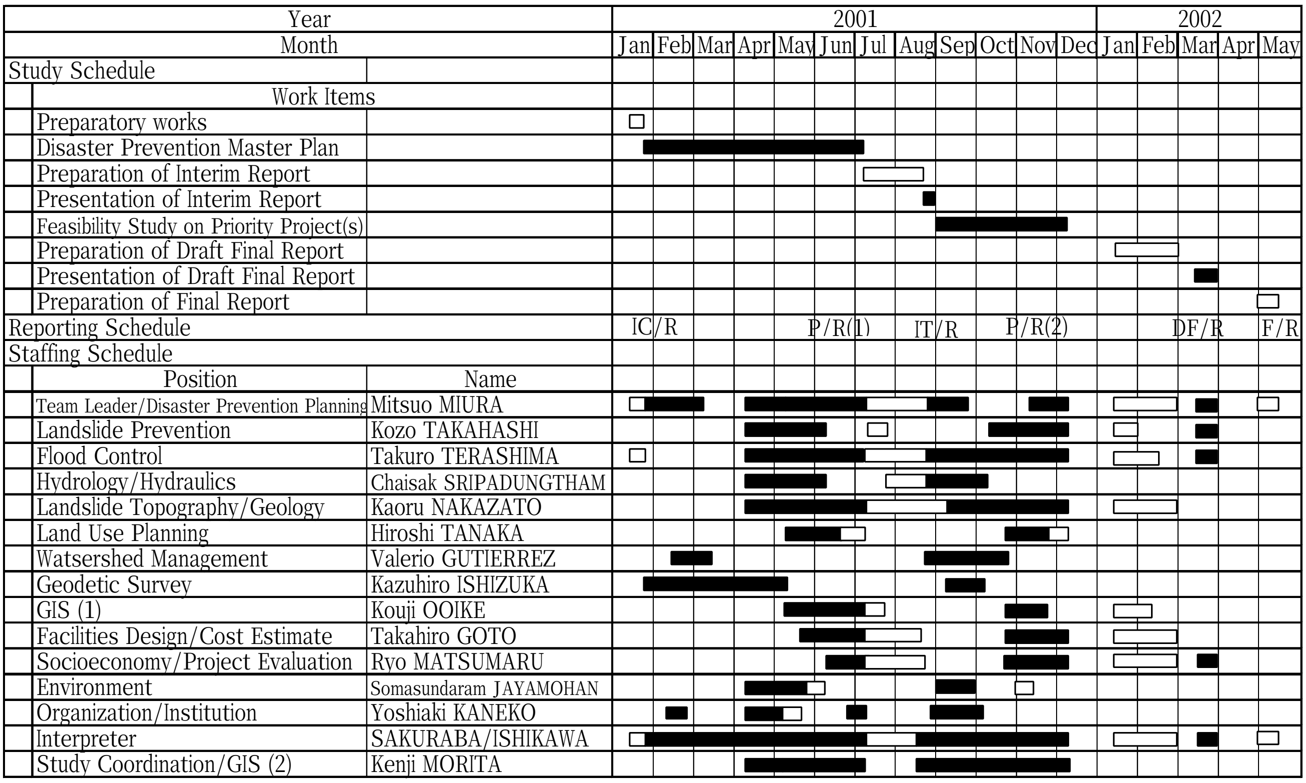

Figure 1.4 Study Schedule

1.6 COMPOSITION OF THE REPORT

The Final Report is composed of the following components:

<u>Main Report</u>

The main report contains all the Study results including the Master Plan and the result of the Feasibility Study of the Priority Projects.

<u>Supporting Report</u>

Each field of the study is accounted in detail in seventeen (17) supporting documents as follows:

- Supporting A Aerial Photo Mapping/River and Ground Survey
- Supporting B Geological Survey
- Supporting C Hydrological/Hydraulic Analysis
- Supporting D River Bed Material Survey
- Supporting E Environmental Consideration
- Supporting F Flood Damage Mitigation Plan
- Supporting G Landslide Damage Mitigation Plan

- Supporting H Hazard Map and Risk Map by GIS
- Supporting I Watershed Management
- Supporting J Land Use Plan
- Supporting K Facility Planning/Cost Estimate
- Supporting L Organizational/Institutional Consideration
- Supporting M Participatory Workshop
- Supporting N Flood/Landslide Damage Survey
- Supporting O Economic/Financial Analysis
- Supporting P Education/Enlightenment and Training Plan
- Supporting Q Disaster Management Information System

Data Book

The Data Book contains the data related to the Study.

GIS Operation Manual

The GIS Operation Manual contains the instruction to handle the GIS data base created in the Study.

Maps

The Maps contain seven important maps created in the Study.

Summary

This report captures the essence of the Main Report in a compact form.

1.7 HOME PAGE OF THE STUDY

A home page of the Study was created and put up in the web-site. The home page was transferred to SOPTRAVI for future utilization for disaster prevention and maintenance of the site. The address of the home page is as follows;

URL:http://www.hondutel.hn/jica/index.html

Chapter 2
Existing Conditions

CHAPTER 2 EXISTING CONDITIONS

2.1 NATURAL CONDITIONS

2.1.1 TOPOGRAPHY AND GEOLOGY OF THE STUDY AREA

The Study Area is located in the upper basin of the Choluteca River and in a mountainous area with the altitude between 900 m and 2,200 m.(*Figure 1.1*) The area is approximately 820 km^2 and divided into the sub-basins of the Choluteca River, namely, the Guacerique River basin, the Grande River basin, the San Jose River basin and the Chiquito River basin.

The geology in and around the Study Area is roughly divided into the Valle de Angeles Group in Cretaceous Period, the Matagalpa Formation in Paleogene Period, the Padre Miguel Group in Tertiary Period and Quaternary volcanic rock and other deposit. Basalt lavas of early Quaternary period exist covering Padre Miguel Group and Matagalpa Formation. *Figure 2.1* shows the geological map of the Study Area.

2.1.2 TOPOGRAPHY AND GEOLOGY OF THE TARGET AREA FOR DISASTER PREVENTION

The Target Area for disaster prevention is Tegucigalpa urban area, as shown in *Figure 1.2*. The total area is 105 km^2 and the elevation is between 900 m and 1,400 m. The area has a basin topography composed of hills and valleys of the Choluteca River and its tributaries. *Figure 2.2* shows the topography of the Target Area for Disaster Prevention.

The geology of the Target Area for Disaster Prevention is also composed of the Valle de Angeles Group in Cretaceous Period, the Matagalpa Formation in Paleogene Period, the Padre Miguel Group in Tertiary Period and Quaternary volcanic deposit. The stratigraphy of the Target Area is shown in *Table 2.1*. *Table 2.1* was prepared through a detailed field survey in this area. The results of the geological field study were compiled as a complete geological map with the scale 1/10,000. *Figure 2.3* shows the geological map of the Target Area.

2.1.3 HYDROLOGY

The annual rainfall amount in the area varies between 800 mm and 1,500 mm and the area average is 1,000 mm/year. *Figure 2.4* shows the isohyetal map of the area. According to the figure, rainfall amount is as large as 1,200 mm to 1,400 mm in the basin of the Guacerique River, the Grande River and in the La Tigra Mountains. On the other hand, rainfall amount in the area of southeast; the basins of the Sabacuante River and the Las Canoas River are as small as 850 mm. The annual evaporation estimated by the annual rainfall amount and the annual run-off is 800 mm.

2.1.4 NATURAL ENVIRONMENT

The riverine environment of Tegucigalpa is severely deteriorated. The rivers in the city are essentially black in color and emanate offensive odor.

The rivers of the city, similar to those of other Latin American cities, serve as open sewers for the discharging of untreated wastewaters resulting from all types of urban uses of domestic, institutional, commercial and industrial origin. Also, this continued disposal of untreated wastewaters in the rivers has resulted in the pollution of riverbeds with the surface of riverbeds being virtually formed with wastewater sludge rather than natural soil, in particular, in those river reaches with low flow velocity. In effect the rivers in the city are essentially ecologically dead with no beneficial uses other than as open sewers for the discharge of untreated wastewaters.

Because of these deteriorated environments, fauna and flora in and along the Choluteca River are poor in the Target Area for disaster prevention.

2.2 SOCIOECONOMIC CONDITIONS

2.2.1 GENERAL

The Republic of Honduras is located in the Central American region, and is bounded by the Republic of Guatemala on the West, El Salvador on the South and Nicaragua on the East and Southeast. It has a territorial extension of 112,492 km^2 and a population of approximately 6 million. It is a developing country with agriculture as its economic base. It has one of the lowest Gross Domestic Products (GDP) in Central America. Its major export products are bananas, coffee, and lumber. These agricultural based industries employ over 60% of the common workers and provide 80% of its export.

2.2.2 POPULATION OF TEGUCIGALPA METROPOLITAN AREA

The latest reliable estimated population has been presented in the project titled “The Study on Water Supply System for Tegucigalpa Urban Area,” (hereinafter referred to as "the Water Supply Study"), which was conducted by JICA in 2000. The Water Supply Study has estimated the present population of Tegucigalpa as 932,000, based on the number of households given by the pre-census 2000, which DGEC prepared for the Census 2000, and the average size of households given by the Permanent Multiple Purpose Questionnaire Survey of Families (EPHPM) conducted by DGEC in March 1999.

2.2.3 GDP AND OTHER ECONOMIC INDICATORS

Table 2.2 shows the GDP of Honduras in the last ten years.

Table 2.2 GDP of Honduras

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
GDP (million US$)	3,091	3,191	3,371	3,581	3,534	3,678	3,811	4,004	4,122	4,044
GDP per Cap (US$)	633.5	634.7	650.7	671.1	643.3	650.6	655.3	669.5	670.5	640.3

Source: IDB WEB site, www.iadb.org/int/sta/ENGLISH/brptnet/english/hndbrpt.htm

For the city of Tegucigalpa, the regional GDP per capita reached almost $900 in 2000 while the amount of national GDP was less than $650.

Since the government of Honduras could not cover the whole cost to manage and to develop the country by their income tax revenue, it is necessary to bring in the external finance source to the country. *Table 2.3* shows the situation concerning external debts

Table 2.3 External Debts

Unit: million USD

Year	1991	1992	1993	1994	1995	1996	1997	1998
Total debts	3,396	3,614	4,077	4,436	4,570	4,533	4,710	5,002
Bilateral public loan	1,089	1,163	1,307	1,470	1,455	1,412	1,368	1,404
Multilateral public loan	1,658	1,801	1,952	2,062	2,153	2,109	2,312	2,379
Total debt service	307	377	361	433	553	564	505	505
Debt service for bilateral loan	55	68	73	82	135	69	106	108
Debt service for multilateral loan	186	229	214	262	262	336	219	211

Source: IDB WEB site, www.iadb.org/int/sta/ENGLISH/brptnet/english/hndbrpt.htm

The Honduran economy has been suffering from a severe inflation like other Latin American countries. The average annual inflation rate during the 1990s was 19.0 % yearly.

2.2.4 LAND USE

(1) Land Use in the Study Area

The land use map of the Study Area was made in 1983 as a part of the study on soil property and vegetation features of the Department of Morazan. Based on this land use map and also on the aerial photo in March 1999, the present land use map of the Study Area of 820 km^2 was prepared as shown in *Figure 2.5.* In the map, the portion of the urban area was revised based on the land use data obtained from the orthophoto prepared in the Study. *Table 2.4* shows the land use of the Study Area.

Table 2.4 Present Land Use in the Study Area

Land use category	The Study Area	
	Unit: ha.	Ratio
Forest & Shrubs	37,534.2	45.80%
Bush Lands	13,152.7	16.05%
Pasture & Grass Lands	18,566.2	22.65%
Agriculture Lands	4734.0	5.77%
Water Bodies	290.3	0.35%
High Density Urbanized Area	6,140.7	7.49%
Settlement Areas	1,488.7	1.82%
Airport	59.0	0.07%
Total	81,965.8	100.00%

(2) Land Use in the Target Area

The present land use of the Target Area for disaster prevention was investigated based on the orthophoto with the scale of 1/10,000 taken in February 2001 and the topographic map with the scale 1/5,000 created from the orthophoto.

Figure 2.6 shows the present land use of the Target Area for disaster prevention. *Figure 2.7* shows the distribution of the built-up area in the Target Area for disaster prevention. *Table 2.5* shows the present land use of the Target Area for disaster prevention.

Table 2.5 Present Land Use of the Target Area

Land Use category	Area (ha)	Ratio
Commercial	310.1	3.0%
Protocol & Business Area	27.8	0.3%
Public Facility	157.0	1.5%
Residential: R-1 to R-5	2,880.7	27.4%
Industrial Area	121.5	1.2%
Military Facility	132.7	1.3%
Airport	59.0	0.6%
Roads & Streets	1,940.5	18.5%
Park & Green Area	201.8	1.9%
Cemetery	25.5	0.2%
Sports Field	51.9	0.5%
Forest & Shrubs	973.5	9.3%
River Reserve Area	389.5	3.7%
Reservoir	46.3	0.4%
Vacant Space	3,178.3	30.3%
Total	10,496.0	100.0%

Residential area by classification	Area (ha)	Ratio
R-1: Residential 250 pers. / ha	1,876.2	65.1%
R-2: Residential 400 pers. / ha	643.4	22.3%
R-3: Residential 500 pers. / ha	179.1	6.2%
R-4: Residential 800 pers. / ha	147.2	5.1%
R-5: Residential >800 pers. / ha	34.8	1.2%
Total	2,880.7	100.0%

Note: Residential classification is applied to on-going planning criteria by the Metroplan of the Municipality

Note: The threshold values were determined through discussion with Metroplan of the municipal office.

2.2.5 HISTORICAL DISTRICT

The cities of Tegucigalpa and Comayaguela have a great number of buildings with historical value, architecture and landscape declared as National Monuments according to the municipal agreement in April 1977. In April 1994, the Municipal Mayor's Office of the Central District and the Honduran Institute of Anthropology and History signed an agreement for the "Conservation of the Historical Area of Tegucigalpa/Comayaguela and Neighboring Areas" as shown in *Figure 2.8*.

2.3 RIVER CONDITION

2.3.1 WATERSHED

As the consequence of the urban expansion of Tegucigalpa, there has been a continuous deforestation in areas for housing, industries or other facilities. The forest has been cut-off to fulfill the need of firewood in zones near the urban areas.

Another factor that urban expansion contributes to erosion is the many forest fires that are generated every dry season. According to the Anuario Estadístico Forestal, 1997, most of them (54%) are produced by arsonists (*incendiarios*), and in less degree by agricultural or livestock activities. Forest fires leave the topsoil without vegetative cover, making it prone to erosion.

In the Study, the erosion characteristics of the soil were estimated using the Universal Soil Loss Equation (USLE). The Study Area was divided into 27 micro-basins and USLE was applied for each micro-basin to assess the soil erosion distribution. (Refer to Supporting I) *Figure 2.9* shows the distribution of potential erosion in the Study Area. It can be observed that there are six (6) micro-basins classified as having heavy potential erosion. Therefore, the remaining ones correspond to moderate and slight potential erosion. The average sediment yield of the whole Study Area is 0.4 mm/year and according to this estimation, the degree of soil erosion of the basin is not so serious.

2.3.2 River Features

The Choluteca River originates in Tegucigalpa City and flows toward north. It turns the course toward south in the middle/lower reaches and finally flows into the Gulf of Fonseca in the Pacific Ocean. Its total length is 320 km and the catchment is 7,465 km^2.

The upper reach of the Choluteca River in the Target Area flows down from south to north in Tegucigalpa City. The main trunk of the Choluteca River is called Grande in its upper reach and is joined by its tributaries such as the San Jose, the Guacerique, the Chiquito, the Sapo and the Cacao Rivers. *Figure 2.10* shows the Choluteca River in the Target Area with the river survey milestone numbers.

2.3.3 River Capacity

Figure 2.11 presents the width of the present river. It shows that at 4.8 km and 4.9 km from point A, the river width is very small compared to the other portion of the river. These two points correspond to the river course near the Berrinche landslide where the landslide mass is intruding into the river course and narrowing the width. Except these two points, the width of the river is wide enough compared to the design width described later.

Figure 2.12 shows the profile of the present river. It shows that the original river has a rather uniform profile with the slope of 1/190 to 1/250.

Figure 2.13 depicts the discharge capacity of each section of the river calculated by a non-uniform flow model. It shows that the river capacity is comparatively small between 3 to 10 km from point A. Especially, at C48 and C49, the discharge capacity is 300 m^3/s and its return period is less than one year. If this is compared with *Figure 2.11*, it is understood that the mal-capacity of the river is not because of the narrow width of the channel but because of the sediment of the river, except C48 and C49, where the Berrinche landslide is intruding into the river.

Therefore, two main causes of the mal-capacity of the Choluteca River are:

- Narrow channel at Berrinche (5 km from point A, C48-C50); and
- Sediment between 3 km and 10 km from point A (C30-C100).

2.3.4 Capacity of Small Tributaries

The Sapo River and the Bambu River join the Choluteca River and the Chiquito River by pipe channel respectively. The sediment in the Choluteca and the Chiquito Rivers made the outlet of the pipe channel small, impeding the capacity of those tributaries.

2.3.5 Rainfall by Hurricane Mitch

There is only one rainfall station in the area where the hourly rainfall data during Hurricane Mitch was obtained. It is the Toncontin rainfall station. *Figure 2.14* shows the hourly rainfall observed at the Toncontin Station. The total amount of rainfall by the storm is 250 mm.

The return period analysis at Toncontin station is shown in *Figure 2.15*. According to the figure, the return period of the rainfall by Hurricane Mitch is around 500 years.

2.3.6 FLOOD BY HURRICANE MITCH

The result of the high water mark survey is shown in *Figure 2.16*.

The USGS conducted a preliminary flood condition and damage survey after Hurricane Mitch struck in 1998. The sequence of flood damage was as follows:

Table 2.6 Flood Condition and Damage during Hurricane Mitch

Date	Time	Condition and Damage
October 30	22:45	Spillway of the Los Laureles dam overflowed
October 30	23:00	Pescado Lake collapsed
October 30	22:00 – 24:00	Severe erosion and landslide occurred at El Country Bridge
October 30 - 31	23:00 – 6:00	Outflow was at peak at the Concepcion Dam
October 30	24:00	Flood at peak in the Chiquito River
October 30 - 31	24:00 – 1:00	Landslide occurred in many locations
October 31	1:00	Flow at Chile Bridge at peak
October 31	Morning	Landslide at Berinche occurred

Source: "Survey Response to the Hurricane in Honduras in 1998" by USGS

In the Study, interviews were made to the residents regarding the time of the peak flood discharge at Mallol Bridge. It was found out that the highest water level there appeared between 24:00 on October 30th and 1:00 on October 31st, while the closure of the Choluteca River by Berrinche landslide occurred at the daybreak of October 31st. By this observation, it was found out that the water level rising caused by Berrinche landslide was lower than the maximum water level throughout the flood phenomenon.

2.3.7 FLOOD SIMULATION OF HURRICANE MITCH

A mathematical model of the present Choluteca River was constructed and the inundation phenomenon during Hurricane Mitch was simulated. The model procedure is explained in Chapter 4 and the details are in Supporting C.

Figures 2.17 and *2.18* show a comparison between the hydraulic model simulation and the result of the inundation survey. *Figure 2.17* is the highest water level distribution along the river and *Figure 2.18* shows the inundation area.

Through the simulation, the following two points have become clear:

- The natural dam break at the outlet of the Pescado Lake affected up to C150 (Loarque).
- The inundation elevation at the center of the city after the closure of the Choluteca River by the Berrinche landslide was lower than the peak water level before the landslide.

2.3.8 FLOOD HAZARD MAP DURING HURRICANE MITCH

Figure 2.19 is the hazard map showing the inundation area by a flood with a scale of Hurricane Mitch. The total area of the inundation is approximately 2 km^2. The total number of households in those inundation areas is approximately 3,000 and the number of residents is estimated at 15,000.

2.3.9 SEDIMENT TRANSPORT IN THE RIVERS

The sediment transport capacity was calculated along the river taking the present configuration of the river into consideration. The capacity was evaluated by the sediment transport capacity of the annual maximum discharge, 1,000 m^3/s and the sediment model with diameter of d_{60}=30 mm. The calculation result is shown in *Figure 2.20*. It shows that in the present river, the sediment transport capacity is low in the upstream of Berrinche area (C50 – C55) because of low energy gradient of the river.

2.4 LANDSLIDE

In Japan, the disaster caused by the movement of earth is classified into three categories, namely "landslide", "slope failure" and "debris flow" and the same classification was applied in this Study. In "landslide" generally, the movement is slow (less than 1 cm/minute) and the movement last long or the movement repeat itself. On the other hand, in "slope failure", the movement velocity is more than 1 m/second and the movement lasts only one hour or less. There are also differences in the scale of the movement and the slope gradient of the original slopes between them.

Vanes(1978) classified slope movements into "Topple", "Slide", "Spread", "Fall" and "Flow". The classification in Japan focuses on the damage degree by the scale and the movement velocity of the land mass and it is not necessarily possible to compare with the classification by Vanes. However, the "landslide" in the Study roughly corresponds to "Slide" by Vanes. The "slope failure" in the Study roughly corresponds to small scale "Slide" and "Fall" by Vanes.

In the target area of disaster prevention in the Study, most earth disasters are "landslide" and "slope failure" with few examples of "debris flow". Therefore, only "landslide" and "slope failure" are studied here.

2.4.1 LANDSLIDE PROBLEMS IN THE AREA

(1) Landslides during Hurricane Mitch

USGS has analyzed the actual landslides caused by Hurricane Mitch based on the aerial photos taken in March 1999. It is a rather accurate data as the photos were taken soon after the disaster and the scars were still fresh. The location map of landslides during Hurricane Mitch is shown in *Figure 2.21(1)*.

(2) Aerial Photography Interpretation and Identification of Landslide Blocks

The aerial photography with the scale of 1/10,000 was scrutinized together with the orthophoto to interpret the topographic features of landslide. The typical landslide topographic features were identified and designated as susceptible landslide blocks. *Table 2.7* shows classification of the degree of landslide danger. *Figure 2.22* shows the distribution of landslide masses with each danger rank.

In the figure, many landslide masses distribute in the north of the area. *Figure 2.23* shows the northern part of the area in a larger scale and with the distribution of lineaments. Lineaments means the linear structure observed in a topographic map or an aerial photo. It often represents fault or geological weakness. This figure shows that prominent landslides such as Berrinche, Campo Cielo, San Martin and Bambu lie on the lineament structure and it is known that faults and fractured zone are triggering landslides.

(3) Affected Area by a Landslide

When making a hazard map of landslide, it is necessary to identify the affected area for each landslide mass. The affected area means the area where a part of the landslide mass caused by the landslide may reach and destroy houses and infrastructures.

The affected area for each landslide mass were estimated taking into account the configuration of the landslide mass and the surrounding topography. (Refer to Supporting B)

As the estimation of the affected area is based on experiences in Japan, it is necessary to accumulated more data and improve the accuracy of estimation in future.

In the hazard map of the landslide, the affected areas were indicated as well as the landslide masses themselves, which are considered as dangerous areas.

2.4.2 SLOPE FAILURE PROBLEMS IN THE AREA

(1) Slope Failures during Hurricane Mitch

USGS has analyzed the actual slope failures caused by Hurricane Mitch based on the aerial photos taken in March 1999. The location map of slope failures during Hurricane Mitch is shown in *Figure 2.21(2).*

(2) Identification of Slope Failure Dangerous Area

The slope failure phenomenon in the Target Area was studied in terms of the gradient of the slope and the geological features of the slope. *Figures 2.24* and *2.25* show their respective classification. The threshold values of slope failure danger were set for each geological classification. *Table 2.8* shows the threshold value to judge danger of slope failure. The affected area by the slope failure was also estimated from the analysis of actual slope failure example and the extent of the affected area.

The above two categories of slope failure danger, namely, “dangerous slope” and “the affected area by a slope failure” are all indicated in the hazard map of slope failure.

2.4.3 HAZARD MAP OF LANDSLIDE AND HAZARD MAP OF SLOPE FAILURE

The hazard map of landslide and the hazard map of slope Failures are shown in *Figure 2.26(1) and 2.26(2)* respectively. In the landslide hazard map, all the landslide masses with the grade of A, B and C together with the affected areas are indicated. The total area of Rank A landslide and the affected area is 1 km^2 and occupies 1% of the whole Target Area. The total number of households in Rank A landslide is 1,500 and the number of people affected is estimated at 7,500.

As for slope failures, “dangerous slope” and “the affected area by a slope failure” are shown in *Figure 2.26(2).* The area covered by these two categories is 26 km^2 and occupies 25 %of the whole Target Area. The total number of households in those two categories is 25,000 and the number of people affected is estimated at 125,000.

2.5 ORGANIZATION

There is a substantial number of government agencies and other institutions involved or concerned with or to undertake activities in the disaster prevention sector. The degree of their involvement, the extent of their participation and the nature of their activities vary from one agency to the other.

The National Emergency Committee (COPECO) was created in 1991 for the natural disaster prevention at national, regional and municipal levels.

Municipality Emergency Commission of Tegucigalpa under COPECO was established in 1998 just few months before Hurricane Mitch. During Hurricane Mitch, even though there existed these organizations for disaster prevention, still there was much damage.

The natural disaster prevention works in Tegucigalpa was under jurisdiction of Municipality of the Central District. After Hurricane Mitch, SOPTRAVI and SERNA are put in charge of flood mitigation and landslide prevention in Tegucigalpa. However, the demarcation of jurisdiction for these sectors (flood mitigation, sediment control or landslide prevention) is not clear.

For disaster prevention including preventive measures, emergency operation and rehabilitation in Tegucigalpa, many agencies are concerned. Among them are SOPTRAVI, SERNA, SANAA, COHDEFOR, COPECO, CODEM, AMDC, and SETCO.

2.6 RELEVANT LAWS AND DECREES

The following laws of Honduras and decrees of Municipality concern disaster prevention. The details are described in Supporting L.

- Law of Contingencies (December 1990)
- Law of Municipalities (November 1990)
- Temporary Law for Uninhabitable Areas (December 1998)
- General Law of the Environment (June 1993)
- Law of National Waters Exploitation (1927)
- Forestry Law (1972)
- Law of Territory Ordinance (draft)
- By-Laws of Zoning, Urbanizing, Lots Division and Construction (1992)
- Decree on River Reserve Area (1997)
- Expropriation Special Law (1999)

The most important regulation of the Municipality is the Decree on River Reserve Area in 1997. According to the decree, 100 m width of the Choluteca, the Guacerique, the Chiquito, the San Jose and the Las Canoas Rivers are designated as the river reserve area and no structure is allowed.

2.7 DISASTER BY HURRICANE MITCH

2.7.1 DAMAGE BY HURRICANE MITCH

(1) Damages to Whole Country

In October 1998, Hurricane Mitch attacked the whole country and caused the worst damage by a hurricane to the country. The human toll has been reported at 5,657 deaths, 8,058 missing, 12,272 injured and a total of 1.5 million people (of the 6 million total population) affected (evacuated). United Nations' ECLAC estimated material losses at around US$3.6 billion, of which US$2.05 billion affected productive sectors while the rest represents damage to social infrastructure (US$ 1.02 billion) and economic infrastructure (US$ 0.51 billion).

With the effort on the mitigation of disaster by the government and other donor agencies, the evacuated people of 1.5 million have been reduced to 700,000 soon after the disaster and 285,000 of them were remained in provisional shelters until the end of November 1998. Most of the refugees in the shelters have already returned back home at present.

(2) Damages in Tegucigalpa

There is no complete information of the damages in Tegucigalpa City caused by Hurricane Mitch. However, according to the report prepared by the World Bank, about 40% of the capital was damaged, half of its 1 million inhabitants were affected, and the city was cut off from the rest of the country for almost a week.

Based on the damage amount of the whole country and national GDP and regional GDP of Tegucigalpa, the estimated damage of Tegucigalpa City caused by Hurricane Mitch would be between US$410 million～US$760 million.

(3) Flood/Landslide Damage Survey

A flood and landslide damage survey was conducted to comprehend the current flood/landslide conditions and assets in the hazardous area. The collected information was processed and used for estimating the damage caused by floods/landslides and the benefit derived from the project.

The surveys were carried out by the counterpart agencies of the Study through interviews with the habitants who are living in the possible flood and landslide area of the Study Area

2.7.2 SOCIO-ECONOMIC IMPACT OF HURRICANE MITCH

The economic estimates indicated that in 1999 the decline in GDP would be around 2.5%. The inflation rate was reaching 10% during the second half of the year, while the average rate at the whole year was 11.6%, down from 13.7% in 1998. In the year 1999, the economy was suffering from full impact of destruction over productive capacity and export.I It was also the year when major effort to reconstruct and transform the Honduran economy was launched with the cooperation of the international community of donors and development financial agencies.

2.8 PROJECT BY OTHER DONORS

There are many disaster-related projects by other donors on-going. Those are shown in *Table 2.9*.

2.9 DEFINITION OF PROBLEMS

From all the study on the present conditions, it is concluded that the problems on flood and landslide in the Target Area are defined as described below. The problems are simplified as shown in *Figure 2.*27.

2.9.1 FLOOD PROBLEMS

The problems of flood in the Target Area are summarized as follows:

- The two-day rainfall amount in Tegucigalpa during Hurricane Mitch has a return period of 500 years
- The inundation of the urban area during Hurricane Mitch was brought about by an abnormal rainfall with a return period of 500 years, but the present river capacity itself is less than the flood with a return period of 1 yearbetween C48 and C50 because Berrinche

landslide is squeezing the river course.

- The causes of mal capacity of the Choluteca River are:
  (1) narrow channel width at Berrinche landslide (C48-C50)
  (2) sediment in the river between C30 and C100
- The natural dam break of the Pescado Lake caused a significant impact on downstream flood,
- The flood along the Sapo River and the Bambu River were caused by the clogging of their pipe culvert outlets by sediment in the main river course and by garbage,
- The sediment transport capacity of the Choluteca River and the Chiquito River are comparatively uniform except between C50 and C55.
- The soil erosion from the whole basin is not so large, although deforestation is on-going in some sub-basins of the area.
- The number of households in the inundation area by a storm with the scale of Hurricane Mitch (2 km^2) is approximately 3,000 and the number of affected people is 15,000.

2.9.2 LANDSLIDE PROBLEMS

The problems of landslide in the Target Area are summarized as follows:

- The mountainous topography and complex geological structures make the area prone to landslides and slope failures triggered by a large amount of rainfall.
- Rank A landslide masses and their affected area (1 km^2) cover 1% of the whole Target Area and the number of households in it is 1,500.
- Slope failure danger area (26 km^2) covers 25% of the whole Target Area and the number of households in it is 25,000.

2.9.3 DAMAGE BY HURRICANE MITCH

The amount of damage and reconstruction cost brought about by Hurricane Mitch for the whole country are estimated at US$3,638.5 million and 4,987.7 million respectively. The damage in Tegucigalpa City caused by Hurricane Mitch would be estimated at between US$410 million～US$760 million.

2.9.4 ORGANIZATIONAL/INSTITUTIONAL ASPECTS OF THE PROBLEMS

There are various organizations involved in disaster prevention activity for the city of Tegucigalpa. However, according to the orientation of the recent organizational set-up of the Honduran Government, COPECO and CODEM are the key organizations for the integrated disaster prevention plan.

As for the legislations, there exist various laws and decrees that seem to be very relevant and important for comprehensive disaster prevention plan. The problem seems that those relevant laws and decrees are not implemented properly. One of the important reasons of it must be the lack of concrete data when those regulations are to be applied.

2.9.5 RELATED PROJECTS

There are many related projects completed or in their implementation stages. The disaster prevention master plan which is prepared in the Study should take into account the results and the interim results of all the related studies. It is also necessary to make a recommendation for the further study of results in those projects that are ongoing.

Chapter 3

Planning Basis

CHAPTER 3 PLANNING BASIS

3.1 CONCEPT OF THE PLAN

As analyzed in Chapter 2, the huge amount of damage and large number of human loss in the Target Area were brought about by Hurricane Mitch, intensified by conditions both natural and social. The unfavorable natural conditions are the abnormal rainfall amount, the river features, and the topographic and geological features of the area. The problematic social conditions are the uncontrolled development of the urban area into the dangerous areas of flood and landslide. According to the Study, the dangerous area defined in the Study occupies 29% of the whole Target Area. The number of people living in dangerous areas is over 150,000 and it is 16% of the total population. This is the reality of Tegucigalpa City.

However, it is impossible to solve the problem of the anticipated disaster completely by removing the houses in the dangerous area in a short time. It is also impossible to solve the problem completely by large-scale civil works to make all the present dangerous area safer.

Therefore, the goal of the plan is defined as follows:

- The damage caused by a disaster in the Target Area should be minimized and no human lives should be lost even by a storm with a scale of Hurricane Mitch.

And the strategy is:

- The above goal should be attained by an optimum combination of structural and non-structural measures.
- As a large scale resettlement of people from dangerous area is unrealistic, the main focuses of non-structural measures are prohibition of new house development in dangerous arrears and forecasting/warning/evacuation during emergencies.

3.2 TARGET YEAR

As this is a master plan, the target year should have a long range. However, the key factors for the target year, namely, population distribution and land use, cannot be projected for a long range because of lack of integrated regional development plan nor urban development plan covering the Target Area.

The latest population projection was made in the project titled “The Study on Water Supply System for Tegucigalpa Urban Area in the Republic of Honduras” (2001, JICA) for the year 2015. As this population projection is backed up with a comprehensive water supply master plan, it is reliable, considering that water supply is one of the most critical constraints on the population growth.

Therefore, the target year of the Master Plan was set as 2015 and the same population projection will be applied.

3.3 SOCIAL FRAMEWORK

As the basis of the planning, the social framework, that is, population in the target year, was set up. The total urban population in 2015 is estimated at 1,376,822.

The land use plan was created in the Master Plan from the viewpoint of disaster prevention in order to allocate the future population in the area properly.

3.4 ITEMS TO BE CONSIDERED IN THE MASTER PLAN

(1) Realistic Plan

It is necessary to make a realistic plan from the viewpoint of finance and social environment. The total project cost should be within the range, which will be set by the affordability of the central as well as the local government. A large-scale land acquisition or resettlement is impossible so that the structural measures should be planned to minimize the land acquisition and resettlement.

(2) Integration with the Related Projects

As there are many related projects on-going, the Master Plan should take into account all the information on those projects. Especially, the projects being carried out by USGS and the US Corp of Engineers are to be coordinated in the Master Plan.

Chapter 4

Master Plan

CHAPTER 4 MASTER PLAN

4.1 INTRODUCTION

The Master Plan for disaster prevention in Tegucigalpa metropolitan area is composed of three components, namely, flood damage mitigation measures, landslide damage mitigation measures and the common non-structural measures for flood/landslide damage mitigation.

Both the flood damage mitigation plan and the landslide damage mitigation plan were made through mechanism analysis of both disasters. The alternative solutions of both structural and non-structural were studied in order to solve the problems.

Structural measures were selected only when they are realistic considering the cost of civil works compared to the benefit, as well as the land acquisition and resettlement problems accompanying the civil works.

Non-structural measures were selected when they are more realistic than the structural measures considering the cost of structural measures, difficulties of land acquisition and resettlement for structural measures.

The proposed Master Plan Projects are shown in *Table 4.1* and the location map of the proposed Master Plan Projects (structural measures) is shown in *Figure 4.1*.

FLOOD DAMAGE MITIGATION PLAN

After understanding the flood mechanism, alternative study was made to select an appropriate choice of design flood for structural measures. Here design flood was selected taking into account the constraints of land acquisition and resettlement when the river had to be widened. River improvement works were planned to accommodate the design flood in the river course safely.

The hydraulic simulation was done again assuming the completion of the structural measures proposed and the inundation area was identified when a storm with a scale larger than the design flood comes. The non-structural measures were planned analyzing the inundation area along the river even after the completion of the structural measures proposed.

The watershed management plan was made through the erosion analysis of each sub-basin of the Study Area.

LANDSLIDE DAMAGE MITIGATION PLAN

The disasters caused by soil and rock movement are classified into “the landslide,” “the slope failure” and “the debris flow” in Japan. As “the landslide” and “the slope failure” are dominant in the Target Area, these two phenomena were taken up separately in the Study.

The number of houses to be relocated in order to implement structural measures for each rank A landslide was counted after assuming suitable structural measures. It was judged most landslide blocks except Berrinche, Reparto and Bambu are not appropriate to adopt structural measures, as the number of houses to be relocated for the civil work is comparatively large to the number of houses to be protected by the works. As for the slope failures, the number of dangerous spots is very large and the cost for structural measures to stop slope failures is comparatively large compared to the number of houses to be protected. Therefore, non-structural measures (land use regulation and forecasting/warning/evacuation) were adopted for slope failures.

4.2 FLOOD DAMAGE MITIGATION PLAN

4.2.1 ALTERNATIVE STUDY OF FLOOD CONTROL

(1) General

Alternative study of flood control plan was made. Alternative study was made for both the facility alternatives and the design discharge alternatives.

(2) Alternative Flood Control Facilities

For flood control purpose, not only the improvement of the river course but also flood water storage structure such as a retarding pond and a dam were taken into account. However, no proper location for a retarding pond was found. The idea of a dam was discarded because the candidate location of the dam is at the upper reach of the river and its catchment area is less than 10% of the whole catchment so that the flood control effect is small.

As the effect of the natural dam break at the outlet of the Pescado Lake was significant in the upper reach, the treatment of the outlet was included in the plan.

(3) Alternative Design Flood Discharges

The peak discharge of the flood during Hurricane Mitch at point A (the downstream end of the Study Area) is 4,000 m^3/s according to the run-off simulation. It is the maximum discharge record at the point. And it is known that the return period of two-day rainfall during Hurricane Mitch is approximately 500 years.

On the other hand, the bank-full capacity of the Choluteca River at point A is 2,000 - 3,000 m^3/s. Considering the built-up area along the Choluteca River in Centro and Comayaguela area, it is difficult to enlarge the river width in a large scale. Thus as peak flood discharge, five alternatives, namely, 1000, 1500, 2000, 2500 and 3000 m^3/s were selected for study.

The design flood distributions were prepared for each alternative based on the proportion of run-off simulation. *Figure 4.2* shows each design flood distribution.

(4) Design Profile of the Choluteca River

The longitudinal profile of the Choluteca River was designed based on the existing river profile. The planned riverbed slopes are 1/200, 1/250, 1/190 at 2.7-5.1 km, 5.1-11.4 km, 11.4-15.5 km respectively. The design profile is shown in *Figure 4.3*.

(5) Design Cross Sections of the Choluteca River

The design cross sections were planned to accommodate each design peak flood (1,000 m^3/s～3,000 m^3/s) taking into account the design profile set above and the design cross sections for each design peak flood discharge. The width of the channels for each case is as follows:

Table 4.2 Width of Channels

Reach	27-51	51-56	56-67	67-93
Discharge(m3/s)	River Width (m)			
1,000	35	36	32	24
1,500	48	49	45	32
2,000	61	63	56	39
2,500	73	76	68	47
3,000	86	89	80	54

(6) Planned Alignment of the Choluteca River

The design alignment of the Choluteca River followed the existing alignment of the river, except C48 and C49 (the river course adjacent to Berrinche landslide), where the river width is very narrow and the capacity of the channel is small. Between C48 and C49, the river course was planned to be shifted to the right hand side by fixing the left periphery of the river in order not to disturb the large landslide mass of Berrinche. (Refer to *Figure 4.4*)

(7) Selection of Design Flood Discharge

Five alternatives were compared in terms of return period, amount of civil works and land acquisition. *Table 4.3* shows the comparison of each alternative.

The problem of land acquisition was discussed with municipal authority which is in charge of the urban planning and it was concluded that alternatives 4 and 5 are quite difficult in terms of land acquisition. Thus alternative 3 with a peak discharge 2,000 m^3/s was selected as the design flood for the structural measures. The corresponding return period is 15 years.

Table 4.3 Comparison of Alternative Design Flood Discharge

No	Q (m3/s)	Return period (year)	Excavation (m3)	Land Acquisition	Overall Evaluation
1	1,000	1	320,000	Ready	
2	1,500	5	520,000	Ready	
3	2,000	15	750,000	Ready	X
4	2,500	35	920,000	Difficult	
5	3,000	80	1,420,000	Difficult	

4.2.2 RIVER IMPROVEMENT PLAN FOR THE CHOLUTECA RIVER

(1) General

River improvement plan for the Choluteca River is composed of the following items:

- Riverbed excavation L= 7 km, V=750,000 m^3
- River widening L= 200 m (with concrete shaft)
- Revetment construction L= 9 km
- Dike construction L= 3 km
- Bridge reconstruction 1 bridge

Each item is explained below.

(2) Riverbed Excavation

Excavation was planned to obtain the required river cross section and required river profile.

However, the lower reach of the river between C 0 and C 27 (approximately 3 km) was eliminated from this operation as there is no house or agricultural land to be protected in the area. Thus the riverbed excavation is planned between C 27 and C 93. The total length of the river for the operation is approximately 7 km and the total excavation volume is 750,000 m^3, of which 40,000 m^3 is rock excavation.

The excavated material was planned to be hauled to downstream of the river and to be filled up along the Choluteca River. At that location, the river has a wide valley and the pile of soil will not give any adverse effect on the flood upstream.

(3) River Widening at Berrinche

The only place where river widening is required is the neighborhood of Berrinche landslide. The required width to accommodate the design flood is 61 m and additional 40 m of widening is necessary. The total length of river widening along the river is approximately 200 m and the excavation volume is 50,000 m^3.

Landslide prevention works were proposed in order not to destabilize Berrinche landslide block in the operation of river excavation. This landslide prevention works target the small scale landslide blocks along the river. (Refer to 4.3.3) In this Master Plan Project, counterweight fill (C45-C46.5) and shaft works (C46.5-C50) were planned to prevent the destabilization of the left bank of the Choluteca River. The diameter of the concrete shaft is4.0 m and the average length of the shaft is 16 m. The concrete shaft is planned to be constructed with an interval along the river by 400 m and the total number of shafts is52. The volume of the counterweight fill is 40,000 m^3. The layout of the structures is shown in *Figure 4.5*.

The right side of the river is planned to be protected by a vertical wall with earth anchors in order to minimize the area of land acquisition.

(4) Revetment

Revetments along the river are needed to stabilize the bank against erosion and prevent further intrusion of houses into the river area. The revetment structure is planned as stonemasonry as it is a common practice in Tegucigalpa. The height of the structure is 8 m. Total length of the structure along the river is 9 km.

(5) Dike

According to the hydraulic simulation, there are some parts along the river where the inland elevation is low and it is necessary to protect it by dike construction. The proposed structure is concrete parapet walls along the river by a length of 3km.

(6) Bridge Replacement

As the existing Mallol Bridge is hampering the flood flow because of its bulky structure, it was planned to reconstruct it and make the structure so that the flood discharges at the point smoothly. The layout of the existing bridge and the proposed new bridge is shown in *Figure 4.6*. The proposed new type was taken from the Carias Bridge, which is located downstream from the Mallo Bridge.

This idea was discussed in the counterpart meeting as well as in the steering committee and with the Honduran Institute of Anthropology and History. The idea of the bridge reconstruction was agreed upon but it was concluded that the new type of the bridge should be discussed further in the later stage of the project, probably in the feasibility stage when the environmental impact assessment is done.

4.2.3 Sediment Control Plan

(1) Erosion Control Plan (Watershed Management)

If the soil erosion in the watershed prevails and the amount of sediment into the river increases, the inflow and outflow balance of sediment in the river is disturbed and sediment accumulate in the river course. This will squeeze the river sections and lower the discharge capacity of the river leading to flood damage. Therefore, it is an important non-structural measure to manage the soil erosion in the watershed and stabilize the river morphology.

Among the six micro-basins with high potential of soil erosion, the Chiquito micro-basin was selected as the pilot micro-basin for soil erosion control project in the Master Plan. This micro-basin was selected because the soil erosion potential is high and the new housing development projects are expected in the basin.

The proposed measures are afforestation and micro Sabo Dam construction. The proposal is shown in *Table 4.4*.

(2) Sediment Transport in the River

The sediment transport capacity was calculated along the river taking the present and planned configuration of the river. The capacity was evaluated by the sediment transport capacity of the average yearly maximum discharge, 1,000 m^3/s and the model sediment with a diameter of d_{60}=30 mm.

The calculation result is shown in *Figure 4.7*. It shows that in the present river, the sediment transport capacity is low in the upstream of Berrinche area where the river capacity is very low. On the other hand, in the planned river profile, the sediment capacity is uniform along the river. Therefore, improvement of the flood capacity of the river also improves the sediment transport capacity of the river.

Riverbed variation was simulated by using the model sediment and the average yearly maximum discharge for 100 years for the planed river. The result is shown in *Figure 4.8*. It shows that the rising or falling of riverbed by sediment transport is within the range of 1 to 2 m in 100 years. It means that the planned river profile is maintained without periodical dredging.

4.2.4 River Improvement Plan for Tributaries

(1) Sapo River

The Sapo River is a small tributary in the left flowing into the Choluteca River at C-50. The catchment area is approximately 3 km^2. The discharge capacity of the culvert portion is 15m^3/s, the return period of which is around 50 years and its capacity is enough to discharge the design flood.

Therefore, dredging of the Choluteca River and exposing the outlet completely will recover the flow capacity of the Sapo River and solve the inundation problem along the river. However, it is necessary to prevent the clogging of the inlet of the culvert by garbage and it is necessary to educate and create the awareness of the people along the river to preserve the river course. It is also necessary for the municipal government to check the capacity of the culvert periodically and maintain it.

(2) Cacao River

Debris along the river is caused by incidents of several landslide masses with the width of 60 – 250 m and the length of 80 – 200 m and it is not practical to adopt any measure to stop this. It is also not practical to realign the river course by resettling the people. Therefore, it was proposed to designate the area along the river as a risk area of debris flow and promote the resettlement of the people.

(3) Pescado Lake

It is proposed to improve the outlet of the Pescado Lake so that further landslide will be prevented and avoid filling up of the outlet and natural dam break. Concept of the outlet improvement is shown in *Figure 4.9.*

4.2.5 FLOOD FORECASTING/WARNING/EVACUATION

COPECO, CODEM and SERNA are working to construct flood forecasting and warning system in Tegucigalpa by the help of USAID and the World Bank. The concept of the system is well established and only some recommendations are made in this Master Plan as follows:

- Three additional rainfall gauging/water level stations with the telemetric system are recommended to supplement the present observation network. This is because the present system covers the whole Choluteca River basin and the distribution density of the observation stations in the Study Area is not enough.
- Reorganize the institutional/organizational set-up for the forecasting/warning/evacuation in Tegucigalpa so that CODEM has more significant role in the work.

The location of the proposed new observation stations and the proposed system concept are shown in *Figures 4.10* and *4.11*.

By the implementation of the proposal, it would be possible to obtain more accurate data on rainfall and discharge in the Study Area and also it would be possible for CODEM to act more promptly to cope with flood emergencies.

COPECO is now making a detailed emergency plan to cope with natural disasters including an evacuation plan. For their reference, rough evacuation plan from flood was prepared based on the inundation simulation in this Study. *Table 4.5* and *Figure 4.12* show the evacuation destination from each probable inundation area if a storm with the scale of Hurricane Mitch comes again.

4.2.6 FLOOD HAZARD MAP

The flood hazard map was prepared corresponding to the storm with scale of 5, 10, 25 and 50 years as shown in *Figure 4.13*. This hazard map shows the without-project (without structural measures) situation. The inundation area with-project situation is shown in *Figure 4.14*. This map should be utilized to educate and enlighten the people for them to be aware of the danger of flood.

For the publication method of the hazard map, the following are proposed:

- To make a simple brochure carrying a simplified version of the hazard map and distribute to all the communities in the city.
- To make a full scale (1/10,000) hazard map and distribute to the community leaders in the dangerous areas.

- To make a full scale hazard map and leave it in the municipality offices so that anybody who is interested in it can observe.
- To make a digital version of the hazard map and publish it on an official website of the Honduran government. The website of COPECO will be an appropriate candidate site.

4.2.7 LAND USE REGULATION

The hydraulic simulation was carried out again to see the expected inundation area by a storm with the scale of Hurricane Mitch with the master plan structural project.

Figure 4.14 shows the result of the simulation with the river reserve area. By overlaying the map on the base map of the area, it was found out that the total number of households affected by the inundation is1,700. They are distributed along the river and if is compared with the designation of the river preservation area of 100 m, most of them are within the designated area.

Therefore, it is considered that this Master Plan Study add to the decree imposed in 1997 a new meaning from the viewpoint of flood disaster prevention. It is proposed here that the decree of river reserve area imposed in 1997 should be applied strictly to eliminate all the structures within the limit in the long run.

The METROPLAN, the planning department of the municipal government, is in charge of zoning and land use planning within the territory of the municipal government. It is recommended that the flood hazard map be always referred to when a new zoning or land use plan is prepared.

In the Study, the land use plan for the Target Area was prepared based on the following policy taking into account the landslide and slope failure danger areas as described later:

- The river reserve area was set along the Choluteca River with a width of 100 m and no structure is allowed,
- Future increase of the population and the resettlement is distributed in the vacant area without any danger of landslide or flood, and
- The housing development applications presently submitted to the municipal government is referred.

The future land use projection is shown in *Table 4.6* and *Figure 4.15.*

Table 4.6 Future Land Use in the Target Area

Land Use category	Area (ha)	Ratio
Commercial	311.3	3.0%
Protocol & Business Area	27.5	0.3%
Public Facility	124.2	1.2%
Residential: R-1 to R-5	3,244.1	31.0%
Industrial Area	135.1	1.3%
Military Facility	130.6	1.2%
Airport	58.8	0.6%
Roads & Streets	1,782.6	17.0%
Park & Green Area	210.6	2.0%
Disaster Prevention Green Area	2,163.1	20.6%
Cemetery	25.4	0.2%
Sports Field	51.6	0.5%
Forest & Shrubs	543.9	5.2%
River Reserve Area	380.1	3.6%
Reservoir	46.1	0.4%
Vacant Space	1251.0	11.9%
Total	10,486.0	100.00%

Residential area by classification	Area (ha)	Ratio
R-1: Residential 250 pers. / ha	2,427.9	74.8%
R-2: Residential 400 pers. / ha	527.6	16.3%
R-3: Residential 500 pers. / ha	143.7	4.4%
R-4: Residential 800 pers. / ha	117.4	3.6%
R-5: Residential > 800 pers. / ha	27.5	0.9%
Total	3,244.1	100.0%

Note: Residential classification is applied on-going planning criteria by the Metroplan of the Municipality

4.2.8 STRUCTURAL CODE APPLICATION

COPECO is working for revision of the structural code taking into account the damage by Hurricane Mitch. The revision work has not yet finished and cannot be applied in this Master Plan. Therefore, in this plan, an example of a structural code application is proposed for further discussion in the future.

Figure 4.16 shows the simulated inundation map in the central area of the city by a Hurricane Mitch scale storm. It shows the inundation depth by a storm with the scale of Hurricane Mitch with the river improvement master plan structural project.

Based on this inundation map, an example of the structural code application was proposed. In the figure there are three zones proposed. One is the area of the river reserve area where no house is allowed. Another is the zone where the new structure should have the floor level more than 1 m higher than the ground level and the rest is the area where the floor level should be 0.5 to 1 m higher than the ground level. The zones where the structural code is applied are show in Supporting J.

4.3 LANDSLIDE DAMAGE MITIGATION PLAN

4.3.1 GENERAL

Considering the large area and the large proportion of the population affected by the landslide including slope failure, the central part of the plan should be non-structural.

Among the various non-structural measures against landslide damage, the most effective and permanent way is permanent resettlement of households from the dangerous areas. However, the number of households in those areas is so large that it is not realistic to make a resettlement plan by expecting foreign loans. Therefore, the non-structural measures are composed of the long-term strategy and the short-term strategy. The long-term strategy is to resettle the people from the dangerous areas and to prohibit new housing developments in the dangerous areas, by using the method of publication of the risk map, education, enlightenment of the residents and land use regulation based on the risk map. The short-term strategy is forecasting, warning and evacuation.

As for structural measures, three landslide blocks were selected from 17 Rank A landslide blocks. These blocks were Berrinche, Reparto and Bambu. As for the other 14 Rank A landslide blocks and all slope failure danger areas, the plan is to utilize non-structural measures.

4.3.2 SELECTION OF LANDSLIDE BLOCKS FOR STRUCTURAL MEASURES

Table 4.7 shows all the Rank A landslide blocks with the number of affected households, the possible countermeasures and the number of households to be relocated for the countermeasures. According to the table, it will be difficult to apply structural measures to most of the blocks because a large number of houses are located on the landslide masses themselves and relocation of houses is inevitable for the implementation of civil works. On the other hand, in the case of Berrinche, Reparto and Bambu, the number of households to be relocated by the civil works is zero or very small.

For Berrinche landslide, the structural measures are a must as the movement of the block may close the flow of the Choluteca River again, causing inundation of the center of the city. And fortunately, all the houses have evacuated from the possible structural work area and there is no need of house relocation.

In the case of Reparto, there are still some houses in the landslide mass and there will be a need of some house relocation but the number will be small.

The case of Bambu needs no house relocation for the civil works while the number of houses affected by the landslide is large.

Because of the reasons mentioned above, Berrinche, Reparto and Bambu were selected as the blocks planned by structural measures.

4.3.3 LANDSLIDE PREVENTION FACILITIES

(1) Berrinche

Berrinche slide is a large-scale landslide 400 m wide and 800 m long having a volume of 3 million m^3. The mechanism analysis of the landslide was done in the feasibility study stage and it is described in Chapter 6. The landslides are classified into large scale landslides and small scale landslides along the Choluteca River.

The basic idea of landslide prevention is as follows:

- to prevent rain water intrusion into the landslide mass
- to remove groundwater in the landslide mass
- to reduce the driving force of the landslide by removing the head part of the landslide mass
- to increase the resistance force of the landslide by applying counter fill and landslide deterrence works (shaft works or anchor works)

In the case of Berrinche, the planned facilities are as follows:

- Embankment
- Soil removal
- Surface drainage

- Sub-surface drainage
- Well drainage
- Horizontal boring drainage
- Concrete shaft

The location map of the facilities is in *Figure 4.17*.

(2) Reparto

The Reparto landslide is about 200 m long, 150 m wide. The mechanism analysis of the landslide was done in the feasibility study stage and it is described in Chapter 6.

The basic idea of landslide prevention is as follows:

- to prevent rain water intrusion into the landslide mass
- to remove groundwater in the landslide mass
- to reduce the driving force of the landslide by removing the head part of the landslide mass

The planned facilities are as follows;

- Soil removal
- Surface drainage
- Sub-surface drainage
- Well drainage

The location and the items of structural measures in Reparto are shown in *Figure 4.18*.

(3) Bambu

It is 180 m wide and 250 m long. The thickness is 5 to 15 m.

The basic idea of landslide prevention is as follows:

- to prevent rain water intrusion into the landslide mass
- to discharge stream flow downstream quickly without causing erosion of landslide blocks

Proposed landslide prevention measures area as follows:

- open channels
- gabion

Figure 4.19 shows the location of civil works.

4.3.4 HAZARD MAP OF LANDSLIDE AND HAZARD MAP OF SLOPE FAILURE

The landslide hazard map was prepared showing the risk area in terms of landslide and slope failure by a rainfall with the scale of Hurricane Mitch. (Refer to *Figure 2.26)* This hazard map shows the without-project situation meaning including Berrinche, Reparto and Bambu. This map should be utilized to educate and enlighten the people for them to be aware of the danger of landslide. The publication method of the map should be the same as the case of **4.2.6 Flood Hazard Map.**

4.3.5 RESETTLEMENT PROMOTION

The total number of households at risk of landslide and slope failure in the area is estimated at 26,500. Through the structural measures, only 800 of which is saved from the risk of landslide and the rest should be dealt with non-structural measures.

A large scale resettlement from dangerous areas to safe places is very difficult and unrealistic in short terms. Realistic idea is to prohibit any further housing development in dangerous areas by regulating the development permission by METROPLAN.

In the Master Plan, it was planned to take up some particular landslide blocks as pilot project of resettlement. The pilot projects are from landslide blocks where the risk is high and resettlement is urgent. Nueva Esperanza and Zapote Centro were selected. The total number of households to be resettled is approximately 200.

The resettlement process should be promoted as follows:

- Preparation of a risk map
- Publication of the risk map to the people living in risky areas
- Education and enlightenment of residents in the areas
- Land preparation for resettlement destination
- Utility preparation for resettlement destination
- Promotion of new occupation for the people who are going to resettle
- Resettlement of people
- Consultation and care of the resettled people

4.3.6 LAND USE REGULATION

Based on the risk map prepared, land use regulation should be imposed strictly. As it is very difficult to uproot people and resettle them elsewhere, the important thing is to prevent housing development in dangerous areas. The hazard map shows the dangerous area without any structural measures. Therefore, it is possible to remove the three areas of Berrinche, Reparto and Bambu from the hazard map except the landslide masses themselves after the completion of the structural measures.

The METROPLAN, which is in charge of the land use regulation of the city area, should make an appropriate land use plan referring to the hazard map prepared in the Study.

In this Study, the proposal on the land use regulation is as follows:

- Rank A block of landslide risk area is to be set as “the disaster prevention green area” where no houses are allowed, and
- All the slope failure risk area is to be set as “the disaster prevention green area” where no houses are allowed.

Based on this proposal, the future land use plan was prepared and shown in *Figure 4.15.* This map shows the idealistic situation where all the dangerous areas have converted to “the disaster green area” after all the houses in the dangerous areas are relocated.

4.3.7 FORECASTING/WARNING/EVACUATION

(1) Selection of Evacuation Destination

COPECO is now making a detailed emergency plan to cope with natural disasters including evacuation plan. Following factors are to be considered in selection of refugee area.

- anticipated number of refugees (number of people to be accommodated) from each landslide block

- accommodation capacity of refugee area
- safety of the evacuation route
- safety of the refugee area from landslide and flood
- structure of refugee buildings
- transportation of emergency goods to the refugee area

Table 4.7 shows the number of affected houses of each landslide block. *Table 4.8* shows the locations of refugee area in the neighborhood. This information should be referred to select proper desitinations.

(2) Landslide Forecasting/Warning by Rainfall Amount and Other Information

Basic information for forecasting of warning for landslide and slope failure area (1) symptoms (2) velocity of ground surface movement and (3) rainfall amount.

<u>Symptom</u>

In the case of landslide or slope failure, there are often some symptoms observed by the people living in the area before the large movement of earth and rock occurs. The following are such common phenomenon.

- Development of cracks or heaving of ground
- Development of cracks on the structures
- Sudden fall of well water or appearance of new springs
- Vibration of ground or earth sounds

It should be noted that slope failures could occur without any symptom as above.

A warning manual should be prepared based on the items described above.

<u>Velocity of ground surface movement</u>

Measurement of ground surface movement is a direct method and most reliable. Following are the measuring instruments of ground surface movement.

- extensometer
- ground inclinometer
- survey (ground survey, GPS survey)

An example of monitoring threshold values are as follows:

- 1mm/hr movement continues three hours or more: emergency preparation
- 4mm/hr or more: evacuation

<u>Rainfall amount</u>

It is considered that a warning system employing rainfall data is the most practical method. However, the threshold value of rainfall amount to be related with the movement of each land mass is not determined at this stage, as not enough information has been accumulated. Therefore, it is recommended to set up a rainfall observation system in the area and collect precise information which can relate the movement of the land and the amount of rainfall in the area. For the time being, conservative tentative values should be designated for warning. According to examples in Japan, the hourly rainfall amount of 10 to 20 mm or the total continuous rainfall amount of 50 mm is the common threshold value to dispatch alarm for evacuation.

As of now, there is no such system working but CODEM is making such a plan. In this Master Plan, a landslide warning system by rainfall stations is proposed based on the discussion with CODEM. *Figure 4.20* shows the location map of the rainfall observation stations.

4.4 OTHER NON-STRUCTURAL MEASURES

4.4.1 EDUCATION/ENLIGHTENMENT AND TRAINING

The education/enlightenment and training plan was made aiming at two purposes, namely, capacity building of the related officials and public education on natural disasters. The capacity building will be enforced to the government officials, educational staffs/teachers and community leaders in charge of disaster prevention and the public education will be implemented to all residents.

The content of education/enlightenment/training is as follows

- education and enlightenment of disaster prevention administrators (capacity building)
- education and enlightenment of school teachers (systematic transfer of disaster knowledge)
- education and enlightenment of urban plan administrators (urban planning considering disaster prevention)
- education and enlightenment of public (knowledge on dangerous area and symptoms, emergency responces)

4.4.2 DISASTER MANAGEMENT INFORMATION SYSTEM

The bottleneck of the disaster prevention activities is the large number of organizations to be involved in decision making and implementation of the plan. As the first step of the good coordination among the related agencies on the matter, it is essential to share identical information on disaster prevention.

Based on this idea, a disaster management information system was proposed as an information sharing system among the related agencies. The system is composed of a combination of hardware and organization. The hardware is composed of devices to collect, process and share the information, such as rainfall gauging stations, water level gauging stations, telemeter system, computers, and optical fibers, among other things. The organization set-up is the one that run the system. *Figure 4.21* shows the flow of the information on disaster.

It is proposed that the system is to be managed by COPECO, which is administrating all information on disaster form all over the country. The organizations to be connected to the system are all counterpart organizations of the study (SOPTRAVI, SETCO, COPECO, SANAA, SERNA, and AMDC) , COHDEFOR, ENEE and others.

4.5 OPERATION AND MAINTENANCE PLAN

4.5.1 RIVER FACILITIES

As described above, it is not necessary to practice constant dredging of the riverbed in order to maintain the planned river profile. In this Master Plan, the design flood return period is 15 years, thus it is considered that flood water overflows the dike once in 15 years. Therefore, the maintenance plan is to repair the structures once in 15 years.

It is important to maintain the river flow of small tributaries by removing garbage from the river course. The practice will be done by the municipal office.

As for the earth anchor works for river widening, it is necessary to check the function of the anchor after experiencing a large forces by a large scale flood or so and re-imposing of pre-stress may be necessary if any losing of stress is observed.

4.5.2 LANDSLIDE PREVENTION FACILITIES

It is important to maintain the function of drainage for landslide prevention. The channels and ditches should be dredged constantly to keep the drainage capacity of the facilities. For the maintenance of the facilities, it is necessary that the people living in the area understand the importance of the facilities. It is proposed that the maintenance of the facilities be entrusted to the residents.

4.5.3 OBSERVATION FACILITIES

Maintenance of rainfall gauging stations, water level gauging stations with telemeters are being maintained by SERNA presently. SERNA is also maintaining the inclinometer and the piezometer at Berrinche. After completion of the installation of the monitoring equipment proposed in the Study, it is proposed that the related agencies have discussion and combine the maintenance operation.

The maintenance of monitoring facilities is composed of protection from vandalism/daily inspection and periodical professional inspection and measurement of the facilities. The first part of the work can be entrusted to the representative of the residents and the last part of the work can be done by professional engineers of the relevant governmental agencies.

(1) Rainfall Gauging Station

Maintenance of rainfall gauging station is important to obtain precise value of the rainfall. The station should be located without any interruption of rainfall catch by trees. The trees and bushes around the stations should be cut and removed constantly. The measurement device and transmission device are to be checked periodically so that there is no error of measurement and transmission of data.

(2) Water Level Gauging Station

Water level gauging station often employs automatic pore pressure meter. It is necessary to check the installation condition of the meter so that the device is able to accurately detect the water level. Constant cross section survey and periodic measurement of discharge are essential to obtain the precise relationship between the water level and the discharge.

(3) Landslide Observation Instruments

The observation instrument of landslide is inclinometers and pore pressure meters. SERNA is now in charge of the measurement of the devices installed by the Corp of Engineers in Berrinche. The observation instruments installed in this Study are to be maintained and observed by SOPTRAVI. The observation data obtained by various organizations should be shared by the agencies concerned through the proposed disaster management information system.

The drainage wells are to be maintained so that the drainage function sustains by re-drilling of drainage borings or washing of the bore holes when they are clogged. The load acting and the deflection of the concrete shaft should be monitored by installing strain gauges, reinforcing steel meters, inclinometers and earth pressure meters on the shaft body. If the deflection is accumulating it is necessary to plan additional measures.

4.6 ORGANIZATIONAL PLAN

4.6.1 ORGANIZATIONAL PLAN FOR DISASTER PREVENTION

Generally, an integrated disaster prevention master plan is composed of “disaster preparation plan,” “emergency action plan” and “rehabilitation plan”. This Master Plan is a “disaster preparation plan” basically.

However, in the organizational plan of the Study, the organization for the emergency action plan and the organization for the rehabilitation plan were also studied. The discussion was made in the participatory workshop with the counterpart team and some examples of integrated disaster prevention master plan of municipalities in Japan were taken up.

Tables 4.9 to *4.11* show the organizational plan for each stage of “the disaster preparation plan,” “ the emergency action plan” and “the rehabilitation plan.”

In order to make the above mentioned set-up to work as planned, it is necessary to agree upon the coordination plan among the agencies involved. The coordination plan for each of the above stage is shown in *Figure 4.22*.

4.6.2 ORGANIZATIONAL PLAN FOR IMPLEMENTATION OF THE MASTER PLAN

All the disaster related activities should be planned according to the proposed organizational set-up described in **4.6.1**. Accordingly, the organization for the implementation of this Master Plan is as follows:

(1) Overall Coordination

As this is an inter-ministerial project, one entity in charge of the overall coordination is necessary. CODEM-DC is proposed as the most appropriate inter-institutional organization for disaster mitigation in Metropolitan area. The steering committee of the Study commented on this proposal in the draft final report, stating that a new steering committee composed of all the counterpart agencies should be formed for this overall coordination task. The organizational set up for the implementation of the project should be discussed further among Honduran side from now on.

(2) Flood Control Structural Measures

This part of the Plan is to be proceeded with by AMDC as organizer with cooperation of other related organizations, especially SOPTRAVI, which have a long history of experience in such river improvement works throughout the country. They have enough technical staff and equipments for implementation of the projects. Presently, SOPTRAVI is in charge of the same kind of project, such as rehabilitation/reconstruction of flood control and landslide prevention structures damaged by Hurricane Mitch, under the On-going National Reconstruction Plan.

(3) Landslide Prevention Structural Measures

This part of the Plan is to be proceeded with by AMDC as organizer with cooperation of other related organizations, especially SERNA as they have been working for the Berrinche landslide problem since the beginning of its occurrence during Hurricane Mitch. As they lack experience of large-scale civil works, it is necessary to collaborate with SOPTRAVI in implementation of the projects.

(4) Watershed Management

Watershed management is to be proceeded with by AMDC with cooperation of other related organizations, especially SANAA, SERNA and COHDEFOR.

(5) Land Use Plan (including Land Use Regulation, Resettlement and Structural Codes)

Land use plan should be dealt with by AMDC with the collaboration of COPECO/CODEM-DC.

(6) Preparation and Publication of Risk Map

Preparation and Publication of Risk Map should be dealt with by CODEM-DC with the collaboration of COPECO, SOPTRAVI and SERNA.

(7) Education/Enlightening

Education/Enlightenment of People should be dealt with by CODEM-DC as they have been preparing the education/enlightenment and training program, with the cooperation of COPECO.

(8) Forecasting/Warning/Evacuation

Forecasting, warning and evacuation of the people should be dealt with by COPECO and the CODEM-DC as a regional organization of COPECO with the collaboration of SERNA and National Meteorological Service (SMN). In this Master Plan, more significant role of CODEM is proposed.

4.7 COST ESTIMATE

4.7.1 CONSTRUCTION COSTS

The construction cost of the civil works was estimated through work volume calculation and unit price calculation of each work item. The result of the cost estimate is shown in *Table 4.12*.

4.7.2 OPERATION AND MAINTENANCE COSTS

The operation and maintenance cost of the Master Plan Project was estimated proportionally to the construction cost of each item considering the nature of the project. An allocation of 0.5% of the construction cost was made for annual maintenance cost for river works except dredging.

As for the river structures, replacement cost of revetment and dike was considered as taking 10% of the construction cost once per 15 years.

The maintenance cost for warning system and disaster management information system was included in the plan taking 0.5% of the installation cost and replacement cost once per 10 years.

4.8 IMPLEMENTATION PROGRAM

Implementation program for the Master Plan Project was prepared in order to realize all the program by the target year 2015. The implementation program is shown in *Table 4.13*.

4.9 SELECTION OF PRIORITY PROJECTS

4.9.1 GENERAL

Among the Master Plan Projects, Priority Projects have been selected for the Feasibility Study. The selection of the Priority Projects was made based on the pre-set criteria and the discussion among the counterpart team members as well as the steering committee of the Honduran side.

As a result, a part of the flood damage mitigation structural measures, all of the landslide damage mitigation structural measures and a part of the non-structural measures were selected as the Priority Projects.

4.9.2 SELECTION CRITERIA FOR PRIORITY PROJECT(S)

The selection criteria for the Priority Projects are as follows:

- Significance
- Urgency
- Immediate Consequence
- Economy

4.9.3 FLOOD DAMAGE MITIGATION STRUCTURAL MEASURES

In terms of flood damage prevention, the main causes of the problem are the bottleneck of the main channel at the location of Berrinche and the large amount of sediment caused by the bottleneck. Therefore, the widening of the Cholteca River adjacent to Berrinche landslide is the most significant project. The next significant project is the removal of the large amount of sediment with the combination of revetment and dike construction. Reconstruction of Mallol Bridge is less significant in terms of the effect to the river discharge capacity. Improvement of the Pescado Lake is also significant considering its large impact to the flood downstream.

In terms of urgency, excavation of the Choluteca River has the first priority, as the mal-capacity of the Choluteca River at the center of the city is lowering the safety factor against flood of the capital. Excavation of the river is also critical in order to solve the problem of inundation along the Sapo River happening almost every year. Other projects have less urgency.

Immediate consequence for the problems will be attained by all the structural measures except the reconstruction of Mallol Bridge where a long-term discussion is needed. Mallol Bridge reconstruction is excluded from the Priority Projects as they are less significant and will take a long time to clear the environmental issues.

The economic justification is to be made by considering the area to be saved from the inundation after the completion of the projects.

Therefore, as the Priority Projects, “river widening at Berrinche”, “river excavation”, “a part of revetment/dike construction” and “Pescado Lake outlet improvement” were selected. In order to determine the extent of the revetment/dike construction, the inundation area along the Choluteca River by a flood with the scale of once in 15 years was prepared. *Figure 4.23* shows the inundation area. According to the figure, the area between C40 and C60 is the inundation area where the population density is high. Therefore, C40-C60 was selected as the priority project for revetment/dike construction.

Construction of revetments were proposed between C40 and C52 in the vicinity of Berrinche landslide in order not to destabilize it by erosion. Another series of revetments and dikes were proposed between C56 and C60 where the inland ground elevation is so low to be inundated by 15 year flood without any dikes. Reinforcement of the toe of the river abutment by gabion was proposed between C32 and C40, and C60 and C77, where no revetment is proposed and houses are located very close to the river.

Choluteca River Improvement

- River widening at Berrinche	L= 200 m
- A part of riverbed excavation	V= C23-C93; 750,000m^3
- A part of revetment construction	L＝ 3 km
- A part of dike construction	L= 1 km

Other Project

- Pescado Lake Outlet Improvement

4.9.4 LANDSLIDE DAMAGE MITIGATION STRUCTURAL MEASURES

In terms of landslide disaster prevention, the most significant component of the Master Plan is non-structural measures as most of the landslide masses or steep slope area where a huge number of people live cannot be coped with by structural measures.

However, the most effective way in the non-structural measures, namely the resettlement, is not attained promptly; it is necessary to cope with the problem with structural measures. Three landslide blocks in the Master Plan are all urgent because their risk is large. The structural measures proposed in the Master Plan are prompt in the sense that there is little need of house resettlement.

The economic justification is to be made by counting the number of houses saved from the danger of landslide by accomplishing the structural measures.

The locations for the Priority Projects proposed are as follows:

- Berrinche
- Reparto
- Bambu

4.9.5 NON-STRUCTURAL MEASURES

The non-structural measures in the Master Plan are composed of watershed management, land use regulation, structural code application, forecasting/warning/evacuation, education and disaster management information system.

The non-structural measures which give immediate consequence are forecasting, warning and evacuation. The watershed management, land use regulation and structural code application will not give prompt solution to the inundation problems or landslide problems. They should be regarded as long-term solutions. The forecasting/warning/evacuation is the most significant project which deal with a large number of households in danger.

Education and disaster management information system are urgent parts of the solution to be initiated as soon as possible.

Therefore, following projects were selected as Priority Projects:

- Forecasting/warning/evacuation
- Education/Enlightenment/Training
- Disaster management information system

Chapter 5

Evaluation of the Master Plan

CHAPTER 5
EVALUATION OF THE MASTER PLAN

5.1 GENERAL

The proposed Master Plan was evaluated from the economic, financial, managerial, technical, environmental and social aspects. The overall evaluation of the Master Plan was made integrating all the aspects of evaluation.

5.2 ECONOMIC ASPECT

5.2.1 ECONOMIC BENEFIT

Benefit of the disaster prevention project is generally defined as an economic difference of damage between “with-project” and “without-project” situation.

There are two kinds of benefit, namely, tangible benefit and intangible benefit. Further, tangible benefit would be classified into direct benefit and indirect benefit.

The direct/tangible benefit of the project is estimated as a reduction in damage to assets such as buildings, household effects, livestock, crops, infrastructure and other facilities. And indirect/tangible benefit also would be estimated as a reduction in damage, which would be derived secondary from the direct damage of the project. Because of the difficulty of estimating the intangible benefit appropriately, the amount of intangible benefit would not be included in the economic evaluation of this Study.

The calculation method of damage reduction is as follows:

(1) Flood Damage Reduction

Inundation simulation was made by the established hydraulic model and the inundation area was identified for floods with the return periods of 5, 10, 50 and Hurricane Mitch scale flood. The simulation was made for both with-projects case and without-projects case.

The inundation area was overlaid on the base map of GIS having the distribution of households in the area. The values of the households composed of structures and furniture were estimated based on the damage survey conducted in the Study. The damage was calculated integrating all the damage caused by each flood with-projects and without-projects. The reduction of damage was calculated as the difference of damage between with-projects and without-projects.

(2) Landslide Damage Reduction

The Master Plan contains landslide structural measures for three landslide masses, namely, Berrinche, Reparto and Bambu. The structural measures were planned targeting a Hurricane Mitch class stormTherefore, it is considered that with-projects those three blocks will be able to withstand a storm with a return period of 500 years. On the other hand, if the projects are not implemented, those three blocks will slide, inflicting damage in the estimated dangerous areas.

Thus, it is assumed that without projects all the households in the area of three landslide blocks are destroyed by a 500-year storm, while all the households in the same area of three landslide blocks are safe against a 500-year storm with the projects.

(3) Damage Reduction Amount

Reduction of flood and landslide damage is calculated as shown in *Table 5.1*.

Table 5.1 Reduction of Flood/Landslide Damage

Return Period (year)	Damage Reduction (US$ million)
5	14.30
10	20.58
15	23.60
50	36.08
Mitch (500)	139.19

5.2.2 ECONOMIC COSTS

The following preconditions and assumptions are applied for calculation of the economic costs in this Study:

- The inflation factor is not included.
- Transfer payment factors such as taxes and duties are applied to goods and services procured locally with following rates:

  Value added tax (VAT) : 12%
  Income tax : 10%
  Import tax : 10% (average)
- Standard conversion factor of 0.9634 is applied as the shadow price for all the costs except imported goods based on the Honduran external trade statistics and the value used for other studies.
- Adjustment factor for personal costs of unskilled laborers was not applied.
- The real exchange rate is assumed to be fixed because so far the government has not introduced any special protective measure for trade and its currency.

Under the preconditions and assumptions mentioned above, the economic costs of the project are estimated from the project costs provided in Chapter 4.

5.2.3 COST BENEFIT ANALYSIS

The project life is economically taken as 50 years after commencement of the project. The benefits together with the OM cost are assumed to accrue throughout the period of project life after completion of the construction works. The partial benefit and OM cost under the construction period would be considered in this analysis.

The estimated EIRR of Master Plan indicates 10.49 % and it can be said that the project is economically feasible, from the viewpoint of the opportunity cost of capital (OCC) in Honduras.

Table 5.2 shows the Net Present Value (NPV) and Cost Benefit Ratio (B/C) of the Project.

Table 5.2 NPV and B/C for the Master Plan Project

Discount Rate	NPV (US$ million)	B/C
4% (Real yield of the Honduran state bond)	47.40	2.11
8%	9.30	1.28

5.3 INTANGIBLE SOCIO-ECONOMIC IMPACT OF THE PROJECT

As it is confirmed in the previous section, the proposed projects would produce direct economic effects, and the conclusion is that the projects are economically feasible. Furthermore, it is expected that the projects would have various intangible effects of reducing the socio-economic damage as follows:

- Spread of Infectious Disasters
- Shortage of Goods
- Steep Rise in Prices
- Lowering of Administrative and Educational Activities
- Decline in Communication
- Decline in the Standard of Living
- Time Lag of Social and Economic Development

5.4 FINANCIAL ASPECT

5.4.1 RAISING OF THE PROJECT FUND

In order to examine a financial viability of the project, consideration would be given on raising the construction fund for the projects.

The project cost excluding O/M cost for the Master Plan Project is estimated at US$ 64 million in total. It is assumed that the fund for the project will be raised from the local-fund and the external debt, under following conditions:

- The external debt will cover the whole project cost except government administration and land acquisition cost. The government administration cost and land acquisition cost would be prepared from local-fund.
- The following loan conditions were assumed based on the actual conditions of IDB loan for Honduras:
    - Repayment period : 40 years
    - Grace period : 10 years (only for principal repayment)
    - Interest rate : 1% for the first 10 years and 2% afterward
- During the grace period, only interest is paid, and repayment of the debt with the interest is made after the grace period.
- Disbursement will be done in the initial year of the Priority Project and the remaining of Master Plan Projects respectively.
- Repayment of principal was calculated based on an equal installment repayment method.

According to the repayment schedule prepared in the Study, the maximum disbursement of US$ 37.46 million will be accrued in 2006 which is the beginning year of the project and the maximum repayment of US$ 2.91 million in2027.

5.4.2 REPAYMENT OF EXTERNAL DEBT

According to the repayment statistics of the external debt of Honduras, the average annual repayment amount for multilateral loan is approximately US$ 240 million for the past 8 years. The annual maximum repayment amount of US$ 2.91 million in 2027 for this project will be 1% of the total annual repayment of Honduras.

It can be judged that the raising of the project fund from external loan seems to be possible, from the viewpoint of the amount of maximum repayment.

5.5 MANAGERIAL ASPECT

The Master Plan is composed of structural measures and non-structural measures. The structural measures consist of flood control projects and landslide prevention projects. The non-structural measures are composed of inter-ministerial projects such as forecasting/ warning/evacuation. Therefore, the management of the implementation of Master Plan Projects is rather complex and difficult. However, it is inevitable to face this managerial problem in solving the disaster prevention problem and it should be challenged.

The organization plan and the coordination plan was proposed in Chapter 4 and if the overall coordination is accomplished as planned, the management of the project will be handled by placing the Municipal government and CODEM in charge.

5.6 TECHNICAL ASPECT

Most of the civil works included in the Master Plan are a combination of simple works although the volume of each work is huge. The process of excavation, hauling and disposal of sediment is a simple but repeatitious operation. Revetment and dike construction work need structural excavation and concreting work in river course and require coffering and dewatering. This coffering and dewatering operation should be limited during dry season so that it will not bring about difficult technical problems.

Bridge reconstruction is being done at present in the city and gives no difficult technical problems.

There is lack of experience of concrete shaft building, drainage well construction and horizontal drainage boring observed in Honduras. It requires technical assistance by foreign consultants and contractors and import of materials, but it is possible to be carried out in Tegucigalpa. The horizontal drainage boring is not common in Honduras but there are some foreign boring companies in Tegucigalpa which have such experience. Therefore, it is possible to introduce some foreign boring companies to do the operation.

Overall, it is necessary to get technical assistance and cooperation of foreign consultants and foreign contractors to implement the Master Plan Projects.

5.7 ENVIRONMENTAL ASPECT

According to literature review and from a local environmental expert, there is no endangered or threatened species of flora or fauna in the Master Plan Projects area.

As there was a fear of inclusion of heavy metal in the river sediment from the urban discharge, investigation was made in the Feasibility Study stage. As a result, no heavy metal was detected with an amount larger than the regulation and the problem was eliminated.

As a whole, there is no significant environmental problem in the Master Plan Project area. *Tables 5.3 and 5.4* show the screening and the scoping of the environmental issue for the Master Plan Projects respectively.

5.8 SOCIAL ASPECT

(1) Land Acquisition/Resettlement

The land to be acquired for the civil works is as shown below.

Table 5.5 Land Acquisition and Resettlement

Project	Land to be acquired (m^2)	Number of houses to be resettled
River widening at Berrinche	12,000	0
Pescado Lake Outelt Improvement	1,000	0
Reparto Landslide Prevention	3,000	10
Total	16,000	10

The land for river widening at Berrinche, 12,000 m^2, was designated as a river area in 1999 by the Planning Department of Tegucigalpa Municipal Office and there is no problem of land acquisition. The outlet of the Pescado Lake is privately owned and the land is to be acquired or to be leased temporarily. The landowner of the place is cooperative toward the project according to initial talks with the Study Team. In Reparto landslide, approximately 10 houses are to be relocated in order to construct a surface drainage channel. The homeowners have not been contacted but they have to be relocated to a safer place anyway. It is considered possible to relocate them by proper compensation.

Thus, overall, there exist problems but the land acquisition and the resettlement related to the Master Plan Projects can be solved by prudent approach to the landowners.

(2) Preservation of Historical Landscape

In April 1994, the Municipal Mayor’s Office of the Central District and the Honduran Institute of Anthropology and History signed an agreement for the “Conservation of the Historical Area of Tegucigalpa/Comayaguela and Neighboring Areas.”

The project related to this matter is the reconstruction of Mallol Bridge. As stated in Chapter 4, the reconstruction of the bridge was basically agreed upon. The type of the new bridge will be discussed further in the feasibility stage of the project in future.

5.9 OVERALL EVALUATION

According to each aspect of the evaluation, the Master Plan Projects proposed are feasible. The implementation of the projects will definitely give great benefit to Tegucigalpa City. As the technical, environmental and social problems are not significant as a whole, the most crucial matter is the project management. The strong leadership of the central as well as the local government will realize the good coordination of this complex and difficult task.

Chapter 6

Feasibility Study of Priority Projects

CHAPTER 6
FEASIBILITY STUDY OF PRIORITY PROJECTS

6.1 GENERAL

The Priority Projects selected for the Feasibility Study are as follows:

(Flood Damage Mitigation Structural Measures)
- Choluteca River Improvement
- Pescado Lake Outlet Improvement

(Flood Damage Mitigation Non-structural Measures)
- Flood Forecasting/Warning and Evacuation

(Landslide Damage Mitigation Structural Measures)
- Berrinche Landslide Prevention
- Reparto Landslide Prevention
- Bambu Landslide Prevention

(Landslide Damage Mitigation Non-structural Measures)
- Landslide Forecasting/Warning and Evacuation

(Common Non-structural Measures for Flood and Landslide)
- Education/Enlightenment/Training
- Disaster Management information System

Figure 6.1 shows the location map of the structural part of the Priority Projects.

In the Feasibility Study of the Priority Projects, additional topographic survey was done to cover all the project site with the scale of 1/500. Geological boring was performed for the sites of Berrinche and Reparto to plan the structural measures for flood damage mitigation and landslide damage mitigation. The environmental impact assessment was made for all the structural measures in the Priority Projects to assess the impact of the project.

Alternative study was made for structural measures after more detailed site investigation including the topographic survey and geological survey. The benefit and the cost of the projects were calculated with higher accuracy and utilized for economic evaluation of the projects. Project evaluation was made from the economic aspect, the financial aspect, the environmental aspect and the social aspect.

6.2 TOPOGRAPHIC SURVEY

Topographic survey with the scale of 1/500 was done for the area of the Priority Projects. The topographic map was utilized to make a more detailed plan for the Priority Projects.

6.3 GEOLOGICAL INVESTIGATION

Boring investigations were made in the sites of Berrinche and Reparto. Detailed field reconnaissance was made for Berrinche, Reparto, Bambu and the Pescado Lake outlet for landslide prevention plan. The location and the amount of boring investigation are shown in *Table 6.1* and *Figure 6.2* respectively.

The summary of the geological investigation is given below. The detailed result of the geological survey is described in Supporting G.

6.3.1 BERRINCHE

(1) Topography and Geology

Berrinche landslide is a landslide with an area of 320,000 m^2, a width of 400 m and a length of 800 m. The top of the land slide mass is around EL 1,060 m and the toe of the mass is at EL 920 m at the bottom elevation of the Choluteca River. The area can be divided into several landslide sub-blocks as shown in *Figure 6.3* according to the landslide mechanism study.

According to the field survey, on the east edge of the landslide mass, silt and mudstone of Rio Chiquito Formation are exposed below EL 1,015 m. On the steep cliff located at the north edge of the mass, volcanic rocks of Ignimbritas are seen underlain by tuff. Tuff is outcropped to the west of Block C and D. Rio Chiqito Formation is outcropped to the east.

(2) Boring Result

In the area, the U.S. Corp of Engineers had performed boring investigation in 2000. The location of borings is shown in *Figure 6.2(1)*. In the Study, borings were added to study the geology of the site further. In *Figure 6.2(1)*, the location of the additional boring is also shown.

By observing the boring core, the slip surface of the landslide during Hurricane Mitch was identified. The identified slip surface of the profile B-4 by the result of boring is described in *Figure 6.4*.

(3) Monitoring Result of Inclinometer and Piezometer

SERNA has been monitoring the behavior of the land mass by using inclinometers and piezometers since 2001. The location map of their observation is shown in *Figure 6.2(3)*. The measurement of the inclinometer shows a movement at BS-4 of 2mm/month at the depth of around 38 m. At the other locations no apparent movement was detected.

The seasonal variation of groundwater level is large at the mountain side at BS-3, BS4 and BS7 while those at the river side at BS-1, BS2, BS5 and BS6 are small.

In the Study, three piezometers and eight inclinometers were installed and observation was made for two month. No movement of the land mass was observed in the period as it was in dry season. The measuring instruments were hand over to SOPTRAVI for continuous monitoring of the movement of the land mass. The obtained data are shown in the Data Book.

(4) Landslide Mechanism

Based on the geological investigation, monitoring result and field reconnaissance, the mechanism of landslide in Berrinche during Hurricane Mitch is interpreted as follows:

- Block A1 started to slide because of groundwater rising after heavy rainfall
- Block A1 pushed Block B and formed a compression topography
- Block A1 pushed Block A2 and Block A3 started to slide
- The end of Block A3 intruded into the Choluteca River and formed a barrier
- Block A1 pushed Block B and Block B started to slide
- The end of Block B intruded into the Choluteca River and formed a barrier
- Block C and D moved down with the movement of Block A1

Thus, it is interpreted that Block A1 started to slide first and it pushed down the block at the lower elevation into the Choluteca River, thus closing off the river.

6.3.2 REPARTO

(1) Topography and Geology

The Reparto landslide is a landslide with an area of 30,000 m^2, 200 m long and 150 m wide. The top elevation of the land mass is EL 1,130 m and the toe elevation is EL 1,070 m. The western parts of steep slope downward from western high land area of El Picacho changes to gently undulating hills at a road to El Picacho, and steep cliffs lie further east with streams. The geology along the road is tuff and the area lower than the road is covered with old landslide materials. The Reparto landslide is interpreted as one block of soil mass.

(2) Boring Result

In the Study, 6 new borings were made to investigate the geology of the area. The location map of the boring is shown in *Figure 6.2(2)*. The slip surface during Hurricane Mitch was assumed from the boring result as shown in *Figure 6.5*.

(3) Landslide Mechanism

According to the boring result and the field reconnaissance, the landslide mechanism of Reparto is as follows:

- The stream on east side that drained the groundwater had been blocked by the construction of the road at the toe of the landslide mass and new ponds had been created.
- During Hurricane Mitch, the heavy rainfall caused a large flow of surface water on the landslide mass together with the water flown into from the road to El Picacho.
- Surface water raised the groundwater level of the mass and the movement of the block was caused.

6.3.3 BAMBU

(1) Topography and Geology

The landslide mass presents typical old age landslide topography composed of small fractured landslide masses broken up through long periods of movements. The size of those fractures is small and the thickness of the layer is of a few meters. The geology of the landslide area above the head scarp is whitish tuff of Ignimbritic Formation. Below the scarp is a moving mass of earth consisting mostly of weathered whitish tuff. At the lower part of the landslide, clay of Rio Chiquito Formation is observed.

(2) Landslide Mechanism

During Hurricane Mitch, heavy rainfall concentrated in the center of the block and a part of the landslide mass collapsed and washed down. It is considered that the debris flow from the part of the landslide mass destroyed some houses and closed the stream of Bambu, causing inundation in the lower area.

6.3.4 PESCADO LAKE OULET

(1) Topography and Geology

The geology around the outlet of the lake consists of lava of Ignimbritas and tuff. Although the rock on the right bank appears to be basic rock formation, it is a large piece of rock that slipped down from the up-hill gradually for a very long period of several tens thousand years.

On the left bank, the lava of Ignimbritas is distributed along the ridge and talus material deposits on the downstream side. The talus material seems to include the material from the right bank in addition to the talus material from the left bank. This observation suggests that the outlet has been subjected to frequent blocking by the collapse of the right bank. *Figure 6.6* shows the geological sketch of the site.

(2) Flash Flood Mechanism

According to the detailed field reconnaissance, the mechanism of flash flood during Hurricane Mitch was estimated as follows:

- Before Hurricane Mitch, the crest elevation of the outlet was higher than the present ground level by 4.5 m protected by a concrete structure 0.5 m wide.
- During Hurricane Mitch a large amount of logs flowed from the upper reach and accumulated at the outlet.
- A part of the right bank collapsed and together with the logs raised the crest elevation of the outlet by another 3.5 m and a large amount of water accumulated in the lake.
- The water level rose higher than the crest level and washed sway all the collapsed soil mass, the logs, the concrete structure and the riverbed material causing flash flood down stream.

6.4 ENVIRONMENTAL IMPACT ASSESSMENT

The impact on environment by the Priority Projects was studied. The detailed result is described in Supporting Report E.

The main points of the EIA are as follows:

- Possibility of contamination of the riverbed material by heavy metals; and
- Resettlement problems caused by structural measures of the projects.

6.5 FLOOD DAMAGE MITIGATION PROJECTS

6.5.1 RIVER WIDENING AT BERRINCHE

In the river widening at Berrinche, landslide prevention measure was planned in order not to affect the Berrinche landslide mass. The prevention measures were planned assuming the slip surface at the toes of Block B1, B3 and Block E. The slip surface considered is the one which is being observed presently as shown in *Figure 6.4*.

The measures were planned so that the safety factor after the project becomes Fs=1.2 from the present safety factor Fs=1.0. Concrete shafts, steel piles and counterweight fill were compared. *Table 6.2* shows the comparison. The counterweight fill was employed in Block E as it is the most reliable method and the location of the slide against the river course. As for Block B and A3, counterweight fill is impossible because of its topography, and concrete shafts and steel piles were compared. The geology at the site makes the construction of steel pile very difficult, and the concrete shaft was selected finally. In Block B and A3, horizontal drainage borings (L =50m) were planned to lower the groundwater level.

Table 6.2 Comparison of Landslide Prevention Measures for River Widening

Block Name	Geology	Type of Structures			
		RC-shaft	Steel Piles	Counterweight fill	Earth Anchor
E	Riverbed deposit, Chiquito layor and sliding soil	-	-	X	-
A3	Sliding soil and debris	X	-	-	-
B	Sliding soil and gravel	X	-	-	-

The diameter of the concrete shaft was selected after comparing some cases. Based on the comparison of cost and construction planning, a diameter of 4.0 m was adopted. On the right bank, earth anchor system was adopted in order to cope with the limitation of available land. (Refer to *Figures 6.7(1) and 6.7(2)*).

6.5.2 RIVERBED EXCAVATION

River excavation volume of Priority Project is about 475,000 m^3 between C11 and C27. The hauling will be done by using 10 t dump trucks and 20 t dump trucks depending upon the location of the excavation site. If the excavation site is downstream from the Carias Bridge, it is possible to use 20 t trucks as there is no hindrance of traffic, but if the site is upstream from the bridge only 10 t trucks will be used for hauling.

The effect of the spoil bank to the water level both at the exact location and upstream was studied. It was found that the water level at the spoil bank location will not rise so much but it was planned to protect the private land at the opposite side of the river where a chicken farm is located.

6.5.3 REVETMENT AND DIKE

The location of the revetment and the dikes were studied in detail based on the topographic map along the river. Between C52 and C56, the channel section was modified to accommodate the newly planned bus terminal on the left side of the river.

6.5.4 IMPROVEMENT OF THE PESCADO LAKE OUTLET

Following countermeasures are planned in order to prevent the closure of the outlet of the Pescado Lake.

- Placing of gabion mattress, which is 15 m wide, 60 m long and 0.5 m thick, at outlet;
- Placing of gabion wall, which is 2 m wide, 3 m high and 60 m long, at left and right slope toe;
- Cut of slope, which is in danger of collapse at right slope side.

6.5.5 FORECASTING/WARNING

The system hardware of the flood forecasting/warning was studied and the cost was estimated. Examples of rainfall gauge, water level gauge and telemeter system are shown in *Table 6.3*.

Table 6.3 Flood Forecasting/Warning System

Item	Specification	Number
Rainfall gauge	0.2 mm unit	3
Water level gauge	Water pressure type	3
Telemeter		3

Note: The installation of the system was included in the cost of the projects.

6.6 LANDSLIDE DAMAGE MITIGATION PROJECTS

6.6.1 BERRINCHE

The structural measures planned are as follows:

- removal of top of the landslide mass,
- surface drainage channel,
- sub-surface drainage channel, and
- drainage well.

The location map of the structures is shown in *Figure 4.17,* and *Figures 6.8* and *6.9* show each of the planned structures. The removed soil will be hauled to the same spoil bank as the riverbed excavation.

6.6.2 REPARTO

The structural measures planned are as follows:

- removal of top of the landslide mass,
- surface drainage channel,
- sub-surface drainage channel, and
- drainage well.

The location map of the structures is shown in *Figure 4.18*. *Figure 6.10 and 6.11* shows the structures. The removed soil will be hauled to the same spoil bank as the riverbed excavation

6.6.3 BAMBU

The structures planned are as follows:

- surface drainage channel, and
- gabion mattress.

Figure 4.19 shows the location map of the structures and *Figure 6.12* depicts the concept of each structure.

6.6.4 FORECASTING/WARNING

The system hardware of the landslide forecasting/warning was studied and the cost was estimated. Examples of rainfall gauge and telemeter system are shown in *Table 6.4*.

Table 6.4 Landslide Forecasting/Warning System

Item	Specification	Number
Rainfall gauge	0.2 mm unit	4
Telemeter		4

Note: The installation of the system was included in the cost of the projects.

6.7 OTHER NON-STRUCTURAL PROJECTS

6.7.1 EDUCATION/ENLIGHTENMENT/TRAINING

The education/enlightenment/training program was prepared targeting both the government officials in charge of disaster prevention and school teachers.

(1) Education/Enlightenment/Training for the Government Officials and School Teachers

Training for capacity building was proposed for CODEM officials. The content of the training should be basic knowledge for disaster prevention, collection/processing/transmission of data on disaster. It was also proposed to train the officials in the planning department of the municipality on the land use planning and the land use regulation based on the risk map.

A training program was proposed for disaster prevention education targeting the school teachers. As the school education is the main part of the disaster prevention education, raising the knowledge level of the school teachers was proposed as the first step.

(2) Education/Enlightenment/Training for the Public

It was proposed to perform public education through school education and community education. One purpose of school education is the transfer of memory of disasters to the next generation through the education of past disasters. Another purpose is scientific understanding of disaster mechanism.

In community enlightenment, it was proposed to conduct a basic level education on the relationship between rainfall and flood/landslide, on the activity of the municipality for forecasting/warning/evacuation and on the method of self-protection through the knowledge of landslide disaster symptom. It was proposed to enlighten the public so that they will move out from dangerous areas and will not build new houses in dangerous areas.

6.7.2 DISASTER MANAGEMENT INFORMATION SYSTEM

Construction of a disaster management information system shared by the related agencies was proposed. This system is composed of the following sub-systems:

- Information Collection and Transmission System
- Database System
- Information Processing System
- Decision-support System
- Information Distribution System

The disaster related information is started from flood/landslide forecasting/warning as stated before, including disaster information in an emergency. The GIS base map utilized to create the hazard map in the Study would be applied as the base map of this Disaster Management Information System.

All the governmental agencies related to disaster prevention would be connected with each other through an optical fiber network. Therefore, it is possible for them to exchange information in an emergency and to implement coordinated disaster prevention policies based on a common database.

6.8 OPERATION AND MAINTENANCE

Operation and maintenance plan for the Priority Projects are the same as that of the Master Plan Projects.

6.9 COST ESTIMATE

Detailed cost estimates were carried out for the Priority Projects. The result of the cost estimate is shown in *Table 4.12*.

6.10 IMPLEMENTATION PROGRAM

The implementation program for the Priority Projects was prepared and is shown in *Table 6.5*. The projects were assumed to commence in the year 2002 for the detailed design and finance preparation. According to this schedule, all the Priority Projects will be completed by the year 2007.

6.11 PROJECT EVALUATION

(1) Economic Aspect

The economic evaluation was done only for the Priority Projects. The evaluation method is the same as the Master Plan Projects'. *Table 6.6* shows the result of economic evaluation.

Table 6.6 Flood/Landslide Damage Reduction

Return Period (year)	Damage Reduction (million US$)
5	14.30
10	13.56
15	22.33
50	36.08
Hurrican Mitch (500)	139.19

The economic internal rate of return (EIRR) was calculated at 13.44%. *Table 6.7* shows the Net Present Value (NPV) and Cost Benefit Ratio (B/C) of the Project.

Table 6.7 NPV and B/C for the Priority Projects

Discount Rate	NPV (US$ million)	B/C
4 % (Real yield of the Honduran state bond)	55.73	2.94
8%	16.91	1.71

(2) Financial Aspect

The total project cost of the Priority Projects is US$37 million and it is small enough compared to the total damage in Tegucigalpa by Hurricane Mitch, which is approximately US$500 million. It is also small compared to the average annual repayment (approximately US$90 million) and it is considered that the financial problem is small to implement the projects by foreign loans.

(3) Natural Environmental and Social Aspect

According to the EIA by a local consultant, the result of the above two problems are as follows:

1) Heavy Metal

The heavy metals checked in the Study are Cr (chromium), Ni (nickel), Cu (copper), Zn (zinc), Cd (cadmium), Hg (mercury), Pb (lead) and As (arsenic). The quantity of heavy metal contained in the riverbed material is small enough compared to the standard of EPA and there is no problem of excavation, hauling and depositing of the riverbed material in the project.

2) Resettlement

According to the detailed plan of structural measures, the lone place where the resettlement of people is needed is Reparto and the number of houses affected is 10. Although there was no direct interview with the relevant residents, the community leader of Reparto said that the residents of the area were well aware of the danger and many of them desired to move out from the area to a safer place if possible. Therefore, it is possible to solve the resettlement problem by seriously considering the resettlement destination and the base line of the new settlement area with enough amount of compensation.

Thus, it is considered that the adverse effect of the Priority Projects on the natural and social environment is small.

Chapter 7

Conclusion and Recommendation

CHAPTER 7
CONCLUSION AND RECOMMENDATION

7.1 CONCLUSION

"The Study on Flood Control and Landslide Prevention in the Tegucigalpa Metropolitan Area of the Republic of Honduras" has been completed. There are three purposes of the Study, namely, the establishment of the Master Plan, the Feasibility Study of the Priority Projects and the technology transfer.

The disaster prevention master plan including the flood damage mitigation plan and the landslide damage mitigation plan by structural and non-structural measures was made targeting a storm with a scale of Hurricane Mitch. Implementation of the proposed Master Plan will enable the Municipality of Tegucigalpa to create asafe city in terms of flood and landslide.

The Feasibility Study of the Priority Projects showed that those projects are feasible from economic aspect, financial aspect, environmental aspect and social aspect. It was concluded that implementation of the Priority Projects will give great benefit to the city.

Technology transfer was made through the Study. On-the-job training was made through the discussion on various problems in the projects, the field trip of the counterpart team members together with the Study Team members and through the participatory workshop among the counterpart team members.

7.2 RECOMMENDATIONS

It is recommended that:

(1) The Master Plan proposed in this Study should be designated as the official disaster mitigation master plan for the city of Tegucigalpa by the central as well as the local government of Honduras,

(2) In order to create a safe capital against storms, this disaster prevention master plan should be implemented according to the proposed schedule,

(3) The Priority Projects should be implemented urgently to bring about immediate consequence of the plan,

(4) It is necessary to update this Master Plan with the development of the city to cope with the change of natural and social background of the plan, and

(5) All parties concerned should cooperate in order to make Tegucigalpa City a safe capital.

Tables

Table 2.1 Stratigraphic Table in Target Area

Era	Period	Epoch	Symbols	Features
Cenozoic	Quaternary	alluvial	dt	Detritus sediment (based on a landslide, a slope failure, etc.). It consists of debris and earth and sand.
			Qal	The latest alluvial sediment. It consists of clay , sand and boulders.
			Qe3	Lower terrace sediment : Fan of Sands and cobbles
		pleistocene	Qe2b	Terrace sediment of middle rank : It consists of sand and stones. A matrix is not solid. An old fan or the sediment on the bottom of a river. It mainly consists of volcanic rock after the Tertiary. The color is from dark gray to gray.
			Qe2a	Terrace sediment of middle rank : It consists of sand, stones, and silt.Tightness is good although a matrix is not solid. An old fan or bottom of river, and the sediment of a lake. It mainly consists of rock of Valle de Angeles group, and volcanic rock after the Tertiary. The color is from dark brown to blackish brown.
			Qe1	Higher terrace sediment : It mainly consists of sand and stones, and tuff layer is inserted. By oldest terrace deposits, the matrix is consolidated weakly.
			Qb	Lava of basalt (olivine slanting feldspar and scoria)
			Qan2	It is distributed on the hill of Cerro Grande. It consists of andesite lava. Although the rock itself is precise hard, joint progresses and it is easy to dissociate massively. In the border part of a range, this stratum serves as cap rock and tends to cause a landslide.
			Qan1	It is distributed over the low rank of Qan2. It consists of andesitic and rhyolitic tuff. Banded structure progresses. It is weak in weathering and easly to deteriorate in it. It becomes the cause of a landslide rarely.
			Odt	It is mainly distributed near a Villa Nueva area. It consists of debris of the stones which made the subject rhyolite with a diameter of 20cm – 3m, and has a Vallu de Angeles Group origin. Half a matrix is solid, tightness is good.
	Tertiary	miocene(Padre Miguel Group)	Tpm3	Ignimbritic sequence, upside member: Tuff of rhyolite of many colors.Some sedimentary rocks equipped with volcanic debris, tuff of quartz andesite nature, and tuff that andesitic tuff. This rock itself is massive and it is solid. When a stratum with weak intensity is distributed over the low rank of this stratum, it is easy to generate a landslide.
			Tep	It consists of rhyolitic tuff and conglomerate, sandstone, and siltstone. It deposits in underwater environments, such as a river. Stratified structure progresses almost horizontally. It is easy to dissociate from a stratum side, and may become the cause of a landslide in the part where the stratum inclines.
			Tcg	Cerro Grande member: Ignimbrite and rhyolite lava equipped with the matrix of crystals of the glassy quartz and crystal feldspar of a violet color. The rock itself is very hard, it is strong in weathering, and tends to form a steep cliff. Logic progresses and it is easy to dissociate. When this rock is distributed on a layer with weak intensity, this rock serves as cap rock and it is easy to generate a landslide. The deterioration action is received locally, and in the portion, intensity is falling remarkably and it is easy to generate a slope failure.
			Tpm2	Ignimbritic sequence middle member: Tuff by which quartz andesite nature was divided by class by style rhyolite. Banded structure progresses and it becomes the cause of a layer slide.
			Tpm1	Member of an Ignimbritic sequence low rank: Tuff of rhyolite of many colors. Some sedimentary rocks equipped with volcanic debris, tuff of quartz andesite nature, and andesitic tuff.
			Tpml	Lahars (debris flow tuff) with clast of tertiary volcanic rocks and cretaceous sediments. It consists of debris and consolidated sandstone. It is hardly the cause of a landslide by massive and hard ones.
		oligocene (Matagalpa F.)	Ti	Rhyolitic intrusive rock which is intrusive in Vallu de Angeles Group: Generally along with a dislocation, it is distributed, deterioration is given to Vallu de Angeles Group, and it is easy to become the cause of a slope failure.
			Tm	Matagalpa formation: It consists of tuff, tuff breccia, and the andesite lava which presents a green color as it's base. It is easy to weather and changes in the shape of clay easily near the surface of the earth. For this reason, it is easy to become the cause of a landslide.
Mesozoic	Cretaceous (Valle de Angeles Group)		Krc	Rio Chiquito formation: It consists of mudstone, siltstone, sandstone, thin conglomerate layer, and thin limestone layer. Stratified structure is made. It's colors are blackish brown. It is easy to weather and changes simply to earth and sand. It is the stratum which is easy to generate a landslide and a slope failure.
			Kvn	Villa Nueva formation: Conglomeratic siliciclastic layers (with clast of metamorphic and volcanic rock and limestone). Brown to light red sandstone and some volcanic tuff. Stratified structure progresses partially. It's colors are thin red to dark purple. Although it is strong compared with Krc, the landslide is generated locally.

Table 2.7 Degree of Danger of Landslides

Rank of danger degree	Topographic Characteristics and Observation
A	There are evidences of present or recent movement of the landslide mass. The landslide blocks which moved during Hurricane Mitch or those which are judged as having moved in these ten years. The slip scarp is not covered by any vegetation and where outcrop reveals. Cracks are observed at the boundaries and misalignment of artificial structures are observed. The bottom part of the landmass is swelling out or small slope failure of tongue shape is observed.
B	Although the typical landslide topographic features are observed, it is judged that there are no movement in recent years. (slip scarp or side cracks are covered by vegetation). Without any typical landslide topographic features, following observations are made;there are examples of recent landslides with a similar geological formation in the neighborhood the structure of the land mass is composed of clay or colluvial deposit and it is weak
C	Although the landslide topographic feature is observed, the age of the slide occurrence is old and the block is stable at present. The slip scarp forms a terrace but is covered by debris and surface soil without revealing the original shape. There observed a swelling shape at the bottom but no new collapse or deformation of structures around. There is no symptom of landslide from the hearing of the residents.

Table 2.8 Threshold Values for Slope Failure Danger for Each Geology

Bed rock	Dangerous Slope		notes
	Slope Gradient (degree)	Area (m^2)	
Kvn	30	645,300	
Krc	20	3,183,500	
Tm	20	1,110,300	
Ti	32	200	The value of "Tcg" is adopted.
Tpml	32	18,900	The value of "Tcg" is adopted.
Tpm1	28	1,192,700	Tpm1, Tpm2, and Tpm3 are united and examined.
Tpm2	28	140,500	Tpm1, Tpm2, and Tpm4 are united and examined.
Tcg	32	1,897,300	
Tep	35	299,800	
Tpm3	28	1,958,600	Tpm1, Tpm2, and Tpm4 are united and examined.
Odt	28	14,300	Odt, Qan1, Qan2, and Qb are united and examined.
Qan1	28	265,400	Odt, Qan1, Qan3, and Qb are united and examined.
Qan2	28	272,200	Odt, Qan1, Qan4, and Qb are united and examined.
Qb	28	217,700	Odt, Qan1, Qan5, and Qb are united and examined.
Qe1	20	115,700	Qe1, Qe2a, Qe2b, and Qe3 are united and examined.
Qe2a	20	320,200	Qe1, Qe2a, Qe2b, and Qe4 are united and examined.
Qe2b	20	79,200	Qe1, Qe2a, Qe2b, and Qe5 are united and examined.
Qe3	20	89,100	Qe1, Qe2a, Qe2b, and Qe6 are united and examined.
dt	25	187,900	
ls	22	707,300	
total area(m^2)		12,715,100	-
The rate to whole area		12.1%	-

Table 2.9 Related Disaster Prevention Projects

Field	Project name	Honduran Organization	Donor Organization	Content	Output	Target area	Term	Category
Flood	Inundation survey	SOPTRAVI		Map preparation by field survey	Inundation map	Tegucigalpa urban area	1998	Emergency Rehabilitation
Flood	Inundation survey	SERNA		Map preparation by field survey	Inundation map	Tegucigalpa urban area	1998	Emergency Rehabilitation
Flood	Inundation survey	AMDC		Map preparation by field survey	Inundation map	Tegucigalpa urban area	1998	Emergency Rehabilitation
Landslide	Landslide block identification	SOPTRAVI	Japan	Map preparation by photo analysis	Landslide block map	Tegucigalpa urban area	1998	Emergency Rehabilitation
Road	Rehabilitation of bridges	SOPTRAVI	Japan	Reconstruction of two bridges	Bridge	Tegucigalpa urban area	2000 - 2003	Rehabilitation
Road	Bridge construction	SOPTRAVI	Sweden	Construction of a bridge	Bridge	Tegucigalpa urban area	2002 -	
Road	Bus terminal construction	SMDC		Construction of a new bus terminal along the Choluteca River	Bus terminal	Tegucigalpa urban area		
Landslide	Berrinche landslide mechanism/ countermeasures	SERNA	WB	Investigation on landslide mechanism and proposal of counter measures	Landslide prevention measures	Tegucigalpa urban area	1999 - 2001	Rehabilitation
Watershed management	Concepcion watershed rehabilitation	IHPEJ (NGO)	Catholic Relief Service	Planting of trees, construction of micro sabo dams	Reforestation Micro sabo dams	Watershed of Concepcion dam	1999 - 2002	Watershed management
Watershed management	Bambu reforestation	Eco Bambu (NGO)		Planting of trees	Reforestation	Bambu landslide	1999 -	Watershed management
Water supply	Water supply facilities rehabilitation	SANAA	BID	Reconstruction of Picacho water pipe	Water pipe	Tegucigalpa urban area	1999 - 2001	Rehabilitation
Water supply	Water supply facilities rehabilitation	SANAA	Japan	Reconstruction of water distribution system	Water pipes and tanks	Tegucigalpa urban area	1999 - 2001	Rehabilitation
Institution	Emergency Act Preparation	COPECO	USAID/ UNDP	Preparation of institution for national emergency system	National Emergency Act	Whole country	2001.3 - 2001.8	Preparation Emergency Rehabilitation
Education	Primary education for disaster prevention	COPECO/ Education Ministry/ Red Cross	Red Cross	Education for primary school students		Whole country	Ongoing	
Forecasting/ warning	Forecasting/Warning System Preparation	SERNA/SMN/ ENEE/ SANAA	USGS	Establishment of flood and landslide warning system	Forecasting/warning system		2000.1 - 2001.12	Preparation Emergency
Structural code	Revision of Structural Code	COPECO	World Bank	Revision of structural code to take into account natural disaster	New structural code	Whole country	2000.10 - 2001.9	Preparation
Land use	Preparation of new land use act	SERNA/Justice Ministry		Preparation of new land use act	New land use act	Whole country		
Hazard map	Hazard map preparation	SERNA	USAID	Preparation of hazard map of 40 municipalities including Tegucigalpa	Hazard map	40 municipalities	1999.3 - 2001.11	Preparation
Disaster Prevention	Natural Disaster Vulnerability Reduction	SERNA/COPECO	World Bank	Monitoring/warning, strengthening of local organization	Monitoring system	Whole country	200.11 - 2005.4	Preparation Emergency

Table 4.1 Proposed Master Plan Projects

	Flood Damage Mitigation	Landslide Damage Mitigation	Common
Structural Measures	Choluteca River Improvement Pescado Lake Outlet Improvement	Berrinche Reparto Bambu	-
Non-structural Measures	Watershed Management Land Use Plan/Land Use Regulation Structural Code Application Foecasting/Warning/Evacuation	Land Use Plan/Land Use Regulation Foecasting/Warning/Evacuation	Education/Enlightenment/Training Disaster Management Information System

Table 4.4 Volume Estimation of Erosion/Sediment Control in the Pilot Project Area

Stream	Material	Height (m)	No. Dams	Section (m^2)*	Width (m)	Volume (m^3)
A) Micro SABO Dams						
Q.Santa Elena	Dry masonry	1	923	1.0	5.0	5.0
	Dry masonry	2	53	2.3	10.0	23.0
10	Gavion	3	162	5.0	15.0	75.0
	Gavion	4	14	7.8	20.0	156.0
Sub-total:			1,152			
Q.Jardinera	Dry Masonry	1	574	1.0	5.0	5.0
	Dry Masonry	2	236	2.3	10.0	23.0
	Gavion	3	87	5.0	15.0	75.0
	Gavion	4	-	7.8	20.0	156.0
Sub-total:			897			
Total:			2,049			
B) Vetiver Live Barriers						
				Length (m)	Width (m)	
Q.Santa Elena				6,400	100	
Q.Jardinera				5,550	100	
Total:				11,950		

* Includes energy dissipator

Table 4.5 Inundated Area and Evacuation Places(in case of Hurricane Mitch scale storm)

Inundated Area	Evacuation Place
Barrio El Chile	Colonia El Porvenir's high land
Barrio Abajo	Barrio Abajo, Barrio Los Dolores's high land, Barrio Buenos Aires
Barrio El Centavo	Barrio El Centavo's high land
Barrio La Bolsa	Barrio La Bolsa's high land
Colonia El Prado	Colonia Humuya
Colonia Maradiaga	Barrio La Granja
Campo de Balompie	Colonia Las Brisas's high land
Colonia San Jose De La Vega	Colonia San Jose De La Vega's high land
Colonia Jardines De Loarque	Colonia Jardines De Loarque's high land
Colonia Satelite	Colonia Stelite's high land

Table 4.7 House Relocation for Structural Measures

No.	Block Name	Numbers of influence houses by landslide	Numbers of houses to be relocated for structural measures	Structural Measures Planed
1	Canaan	113	60	Drainage
2	Reparto	452	10	Drainage, Excavation
3	Bambu	42	0	Drainage
4	Bosque	196	40	Drainage
5	Buena Vista	7	2	Drainage
6	Berrinche	361	0	Drainage, Excavation
7	Campo Cielo	25	15	Drainage
8	San Martin	74	60	Drainage, Counter fill
9	Flor 1	21	25	Counter fill
10	Zapote Centro	126	70	Drainage, Counter fill
11	Zapote Norte	4	6	Counter fill, Excavation
12	Villa Union	5	6	Counter fill
13	Brasilia	61	40	Counter fill
14	Centro America	6	2	Counter fill
15	Nueva Esperanza	16	60	Excavation
16	Las Torres Este	19	15	Excavation
17	Las Torres Oeste	15	10	Excavation
Add		*1,543*		

Table 4.8 Proposed Evacuation Site

No.	Name	Proposed Evacuation Site
1	Canaan	The top of the east spur side and the west spur side. C0L.CANAAN
2	Reparto	A top of the spur on the east. COL. GUILLEN
3	Bambu	A Western and eastern top of the spur. Bo.EL EDEN No.1, Co.ALTOS de LA CABANA
4	Bosque	A south flat area. Bo. EL BOSQUE
5	Buena Vista	The flat area of the north side. Bo. BUENA VISTA
6	Berrinche	The left bank of the Choluteca River is dangerous. The hill in the downtown area, or Cerro Grande hill is appropriate. Bo.LA CHIVERA
7	Canpo Ciero	An evacuation area is restricted. The top of the north or west spurs or the Western are comparatively stable, and can be chosen as an evacuation area. Co.CAMPO CIELO, Co.SAN MARTIN
8	San Martin	Surrouning slopes are dangerous. The plateau on the north can be chosen as evacuation site. Co.SAN MARTIN
9	Flor 1	The gentle slope above a northeast side. Co.LA FLOR No.1
10	Zapote centro	Compared with the lower part, the northwest side upper part is safe. Co.FUERZAS ARMADAS
11	Zapote norte	It is better to avoid refuge along the streams. There is a safe place on a south slope. Co.3 de MAYO
12	Villa Union	Since almost all surrounding slopes are hazard areas, they need to choose a far place. The top of the spur 300m southeast is suitable. Co.FLOR No.1
13	Brasilia	The south downward slope has loose land, and can be chosen as an evacuation area. Co.EL CARRIZAL
14	Centro America	The neighborhood has many flat areas and they can be chosen as evacuation areas. Re.CENTRO AMERICA
15	Nueva Esperanza	The upper gentle slope is suitable as an evacuation area. Co.NUEVA ESPERANZA, Co.NUEVA ESPERANZA Ⅲ ETAPA
16	Los Torres este	The plateau top 50m or more away from the cliff above a slope. Co.INESTROZA
17	Los Torres oeste	The plateau top above the south of slope. Co.INESTROZA

Table 4.9 Matrix of Assignment and Functions (before)

		1	2	3	4	5	6	7	8	9	10
		PREVENTIVE MEASURES									
	SUPPORTING COMMITTEE	GENERAL MANAGEMENT	INSTALLATION AND OBSERVATION OF METEOHYDROLOGICAL EQUIP.	DRILL OF EVACUATION	PRESERVATION OF FOODS FOR EMERGENCY	COMMUNICATION SYSTEM FOR EMERGENCY	IMPROVEMENT OF RIVER, MOUNTAIN STREAM, CANAL	LANDSLIDE PROTECTION	MONITORING /REGULATION OF LAND USE	REGULATION OF HOUSE STRUCTURE	WATERSHED MANAGEMENT
1	FFAA			A	A	A	A	A			A
2	BONBEROS			A		A					A
3	CRUZ ROJA HONDURENA			A	A	A					
4	CRUZ VERDE			A	A	A					
5	BOY SCOUTS			A	A	A					A
6	SECRETARIA DE SALUD	A		A	A	A				A	A
7	IHSS										
8	COLEGIO MEDICO										
9	COLEGIO DE ENFERMERAS										
10	UNAH		A	A	A			A	A	A	
11	SOPTRAVI	A	A	A	A	A	A	A		A	
12	MUNICIPALIDAD DC	A		A	A	A	C	C	C	C	C
13	FHIS	A					A	A	A	A	A
14	SERNA	A	C	A			A	A	A	A	A
15	COHDEFOR	A				A	A	A	A		A
6	INA						A	A	A		A
17	SAG				A			A			A
18	SECRETARIA DE EDUCACION	A		A	A		A				A
19	ONGS/OPDS	A			A		A				A
20	CODEM-DC	C	A	C	C	A	A	A	A	A	A
21	ENEE	A	A	A		A					A
22	SECRETARIA DE GOBERNACION								A		
23	POLICIA NACIONAL			A	A	A					
24	SANAA	A	A	A	A	A	A	A	A	A	A
25	HONDUTEL			A	A	A					
26	CONATEL					C					
27	R/AFICIONADOS			A	A	A					
28	SERVICIO METEOROLOGICO NACIONAL		A	A							A
29	MINISTERIO PUBLICO			A	A		A	A	A		
30	INFOP	A		A	A						
31	SECRETARIA DE RR EE										
32	SETCO	A									
33	IHNFA										
34	IHMA			A	A						
35	BANASUPRO			A	A						
36	SECRETARIA DE TRABAJO										
37	SECRETARIA DE FINANZAS	A			A				A		A
38	CARE/CAMI				A						
39	COPECO	A	A	A	A	A		A	A	A	A
40	PMA				A						
41	COLEGIO DE INGENIEROS CIVILES DE HONDURENO									A	
42	COLEGIO DE ARQUITECTOS									A	

Table 4.10 Matrix of Assignment and Functions (during)

		1	2	3	4	5	6	7	8	9	10	11
		EMERGENCY OPERATIONS										
	SUPPORTING COMMITTEE	MONITORING AND ALERT	COMMUNICATIONS	SEARCHES, RESCUE AND EVACUATION	SECURITY	TRANSPORTATION AND MACHINE	TEMPORALY REFUGES AND FOODS	EVALUATION OF DAMAGES AND NECESSITY ANALYSIS	HEALTH	DANGEROUS MATERIALS	FOREST PROTECTION	MANAGEMENT OF INTERNATIONAL COOPERATION
1	FFAA	A	A	C	A	A	A	A	A	A	A	
2	BONBEROS		A	A					A	A	A	
3	CRUZ ROJA HONDURENA	A	A	A		A	A	A	A			A
4	CRUZ VERDE			A			A	A	A			
5	BOY SCOUTS			A	A		A					
6	SECRETARIA DE SALUD		A			A	A	A	C	A		A
7	IHSS								A			
8	COLEGIO MEDICO								A			
9	COLEGIO DE ENFERMERAS								A			
10	UNAH	A					A	A	A	A		
11	SOPTRAVI					C		A				
12	MUNICIPALIDAD DC	A			A	A	C	A			A	A
13	FHIS					A	A	A				
14	SERNA	A				A		A		C	A	
15	COHDEFOR	A	A			A		A			C	
16	INA					A						
17	SAG					A		A		A	A	
18	SECRETARIA DE EDUCACION						A				A	
19	ONGS/OPDS						A					A
20	CODEM	C	C			A	A	C			A	A
21	ENEE	A	A				A	A			A	
22	SECRETARIA DE GOBERNACION							A			A	
23	POLICIA NACIONAL	A	A	A	C					A	A	
24	SANAA	A	A				A	A			A	
25	HONDUTEL		C		A		A					
26	CONATEL	A	A									
27	R/AFICIONADOS	A	A									
28	SERVICIO METEOROLOGICO NACIONAL	A	A								A	
29	MINISTERIO PUBLICO				A					A	A	
30	INFOP						A					
31	SECRETARIA DE RR EE											
32	SETCO		A			A						C
33	IHNFA						A					A
34	IHMA						A					
35	BANASUPRO						A					
36	SECRETARIA DE TRABAJO						A					
37	SECRETARIA DE FINANZAS											A
38	CARE/CAMI											
39	COPECO	A	A	A		A	A	A				A

Table 4.11 Matrix of Assignment and Functions (after)

		1	2	3	4	5	6	7	8		
		OPERATION OF RECONSTRUCTION									
	SUPPORTING COMMITTEE	RECONSTRUCTION OF INFRASTRUCTURE	REHABILITATION OF INSTALLATIONS	STABILIZATION OF LANDSLIDE SITE	CONSTRUCTION OF REFUGEE'S HOUSE	PREVENTION OF EPIDEMIC	EDUCATION FOR REFUGED CHILDREN	SECURITY	INTERNATIONAL COOPERATION MANAGEMENT		
1	FFAA	A			A	A		A			
2	BONBEROS					A					
3	CRUZ ROJA HONDURENA				A	A			A		
4	CRUZ VERDE				A	A			A		
5	BOY SCOUTS										
6	SECRETARIA DE SALUD				A	C	A		A		
7	IHSS					A					
8	COLEGIO MEDICO					A					
9	COLEGIO DE ENFERMERAS					A	A				
10	UNAH		A			A	A				
11	SOPTRAVI	A	A	A	C				A		
12	MUNICIPALIDAD DC	C	A	C	A	A	A	A	A		
13	FHIS	A	A	A	A				A		
14	SERNA	A	A	A	A				A		
15	COHDEFOR		A	A	A						
16	INA				A						
17	SAG										
18	SECRETARIA DE EDUCACION						C		A		
19	ONGS/OPDS	A	A	A	A	A	A		A		
20	CODEM DC	A	C	A	A		A	A	A		
21	ENEE		A		A						
22	SECRETARIA DE GOBERNACION							A			
23	POLICIA NACIONAL(Secretaria de Seguridad)				A			C			
24	SANAA	A	A	A	A	A			A		
25	HONDUTEL		A		A			A			
26	CONATEL		A					A			
27	R/AFICIONADOS										
28	SERVICIO METEOROLOGICO NACIONAL(SOPTRAVI)		A								
29	MINISTERIO PUBLICO				A			A			
30	INFOP				A		A				
31	SECRETARIA DE RR EE								A		
32	SETCO								C		
33	IHNFA						A	A			
34	IHMA										
35	SUPLIDORA NACIONAL DE PRODUCTOS BASICOS BANASUPRO										
36	SECRETARIA DE TRABAJO										
37	SECRETARIA DE FINANZAS								A		
38	CARE/CAMI								A		
39	COPECO		A		A		A		A		
40	PMA				A				A		
41	COLEGIO DE INGENIEROS CIVILES DE HONDURENO	A			A						
42	COLEGIO DE ARQUITECTOS	A			A						
43	OIM				A						

Table 4.12 Project Cost

Items	Unit	Unit Cost(USD)	Master Plan Project Quantity	Master Plan Project Amount(USD) Total	Master Plan Project Amount(USD) L.C.	Master Plan Project Amount(USD) F.C.	Priority Project Quantity	Priority Project Amount(USD) Total	Priority Project Amount(USD) L.C.	Priority Project Amount(USD) F.C.
1. Flood Damage Mitigation				33,124,336.0	25,275,380.1	7,848,955.8		19,971,478.3	13,693,742.9	6,277,735.3
1.1 Structural Measures				31,554,452.7	24,064,697.7	7,489,754.9		19,920,478.3	13,693,742.9	6,226,735.3
Earth excavation	m^3	6.44	709,810	4,571,176.4	1,930,683.2	2,640,493.2	709,810	4,571,176.4	1,930,683.2	2,640,493.2
Rock excavation	m^3	14.50	38,163	553,363.5	304,922.4	248,441.1	38,163	553,363.5	304,922.4	248,441.1
Revetment (A)	m	1,883.25	2,543	4,789,104.8	4,332,229.4	456,875.4	2,543	4,789,104.8	4,332,229.4	456,875.4
Revetment (B)	m	1,878.43	5,175	9,720,875.3	8,791,134.8	929,740.5	0			
Parapet wall	m	296.57	2,451	726,893.1	670,936.7	55,956.3	290	86,005.3	79,384.6	6,620.7
Gabion	m	364.67	3,853	1,405,073.5	1,192,503.5	212,570.0	3,853	1,405,073.5	1,192,503.5	212,570.0
Shaft works	pieces	93,058.30	52	4,839,031.6	3,266,668.6	1,572,363.0	52	4,839,031.6	3,266,668.6	1,572,363.0
Counterweight fill	m^3	0.79	42,631	33,678.5	14,068.2	19,610.3	42,631	33,678.5	14,068.2	19,610.3
Anchor works	ls.	370,220.89	1	370,220.9	205,597.5	164,623.4	1	370,220.9	205,597.5	164,623.4
Spoil Bank	m^3	0.79	959,562	758,053.9	316,655.4	441,398.5	954,797	754,289.5	315,082.9	439,206.5
Gabion h=4m (Spoil Bank)	m	270.64	1,800	487,152.0	392,544.0	94,608.0	1800	487,152.0	392,544.0	94,608.0
Revetment(Spoil Bank)	m	1,883.25	400	753,300.0	681,436.0	71,864.0	400	753,300.0	681,436.0	71,864.0
Parapet wall(Spoil Bank)	m	296.57	300	88,971.0	82,122.0	6,849.0	300	88,971.0	82,122.0	6,849.0
Mallol Bridge Reinforcement	l.s.		1	322,445.6	293,487.9	28,957.7	1	322,445.6	293,487.9	28,957.7
Mallol Bridge Replacement	l.s.	951,867.99	1	951,868.0	826,256.3	125,611.7				
Demolition work (Bridge)	l.s.	316,578.8	1	316,578.9	160,439.1	156,139.8				
Pescado Lagoon	l.s.	77,404.30	1	77,404.3	52,578.8	24,825.5	1	77,404.3	52,578.8	24,825.5
Replacement of Sewage Pipes	m	455.55	1,100	501,105.0	471,570.0	29,535.0	1,100	501,105.0	471,570.0	29,535.0
Replacement of Water Supply	l.s.		1	288,156.4	78,863.9	209,292.5	1	288,156.4	78,863.9	209,292.5
1.2 NoN-Structural Measures				1,569,883.3	1,210,682.4	359,200.9		51,000.0	0.0	51,000.0
Watershed Management	l.s.		1	1,518,883.3	1,210,682.4	308,200.9				
Warning System (Transmitter)	l.s.	17,000.00	3	51,000.0		51,000.0	3	51,000.0		51,000.0
2. Landslide Damage Mitigation				5,248,009.7	3,602,043.8	1,645,965.9		4,548,009.7	2,902,043.8	1,645,965.9
2.1 Structural Measures				4,363,009.7	2,902,043.8	1,460,965.9		4,363,009.7	2,902,043.8	1,460,965.9
Berrinche	l.s.	3,090,747.03	1	3,090,747.0	1,973,840.9	1,116,906.1	1	3,090,747.0	1,973,840.9	1,116,906.1
Reparto	l.s.	1,184,313.06	1	1,184,313.1	860,894.6	323,418.5	1	1,184,313.1	860,894.6	323,418.5
Bambu	l.s.	87,949.58	1	87,949.6	67,308.3	20,641.3	1	87,949.6	67,308.3	20,641.3
2.2 NoN-Structural Measures				885,000.0	700,000.0	185,000.0		185,000.0	0.0	185,000.0
Resettlement	houses	3,500.00	200	700,000.0	700,000.0					
Warning System (Transmitter)	l.s.	15,000.00	4	60,000.0		60,000.0	4	60,000.0		60,000.0
(Receiver)	l.s.	125,000.00	1	125,000.0		125,000.0	1	125,000.0		125,000.0
3. Other				2,000,000.0	2,000,000.0	0.0		500,000.0	500,000.0	0.0
Education	l.s.		1	1,000,000.0	1,000,000.0		1	500,000.0	500,000.0	
Disaster Mitigation System	l.s.		1	1,000,000.0	1,000,000.0					
4. Direct Construction Cost				40,372,345.7	30,877,423.9	9,494,921.7		25,019,488.0	17,095,786.7	7,923,701.2
5. Administration	l.s.	-		2,492,102.1	2,492,102.1			1,724,459.2	1,724,459.2	
Administration	l.s.			2,018,617.3	2,018,617.3			1,250,974.4	1,250,974.4	
Land cost	houses	47,348.48	10	473,484.8	473,484.8		10	473,484.8	473,484.8	
6. Engineering service	l.s.	-		6,789,595.3	1,701,795.3	5,087,800.0		3,615,317.6	975,717.6	2,639,600.0
7. Physical contingency	l.s.	-		4,037,234.6	3,087,742.4	949,492.2		2,501,948.8	1,709,578.7	792,370.1
(Sub-total : 4+5+6+7)				53,691,277.7	38,159,063.7	15,532,213.9		32,861,213.6	21,505,542.2	11,355,671.3
8. Price contingency	l.s.	-		10,220,000.0	7,710,000.0	2,510,000.0		3,830,000.0	2,530,000.0	1,300,000.0
Total				**63,911,277.7**	45,869,063.7	18,042,213.9		**36,691,213.6**	24,035,542.2	12,655,671.3

Table 4.13 Implementation Program

Items	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Detailed Design	■					■										
Tendering Procedure		■					■									
Construction			■	■	■			■	■	■						
1 **Structural Measures**																
Earth excavation			■	■	■											
Rock excavation				■	■											
Revetment (A)			■	■	■											
Revetment (B)								■	■	■						
Gabion				■	■											
Parapet wall					■			■	■	■						
Shaft works			■	■	■											
Counterweight fill				■												
Anchor works			■													
Spoil Bank			■	■	■			■	■	■						
Gabion (Spoil Bank)			■	■	■											
Revetment(Spoil Bank)			■													
Parapet wall (spoil Bank)				■												
Pescado Lagoon			■													
Mallol Bridge(Reinforcement)			■													
Mallol Bridge(Replacement)								■	■	■						
Demolition Work								■								
Replacement of Sewage Pipes			■	■												
Replacement of Water Supply			■	■												
NoN-Structural Measures																
Watershed Management								■	■	■	■	■	■	■		
Warning System			■													
2 **Landslide Prevention**																
Structural Measures																
Berrinche			■	■	■											
Reparto			■	■												
Bambu			■													
NoN-Structural Measures																
Resettlement								■	■	■						
Warning System			■													
3 **Other**																
Education			■	■	■	■	■	■	■	■						
Disaster Mitigation System			■	■	■	■	■	■	■	■	■	■	■	■		
Administration			■	■	■	■	■	■	■	■						
Construction Supervision			■	■	■			■	■	■						

Table 5.3 Screening (Flood Control and Landslide Prevention)

Environmental Item			Description	Evaluation	Remarks (reason)
Social Environment	1	Resettlement	Resettlement due to land occupancy (transfer of rights of residence/land ownership)	Y	Reparto landslide prevention
	2	Economic Activities	Loss of base of economic activities, such as land, and change of economic structure	N	
	3	Traffic and Public Facilities	Impacts on schools, hospitals and present traffic conditions, such as the increase of traffic congestion and accidents	Y	Traffic for civil works
	4	Split of Communities	Community split due to interruption of area traffic	N	
	5	Cultural Properties	Damage to or loss of value of churches, temples, shrines, archeological remaining or other cultural assets	Y	Mallol Bridge
	6	Water Rights and Rights of Common	Obstruction of fishing rights, water rights, rights of common	N	
	7	Public Health Condition	Worsening of public health and sanitation conditions due to the generation of garbage and the increase of vermin	N	
	8	Waste	Generation of construction waste, debris and logs	Y	Civil works
	9	Hazard(risk)	Increase in danger from ground failures, caverns, etc.	N	
Natural environment	10	Topography and Geology	Changes of valuable topography and geology due to excavation or filling work	N	
	11	Soil Erosion	Topsoil erosion by rainfall after reclamation and deforestation	N	
	12	Groundwater	Lowering of the groundwater table due to over drafting and turbid water caused by construction work	Y	Drainage works
	13	Hydrological Situation	Changes of river discharge, flow velocity and riverbeds condition due to filling work and diversion channel	Y	Riverbed excavation
	14	Coastal Zone	Coastal erosion and change of vegetation due to coastal reclamation and coastal changes	N	
	15	Fauna and Flora	Obstruction of breeding and extinction of species due to change of habitat conditions	Not known	
	16	Meteorology	Changes of temperature, rainfall, wind, etc, due to large-scale reclamation and building construction	N	
	17	Landscape	Changes of topography and vegetation due to reclamation. Deterioration of aesthetic harmony by structures	N	
Pollution	18	Air Pollution	Pollution caused by exhaust gas or toxic gas from vehicles or factories	Y	Traffic of civil work
	19	Water Pollution	Pollution caused by the decrease of discharge or the inflow of sediment	Y	Riverbed excavation
	20	Soil Contamination	Contamination caused by discharge of diffusion of sewage or toxic substances	Not known	Riverbed excavation
	21	Noise and Vibration	Noise and vibrations generated by vehicles and pumping operations	Y	By civil works
	22	Land Subsidence	Deformation of the land and land subsidence due to lowering of groundwater table	N	
	23	Offensive Odor	Generation of exhaust gas and offensive odor by facility construction and operation	N	

Table 5.4 Scoping

Environmental item			Evaluation	Reason
Social environment	1	Resettlement	B	Ten houses to be resettled by Reparto landslide prevention works
	2	Economic Activities	D	No effect
	3	Traffic and Public Facilities	D	No effect
	4	Split of Communities	D	No effect
	5	Cultural Properties	A	Historical structures in Centro and Comayaguela near the Choluteca River
	6	Water Rights and Rights of Common	D	No effect
	7	Public Health Condition	D	No effect
	8	Waste	B	Produced by civil works
	9	Hazard(risk)	D	No effect
Natural environment	10	Topography and Geology	D	No effect
	11	Soil Erosion	D	No effect
	12	Groundwater	D	Drainage work will lower the groundwater table
	13	Hydrological Situation	D	No effect
	14	Coastal Zone	D	No effect
	15	Fauna and Flora	C	To be checked in the field reconnaissance
	16	Meteorology	D	No effect
	17	Landscape	D	No effect
Pollution	18	Air Pollution	C	By civil works
	19	Water Pollution	B	By civil works
	20	Soil Contamination	C	To be checked in sampling and testing
	21	Noise and Vibration	B	By civil works
	22	Land Subsidence	D	No effect
	23	Offensive Odor	D	No effect

Note 1; evaluation categories:

A: serious impact is expected

B: some impact is expected

C: extent of impact is unknown(examination is needed. Impact may become clear as study progresses.)

D: no impact is expected. IEE/EIA is not necessary

Note 2; evaluation should be made with reference to the "explanation of item"

Table 6.1 Boring Investigation

Borehole No.	Depth (m)	Borehole No.	Depth (m)
El Berrinche		C-1	15
B-1	40	C-2a	17
B-2	50	C-2b	8
B-3	35	C-3	20
B-4	25	C-4	15
B-5	25	***El Reparto***	
B-6	60	R-1	39
B-7	25	R-2	30
B-8	25	R-3	35
B-9	30	R-4	35
W-1	25	R-5	7
W-2	35	R-6	4

Total Linear Meters Cored	**600 m**

Table 6.5 Implementation Program

Items	2002	2003	2004	2005	2006
Detailed Design	■				
Tendering Procedure		■			
Construction			■	■	■
1 **Structural Measures**					
Earth excavation			■	■	■
Rock excavation				■	■
Revetment (A)			■	■	■
Revetment (B)					
Gabion				■	■
Parapet wall					■
Shaft works			■	■	■
Counterweight fill				■	
Anchor works			■		
Spoil Bank			■	■	■
Gabion (Spoil Bank)			■	■	■
Revetment(Spoil Bank)			■		
Parapet wall (spoil Bank)				■	
Pescado Lagoon			■		
Mallol Bridge(Reinforcement)			■		
Mallol Bridge(Replacement)					
Demolition Work					
Replacement of Sewage Pipes			■	■	
Replacement of Water Supply			■	■	
NoN-Structural Measures					
Watershed Management					
Warning System			■		
2 **Landslide Prevention**					
Structural Measures					
Berrinche			■	■	■
Reparto			■	■	
Bambu			■		
NoN-Structural Measures					
Resettlement					
Warning System			■		
3 **Other**					
Education			■	■	■
Disaster Mitigation System			■	■	■
Administration			■	■	■
Construction Supervision			■	■	■