No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

METROPOLITAN DISTRICT OF CARACAS
BOLIVARIAN REPUBLIC OF VENEZUELA

STUDY ON

DISASTER PREVENTION BASIC PLAN IN THE METROPOLITAN DISTRICT OF CARACAS IN THE BOLIVARIAN REPUBLIC OF VENEZUELA

FINAL REPORT
SUMMARY

March 2005

PACIFIC CONSULTANTS INTERNATIONAL
In association with
OYO INTERNATIONAL CORPORATION

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PREFACE

In response to the request from the Government of the Bolivarian Republic of Venezuela, the Government of Japan decided to conduct the Study on the Disaster Prevention Basic Plan in the Metropolitan District of Caracas and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched the study team headed by Mr. Mitsuo MIURA of Pacific Consultants International (PCI) and composed of staff members of PCI and OYO International Corporation to Venezuela, seven times from December 2002 to March 2005. In addition, JICA set up the advisory committee headed by Mr. Yasuo NAKANO and Mr. Haruo NISHIMOTO, Japan International Cooperation Agency, from December 2002 to March 2005, which examined the Study from the technical points of view.

The team held discussions with the officials concerned of the Bolivarian Republic of Venezuela 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 Bolivarian Republic of Venezuela for their close cooperation extended to the team.

March, 2005

Etsuo Kitahara

Vice President

Japan International Cooperation Agency

THE STUDY ON THE DISASTER PREVENTION BASIC PLAN IN THE METROPOLITAN DISTRICT OF CARACAS, THE BOLIVARIAN REPUBLIC OF VENEZUELA

March, 2005

Mr. Etsuo Kitahara

Vice President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit you the final report entitled "the Study on the Disaster Prevention Basic Plan in the Metropolitan District of Caracas, Bolivarian Republic of Venezuela". This report has been prepared by the Study Team in accordance with the contracts signed on 9 December 2002, 7 May 2003 and 30 April 2004 between the Japan International Cooperation Agency and the Joint Study Team of Pacific Consultants International and OYO International Corporation.

The report examines the existing conditions related to earthquake and sediment disasters in the three municipalities in the Metropolitan District of Caracas and presents the master plan for the disaster prevention of the area. It also presents the result of the feasibility study of the priority projects selected from the master projects.

The report consists of the Summary, Main Report, Supporting Report, Data Book 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. The Maps contains the important maps prepared in the Study.

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, Japan Bank for International Cooperation, Embassy of Japan in the Bolivarian Republic of Venezuela, and other donors, and also to Venezuelan 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 disaster prevention of the Metropolitan District of Caracas, and that friendly relations of both countries will be promoted further by this occasion.

Yours faithfully,

Mitsuo Miura
Team Leader

EXECUTIVE SUMMARY

STUDY ON DISASTER PREVENTION BASIC PLAN

FOR THE METROPOLITAN DISTRICT OF CARACAS

Existing Problems and Target of the Master Plan

Caracas is the largest city of Venezuela and has a population of 3.1 million and 777 km^2 of area. It also has the largest concentration of asset is the nation. Much more, it has a function of capital city with the administration of national government, national congress and the supreme court as well as the headquarter of national bank.

Caracas has been experiencing several large scale earthquakes since its history began in 16^{th} century. The largest earthquake hit the city is in 1812, when around 2,000 people lost their lives. The most recent earthquake is in 1967, when about 1,800 buildings damaged and 274 people died. Thus, Caracas has possibility of large earthquakes such as 1812 earthquake or 1967 earthquake.
Caracas also has a history of frequent sediment disasters. In December 1999, Caracas was hit by a heavy rainfall caused by cold weather front from Caribbean Sea and debris flow was generated in the mountain streams of Catuche and Anauco. It caused death of around 100 people. Similar debris flow occurred in February of 1951. Thus, Caracas has possibility of debris flow such as 1951 or 1999 in future.

The disaster prevention administration in the Metropolitan District of Caracas is defined in the "Law of Organization for Civil Protection and Disaster Administration" issued in 2001. The responsibility of Civil Protection of national and regional level is clearly defined there and one of the responsibilities of the Civil Protection of ADMC is to prepare a regional disaster prevention plan for the Metropolitan District of Caracas but the plan is not being prepared. The national disaster prevention plan, which would be the guideline for the regional disaster prevention plan is not being prepared either.

Thus, the Metropolitan District of Caracas, the most important city of the nation, is under a threat of natural hazard such as earthquakes and sediment disasters. However, the disaster prevention administration is under development and the regional plan for disaster prevention is not being prepared yet.

Based on the above mentioned background, the target of the disaster prevention master plan for the area is as follows;

1. Even with the occurrence of 1967 scale earthquake or 1812 scale earthquake, the human lives will be saved. The assets damage will be minimized. The important function of the city such as main road, lifelines and disaster prevention administration function will be preserved.
2. Even with the occurrence of debris flow with the scale of 1999 Caracas by the rainfall of once in hundred years, buildings and human lives along the mountain streams will be saved.
3. Human lives will be saved from landslides or steep slope failures in the area.

Master Plan

1. Master Plan Projects

In order to attain the above targets, 20 projects were proposed and seven major projects were selected among them taking into account "significance", "urgency", "intention of the counterpart", etc. The seven major projects are as follows;

Projects for "Making a Safer Caracas"

1. Seismic Reinforcement of Buildings (Ministry of Housing, FUNVI, Municipalities)
2. Seismic Reinforcement of Bridges (Ministry of Infrastructure)
3. Debris Flow Control Structures (Ministry of Environment and Natural Resources)
4. Resettlement of People Living in River Channels (Ministry of Planning and Development, Urban Planning and Environment Secretary ADMC, Municipalities)

Projects for "Acting Effectively in Emergency"

5. Early Warning and Evacuation (Ministry of Environment and Natural Resources, Civil Protection ADMC, Civil Protection Municipalities)
6. Emergency Command Center (Civil Protection ADMC)

Project for "Strengthening Coordination between the Government and the Citizens"

7. Strengthening Community Activities (Civil Protection National, ADMC, Municipalities)

2. Project Cost

Approximately 2,800 Million US$ for 16 years of period

3. Evaluation of the Master Plan

Economic	Total economic evaluation is difficult but the seismic reinforcement of building project, which occupies a large portion of the plan makes its economic benefit equivalent to the economic cost.
Financial	The total project cost is around 2 % of the national GDP and around 10% of the national budget. The financial effect is large considering the importance of the area.
Social	It is possible to reduce the number of casualties significantly by employing the projects of "seismic reinforcement of buildings", "debris flow control structures", "resettlement of people from risky area", and "land use and development regulation", giving big social benefit.
Technical	All the projects are possible by local technologies.
Environmental	The Sabo dams of the debris flow control structures are planned inside of the Avila National Park. The environmental aspect of the project was explained and admitted by the Ministry of Environment and Natural Resources, with the condition of design and construction method appreciating environmental conservation.

Feasibility Study of Priority Projects

1. Selection of Priority Projects

According to the selection criteria of "significance", "urgency", "prompt consequences", "technology", "economics", "environmental effect", "social needs", "intention of the counterpart", etc, two projects were selected for feasibility study.

Seismic Reinforcement of Buildings: Structural Measures for Earthquake Disaster Prevention (Joint Study with FUNVISIS)

Early Warning and Evacuation for Debris Flow Disaster Prevention: Non-structural Measures for Sediment Disaster Prevention (Joint Study with IMF-UCV)

2. Project Description

a. Seismic Reinforcement of Buildings

Among 310,000 buildings in the target area, around 180,000 buildings will be reinforced. The reinforcement method for urban area houses is proposed to be based on 2001 building code. The reinforcement method for barrio area houses was studied by a field test in the Study.

b. Early Warning and Evacuation for Debris Flow Disaster Prevention

The meteorological/hydrological observation network as well as communication network will be installed. The critical rainfall amount will be designed for early warning indicators. The institutional framework composed of the Ministry of Environment and Natural Resources, the Civil Protection ADMC, Civil Protection Municipalities and Communities, will be established based on the agreement signed by the parties involved.

3. Project Cost and Implementation schedule

3.1 Reinforcement of Buildings 2,600 MUSD

Rapid Visual Screening	2005-2008
Detail Seismic Evaluation	2005-2018
Reinforcement Design	2005-2019
Reinforcement Work	2007-2020

3.2 Early Warning and Evacuation 1 MUSD

Establishment of Agreement	2005-2006
Establishment of Information System	2006-2007
Emergency Command Center	2006-2007
Implementation of Early Warning and Evacuation	2006-2007

4. Effect of the Project

4.1 Seismic Reinforcement of Buildings

The project will reduce the number of heavily damaged buildings from aroudn 10,000 to around 1,300 and the number of casualties from froudn 4,900 to around 400 in the case of 1967 earthquake. It will reduce the number of heavily damaged buildings from around 32,000 to around 2,300 and the number of casualties from around 20,000 to around 2,300 in the caseof 1812 earthquake.

4.2 Early Warning and Evacuation for Debris Flow Disaster Prevention

By the implementation of the project, it will become possible for the 19,000 pople living in the risky area ofdebris flow of various scales.

5. Project Evaluation

5.1 Seismic Reinforcement of Buildings

Economic : The economic benefit is equivalent to the economic cost. The benefit of the project in the case of 1967 earthquake is calculated as around 530 million dollars by combining direct and indirect benefit. This value is equivalent to the reinforcement cost of 10,000 buildings, which are estimated to be heavily damaged by the 1967 earthquake.

Financial: The project cost is 3 % of the national GDP and the most of it is paid by the building owners. The people in urban area can afford to pay the cost but it is necessary ot subsidize for the people in barrio area.

Technical: The prject is technically feasible including barrio houses.

Social: It is th most effective method to reduce the number of casualties.

5.2 Early Warning and Evacuation for Debris Flow Disaster Prevention

Economic : The economic evaluation is difficutl because it will not preserve properties.

Financial: The project cost is 1 % of ADMC budget and it is justifed to invest considering the importance of the area.

Technical: The project is technically feasible based on the accurate meteorological/hydrological observation and debris flow observation by the initiative of the Ministry of Environment and Natural Resources.

Social: The community organizations of the area is generally active and it is possible to establish early warning and evacuation system utilizing the existing community organizations.

Limitation of the Study

There are following limitations of the Study. As the Study has been done with the following limitations, it is necessary to continue further investigations and discussion in order to supplement those limitations.

(1) Study Area

Although, the title of the Study is “Study on Disaster Prevention Basic Plan for the Metropolitan District of Caracas”, the Study area does not cover all the five municipalities in the Metropolitan District, namely Libertador, Chacao, Sucre, Baruta and El Hatillo. The Study area is limited to the three municipalities, namely Libertador, Chacao and Sucre. This is because the Scope of Work signed in March 21st, 2002 defines it and the Minutes of Meetings signed at the same time says that “ In the future the Metropolitan District of Caracas office of the Mayor will apply knowledge and methodology obtained through the course of the Study to formulate disaster prevention plan for

Baruta and El Hatillo municipalities". It is expected that the Venezuelan side will formulate the plan for the rest of the Metropolitan District of Caracas based on the idea stated in the Minutes of Meetings.

(2) Legal Status of the Restlu of the Study
According to the "Law of the National Organization of Civil Protection and Administration of Disasters (Ley de la Organización Nacional de Protección Civil y Administración de Desastres) ", regional disaster prevention plans shall be proposed by the regional Civil Protection offices to the Coordination Committee for Civil Protection and Administration of Disasters in each region for final authorization. Therefore, the Disaster Prevention Plan prepared in the Study shall be reviewed by the Metropolitan Civil Protection and shall be proposed to the Metropolitan Committee for Civil Protection and Administration of Disasters for final authorization.

(3) Employment of deterministic approach in earthquake disaster prevention
There are two approaches to evaluate the effect of earthquake, deterministic and probabilistic.
In this study, deterministic approach is employed, which defines several scenario earthquakes and estimates ground motions and its damages to establish a plan for earthquake disaster prevention.
On the other hand, the probabilistic approach considers all possible earthquakes that would affects the study area, to estimate the ground motion for fixed period of time and fixed probability of occurrence. The result ground motion is not the one that would happen during an earthquake, and will be used for the establishment of seismic code or calculation of insurance premium.
In this study, deterministic approach is employed and its results are used to prepare an emergency response plan, since the object of the study is to establish an earthquake disaster prevention plan. With respect to the seismic reinforcement plan of existing buildings, all the necessary buildings were considered, because the area that needs reinforcement cannot be specified due to the fact that the location of future earthquake cannot be predicted.

(4) Effect of scenario earthquake
In this study, typical past earthquakes were considered as scenario earthquake, because the earthquake prediction for future events is difficult. Scenario earthquakes considered in this study do not mean the prediction nor prophesy of earthquake in the future, but they should be used to understand the magnitude of damage in case same earthquake that occurred in the past happens today.
As there are numerous studies regarding the past major earthquakes, several models can be developed regarding the fault location of scenario earthquake. In this study, model that can best reproduce the observed damage or ground motion was adopted. It should be noted that higher damage degree in the northwestern part of Caracas metropolitan area by the 1967 and the 1812 scenario earthquakes are due to the fact that those earthquake fault are located in the northwestern part of Caracas.

(5) Damage function of buildings
In this study, statisitcal treatment is necessary to estimate damage of all the building in the study area by scenario earthquake. For this reason, the whole buildings needs be classified into several groups. While strucurral details such as configurations, irregularity, and disposition of wall are important factors to inspect individual buildings. However, basic factors such as structural type, year of construction, and number of floors are used to classify buildings for statistical damage estimation of all buildings in this study.
The damage function used in this study to estimate buildings' damage was developped through discussion with experts in FUNVISIS using earthquake damage data in Europian countries and the 1967 Caracas earthquake, based on EMS-98 (European Macroseismic Scale 1998). The defined function was calibrated by observed damage by the 1967 Caracas earthquake.
It sould be noted that building database of urban area was developped by field sampling in this study, because cadastral database was not a complete one. Building database for Barrio was developped also by estimation using the relationship between area and number of houses in Barrio. Development of

better quality database as well as damage study by statistical manner during major earthquake would be necessary to improve the methodology.

(6) Barrio Building breaking test

The building breaking test was executed to obtain a data on strength of houses in Barrio area, in addition to make an educational material to promote seismic reinforcement. By this nature, the test does not intended to propose a concrete method of reinforcement. As this kind of experiment was made for the first time in Venezuela, yet only four models are tested, it is recommended to continue this kind of experiment by Venezuelan side in the future.

(7) Exclusion of Flood and Urban Draiange Problems

The sediment disasters defined in the Study does not include flood problems nor urban drainage problems. Flood problems are for example, the inundation around Gaire River because of mal-cpacity of the river course. Urban drainage problems are for example, the inundation in the urban area because of mal-capacity of drainage system when a heavy rainfall ocures in the urban area itself. Both problems are different from sediment disasters defined in the Study (debris flow, land slide and steep slope failure) and are excluded from the Study Scope.

STUDY ON
DISASTER PREVENTION BASIC PLAN
IN THE METROPOLITAN DISTRICT OF CARACAS

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CHAPTER 1

INTRODUCTION

CHAPTER 1. INTRODUCTION

1. 1 General Information

In response to the request presented by the Government of the Metropolitan District of Caracas, through the Government of the Bolivarian Republic of Venezuela, (hereinafter referred to as the Government of Venezuela), the Japanese Government, through the Japan International Cooperation Agency (JICA), official agency responsible of the technical cooperation program, in accordance with the relevant laws and regulations in force in Japan, has agreed to conduct the Study on the Disaster Prevention Basic Plan in the Metropolitan District of Caracas.

Consequently, in March 2002, JICA dispatched the Preparatory Study Team headed by Mr. Yasuo Nakano, in order to make the preliminary evaluation as well as the Scope of Work for the Study. Based on the discussion between the Government of the Metropolitan District of Caracas and the JICA Preparatory Study Team, the Scope of Work was established by the respective Minutes of Meeting.

In accordance with the Scope of Work, the JICA Study Team was constituted, and later came to Venezuela in order to begin the Study on May 7th 2003. The Study has been conducted according to the initial schedule and by March 5^{th} 2004, all the Study in Venezuela was completed. This Final Report includes all the result of the study up to date.

1. 2 Objectives of the Study

The objectives of the Study, included in the Scope of Work, are as follows:

1. To formulate a master plan in order to prevent the Metropolitan District of Caracas from damage resulting from natural disasters due to sediment, mass movement and earthquake.
2. To conduct a feasibility study on urgent and priority project(s).
3. To transfer technology to the counterpart personnel in the course of the Study.

1. 3 Study Area

As a whole, the study area includes two different aspects: one for earthquake disaster prevention and another for sediment disaster prevention formed by debris flow, landslide and steep slope failure.

The area destined to the earthquake aspect covers all the territory of the Libertador, Sucre and Chacao Municipalities. The study area for sediment disaster is specified in the Figure 1.3.1, and covers all the previously mentioned municipalities limited from north to south by El Avila Mountain Range to the

North and the Guaire River to the South, to the East the Caurimare Stream in the Sucre Municipality and the Caroata and Agua Salada Streams to the west.

1. 4 Study Organization

The organization of the JICA Study Team is showed in Figure 1.4.1.

For this, in Venezuelan side, a task force has been made, integrated by a General Coordination, through the Metropolitan Direction of International Cooperation, a Steering Committee, a Technical Committee and the National Counterpart Team as showed in Figure 1.4.2.

1. 5 Composition of the Final Report

(1) Composition of the Final Report

This Final Report is composed of the following volumes;

Summary Report	English
Summary Report	Spanish
Main Report	English
Main Report	Spanish
Supporting Report	English
Supporting Report	Spanish
Data Book	English
Data Book	Spanish
Maps	English
Maps	Spanish

(2) Composition of the this Summary Report

This Summary Report is composed of the following chapters;

Chapter 1	Introduction	: study purpose and study area and etc.
Chapter 2	Existing Conditions	: natural and social conditions
Chapter 3	Earthquake Disaster Study	: earthquake disaster prevention study
Chapter 4	Sediment Disaster Study	: sediment disaster prevention study
Chapter 5	Social Studies	: institution/peoples organization/social survey
Chapter 6	Disaster Scenarios	: disaster scenarios as basis of the plan

Chapter 7	Planning Basis	: basic policy of the plan
Chapter 8	Disaster Prevention Basic Plan	: disaster prevention plan
Chapter 9	Evaluation of the Plan	: evaluation of the plan
Chapter 10	Feasibility Study of Priority Projects	: feasibility study for selected projects
Chapter 11	Geographical Information System (GIS) and Database System	: GIS
Chapter 12	Conclusion and Recommendation	: conclusion of the study and recommendation

1. 6 Limitation of the Study

There are following limitations of the Study. As the Study has been done with the following limitations, it is necessary to continue further investigations and discussion in order to supplement those limitations.

(1) Study Area

Although, the title of the Study is "Study on Disaster Prevention Basic Plan for the Metropolitan District of Caracas", the Study area does not cover all the five municipalities in the Metropolitan District, namely Libertador, Chacao, Sucre, Baruta and El Hatillo. The Study area is limited to the three municipalities, namely Libertador, Chacao and Sucre. This is because the Scope of Work signed in March 21st, 2002 defines it and the Minutes of Meetings signed at the same time says that " In the future the Metropolitan District of Caracas office of the Mayor will apply knowledge and methodology obtained through the course of the Study to formulate disaster prevention plan for Baruta and El Hatillo municipalities". It is expected that the Venezuelan side will formulate the plan for the rest of the Metropolitan District of Caracas based on the idea stated in the Minutes of Meetings.

(2) Legal Status of the Restlu of the Study

According to the "Law of the National Organization of Civil Protection and Administration of Disasters (Ley de la Organización Nacional de Protección Civil y Administración de Desastres) ", regional disaster prevention plans shall be proposed by the regional Civil Protection offices to the Coordination Committee for Civil Protection and Administration of Disasters in each region for final authorization. Therefore, the Disaster Prevention Plan prepared in the Study shall be reviewed by the Metropolitan Civil Protection and shall be proposed to the Metropolitan Committee for Civil Protection and Administration of Disasters for final authorization.

(3)Employment of deterministic approach in earthquake disaster prevention

There are two approaches to evaluate the effect of earthquake, deterministic and probabilistic.

In this study, deterministic approach is employed, which defines several scenario earthquakes and estimates ground motions and its damages to establish a plan for earthquake disaster prevention.
On the other hand, the probabilistic approach considers all possible earthquakes that would affects the study area, to estimate the ground motion for fixed period of time and fixed probability of occurrence. The result ground motion is not the one that would happen during an earthquake, and will be used for the establishment of seismic code or calculation of insurance premium.
In this study, deterministic approach is employed and its results are used to prepare an emergency response plan, since the object of the study is to establish an earthquake disaster prevention plan. With respect to the seismic reinforcement plan of existing buildings, all the necessary buildings were considered, because the area that needs reinforcement cannot be specified due to the fact that the location of future earthquake cannot be predicted.

(4)Effect of scenario earthquake

In this study, typical past earthquakes were considered as scenario earthquake, because the earthquake prediction for future events is difficult. Scenario earthquakes considered in this study do not mean the prediction nor prophesy of earthquake in the future, but they should be used to understand the magnitude of damage in case same earthquake that occurred in the past happens today.
As there are numerous studies regarding the past major earthquakes, several models can be developed regarding the fault location of scenario earthquake. In this study, model that can best reproduce the observed damage or ground motion was adopted. It should be noted that higher damage degree in the northwestern part of Caracas metropolitan area by the 1967 and the 1812 scenario earthquakes are due to the fact that those earthquake fault are located in the northwestern part of Caracas.

(5) Damage function of buildings

In this study, statisitcal treatment is necessary to estimate damage of all the building in the study area by scenario earthquake. For this reason, the whole buildings needs be classified into several groups. While strucurral details such as configurations, irregularity, and disposition of wall are important factors to inspect individual buildings. However, basic factors such as structural type, year of construction, and number of floors are used to classify buildings for statistical damage estimation of all buildings in this study.
The damage function used in this study to estimate buildings‘ damage was developped through discussion with experts in FUNVISIS using earthquake damage data in Europian countries and the 1967 Caracas earthquake, based on EMS-98 (European Macroseismic Scale 1998). The defined function was calibrated by observed damage by the 1967 Caracas earthquake.
It sould be noted that building database of urban area was developped by field sampling in this study, because cadastral database was not a complete one. Building database for Barrio was developped also by estimation using the relationship between area and number of houses in Barrio. Development of

better quality database as well as damage study by statistical manner during major earthquake would be necessary to improve the methodology.

(6) Barrio Building breaking test

The building breaking test was executed to obtain a data on strength of houses in Barrio area, in addition to make an educational material to promote seismic reinforcement. By this nature, the test does not intended to propose a concrete method of reinforcement. As this kind of experiment was made for the first time in Venezuela, yet only four models are tested, it is recommended to continue this kind of experiment by Venezuelan side in the future.

(7) Exclusion of Flood and Urban Draiange Problems

The sediment disasters defined in the Study does not include flood problems nor urban drainage problems. Flood problems are for example, the inundation around Gaire River because of mal-cpacity of the river course. Urban drainage problems are for example, the inundation in the urban area because of mal-capacity of drainage system when a heavy rainfall ocures in the urban area itself. Both problems are different from sediment disasters defined in the Study (debris flow, land slide and steep slope failure) and are excluded from the Study Scope.

1. 7 Acknowledgements

All of the work presented in this Draft Final Report has been accomplished thanks to the contribution of several public and private institutions, communities and non-governmental organizations. We sincerely acknowledge the fruitful cooperation and support of the Government of the Metropolitan District of Caracas, specially the Direction of International Cooperation as general coordinator of the Study, the Metropolitan Firefighters Department for making their facilities available, and the Direction of Civil Protection of the Metropolitan District for its kind support and contribution to the Study. Also, we would like to thank all the people and organizations that provided essential information and expertise, and those who had an instrumental role in making this international cooperation study possible. We would like to express our sincerest gratitude to all Venezuelan counterpart who worked together with us through all stages of the Study, and all the people who participated in the exhaustive revision of this document. Our sincerest regards are to the following institutions:

ADMC, Direction of International Cooperation
ADMC, Direction of Public Works and Services
ADMC, Finance Secretary
ADMC, Secretary of Urban Planning and Environmental Management

Anauco Community
Andean Financing Corporation (CAF)
Catuche Community
Caracas Subway Rescue Group
Center for Integral Environmental Studies/Central University of Venezuela (CENAMB, UCV)
Civil Protection, ADMC
Civil Protection, Carabobo State
12 de Octubre (Petare) Community
Electricity of Caracas
Fifteen (15) Communities in Social Vulnerability Survey
Fluid Mechanics Institute/ Central University of Venezuela (IMF, UCV)

Geographic Institute of Venezuela Simon Bolivar
Hidrocapital and all its dependencies
Implementation Center for Environmental and Territorial Development Research (CIDIAT)
Institute of Psychology / Central University of Venezuela (UCV)
Institute for Experimental Development of Construction/Central University of Venezuela (IDEC, UCV)
Institute of Material and Structural Modeling/Central University of Venezuela (IMME, UCV)
La Floresta Community
Local Support Service A.C. (SOCSAL)
Los Chorros Community
Los Laños Community
Margarita (La Vega) Community
Metropolitan Civil Protection
Metropolitan Firefighters Department
Metropolitan Police
Ministry of Education
Ministry of Environment and Natural Resources and all its dependencies
Ministry of Foreign Affairs
Ministry of Infrastructure
Ministry of Planning and Development and all its dependencies
Ministry of Science and Technology
Municipality of Chacao and all its dependencies
Municipality of Libertador and all its dependencies

Municipality of Sucre and all its dependencies
National Anonymous Telephone Company of Venezuela (CANTV)
National Assembly (Congress)
National Civil Protection Direction
National Fund of Science, Technology and Innovation (FONACIT)
National Fund for Urban Development (FONDUR)
National Geological and Mining Institute (INGEOMIN)
National Housing Commission (CONAVI)
National Statistics Institute (INE)
Pan-American Health Organization (PAHO)
Petroleum of Venezuela S.A. (PDVSA)
San Bernandino Community
School of Political Science/Central University of Venezuela
Institute of Regional & Urban Studies /Simon Bolivar University (IERU USB)

Team of Volunteers, Metropolitan District
Venezuelan Foundation for the Seismic Investigations (FUNVISIS)
Venezuelan Red Cross
World Health Organization (WHO)

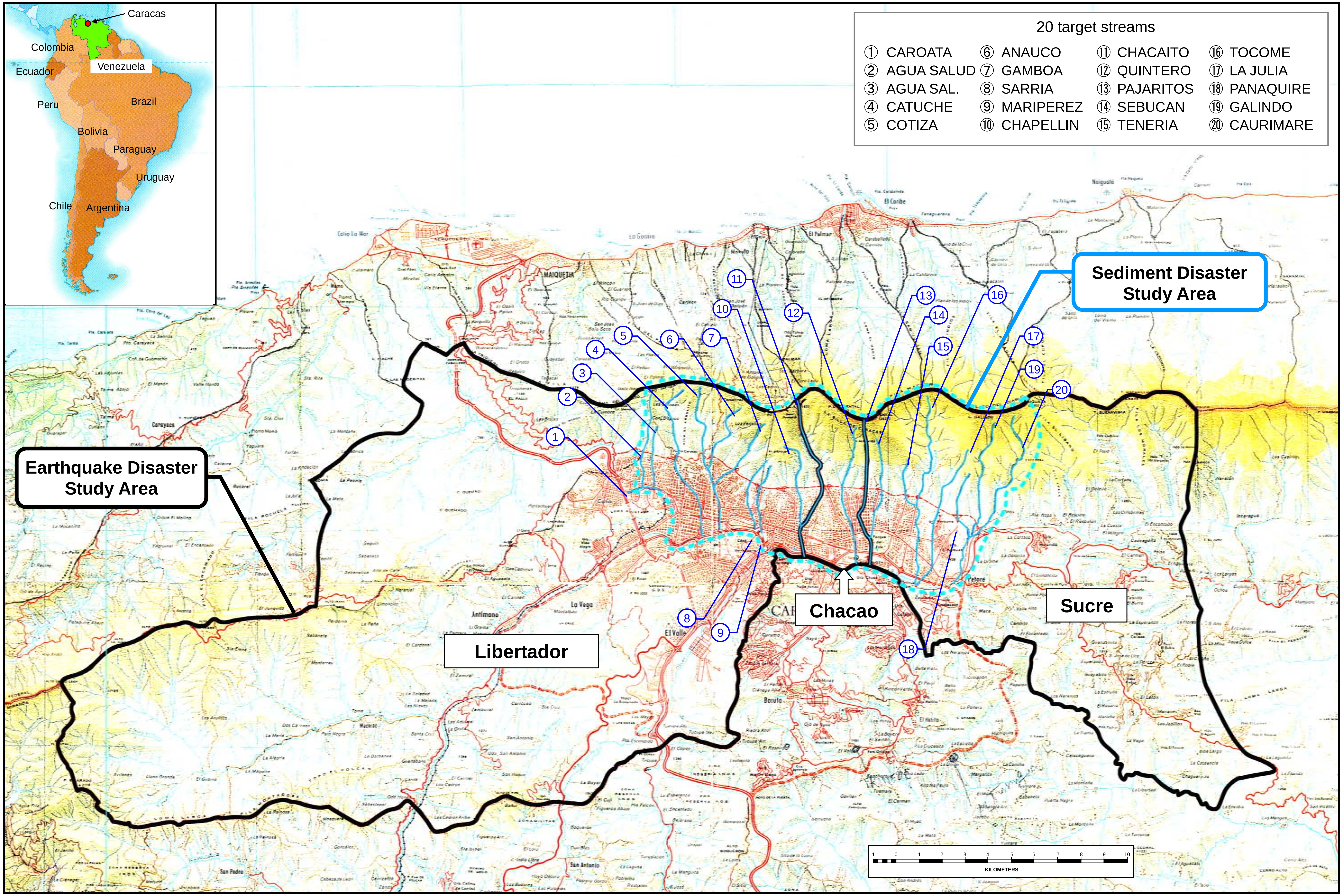

Figure.1.3.1 Study Area Map

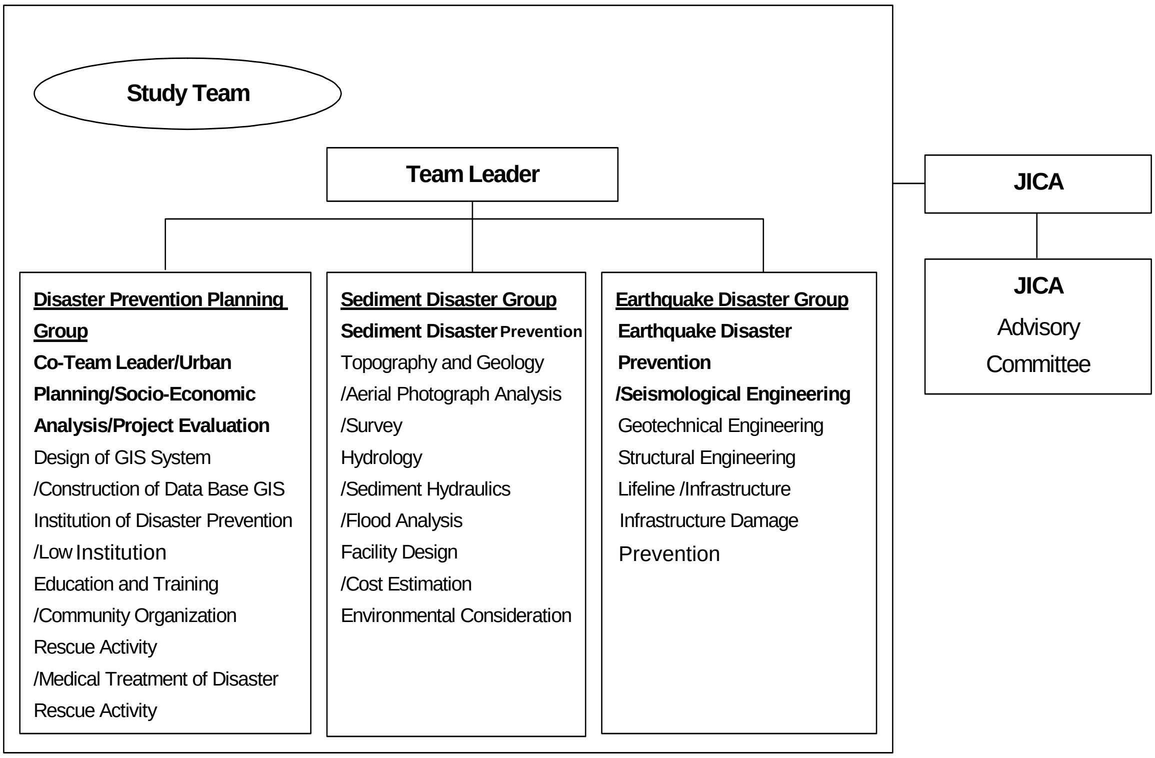

Figure 1.4.1 Organization of the Study Team

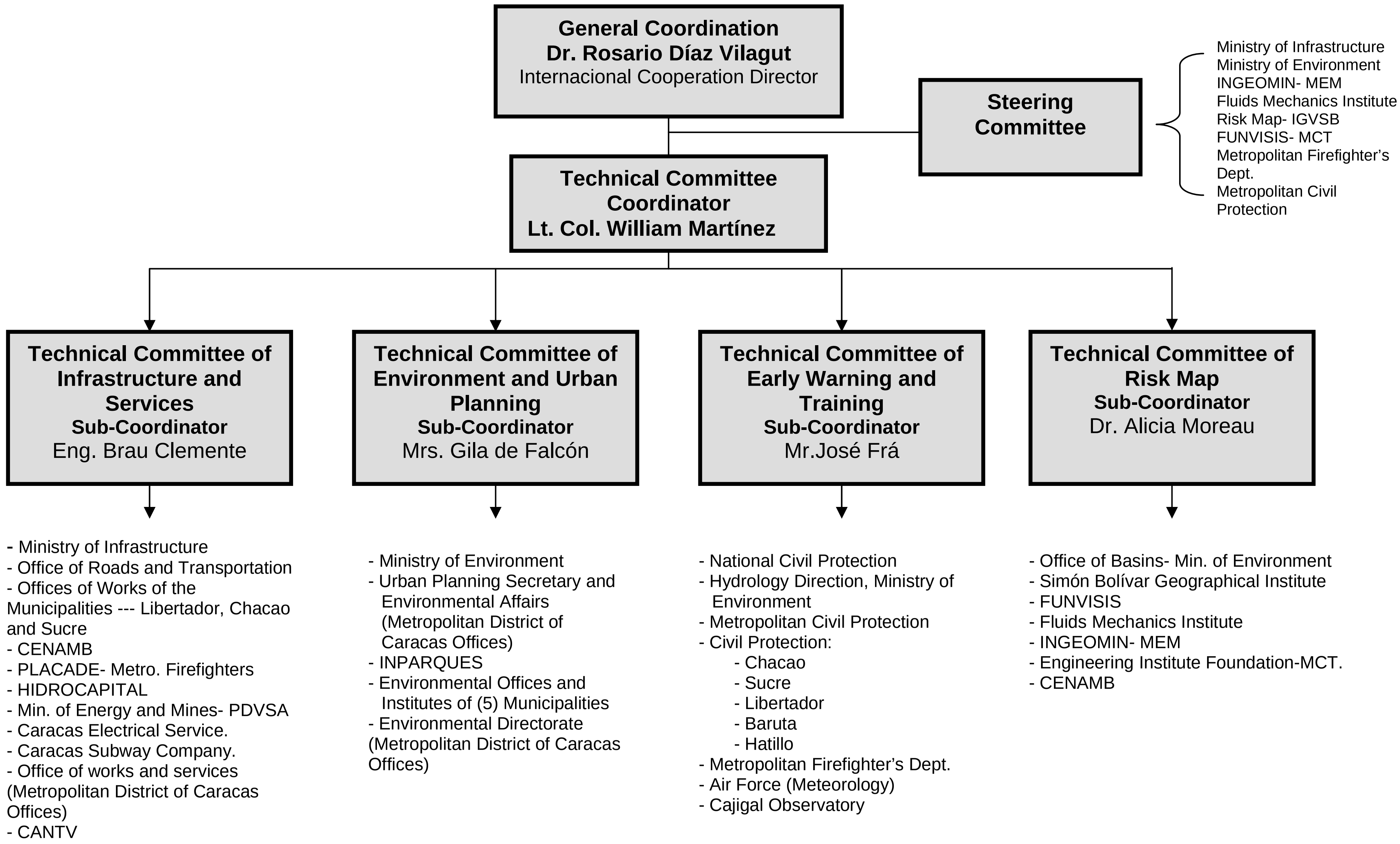

Figure 1.4.2 Organizational Flow Chart of the Venezuelan Counterpart

CHAPTER 2

EXISTING CONDITIONS

CHAPTER 2. EXISTING CONDITIONS

2. 1 Natural Conditions

2. 1. 1. Topography and Geology

The area of Caracas can be subdivided into three topographic units, which form part of La Costa Mountain Range.

- *Topographic Unit 1*, represented by the Avila Massif, with 2,765 m above sea level (m.a.s.l.) as maximum height (Naiguata Peak).

- *Topographic Unit 2*, comprised by the Caracas Valley, with heights that do not surpass 900m.

- *Topographic Unit 3*, formed of hills at the east, west and south of Caracas, with heights between 1,200 and 1,500 m.a.s.l.

The Caracas area is lithologically formed by rocks that belong to the Avila Metamorphic Association and the Caracas Metasedimentary Association (Rodríguez et. al, 2002).

The Avila Metamorphic Association extends from Carabobo State to Cabo Codera, Miranda State (from west to east, respectively) and covers the southern part of the Avila Massif, in the area between the Avila's crest until the contact with the quaternary sediments that fill Caracas Valley, at about 900 – 1,000 m.a.s.l. It is formed of the metamorphic rocks of the San Julian Complex and the Peña de Mora Augengneiss.

2. 1. 2. Meteorology and Hydrology of the Study Area

The climate of the Caracas Valley is affected by the North-Northeast trade wind, the South-Southeast trade wind, the position of the Inter Tropical Convergence Zone (ITCZ) and the topography of El Avila Mountain. The Caracas Valley is located at latitude 10 degree 30 minutes in the northern hemisphere and is within ITCZ, thus it is affected by unstable atmosphere. When ITCZ shifts close to the equator, the north and northeast wind become dominant over the entire Venezuelan territory as well as the Caracas Valley.

The annual rainfalls in the Cajigal and La Mariposa Stations are 834.8 mm and 891.2 mm, respectively. In Cajigal and La Mariposa, the rainy seasons are identical from May-June to November. The monthly average temperatures in Cajigal and La Mariposa are lower than 21°C

The Guaire River flows through the Caracas Metropolitan Area to join the Tuy River in Miranda State and the catchment area is about 546 km^2 at Baloa Bridge in Petare and 652 km^2 after the confluence of El Hatillo stream. The tributaries of the Guaire River are the San Pedro River, Macarao River, El Valle River, the Mariposa Dam watershed and the Guairita River in Baruta and the mountain streams from the southern part of the Avila Mountain.

The riverbed slope of the Guaire River varies from 9 m/km in upstream reach to 2 m/km in La California Sur at Petare.

2. 2 Socioeconomic Conditions

2. 2. 1. Administrative System

The Metropolitan District of Caracas is formed by five municipalities: Libertador, Chacao, Sucre, Baruta, and El Hatillo. During 1960's, this area was integrated by two districts, namely Sucre District and Federal District, as shown in Fig 2.2.1. In year 1977, the Sucre District was divided into four municipalities, namely Chacao, Sucre, El Hatillo, and Baruta. At the same time, the Federal District was divided into the Libertador and Vargas. In year 2000, the National Assembly, by mandate of the Constitution (Article No. 18), promulgated the "Special Law of the Caracas Metropolitan District Regime". This Law establishes that the Metropolitan District of Caracas is formed by five municipalities as stated above (Fig 2.2.1). .

The Administrative unit below the municipality level is called *Parroquia*. At present, Libertador consists of 22 parroquias, Chacao forms only one parroquia, and Sucre has five parroquias, as shown in Table 2.2.1 and Figure 2.2.2.

2. 2. 2. Population

According to the "2001 Census", Metropolitan District of Caracas has 3,090,447 people, accounting for 12.4% of the national total of 24,915,902. The study area has 2,740,381 people, accounting for 88.7% of the Metropolitan total. Libertador has 2,061,094 (75.2% of the study area), Chacao 71,806 (2.6%), and Sucre 607,481 (22.2%).

Population of Caracas increased by 1.28% per annum from 1990, according to the last 3 census, much lower than a national average of 2.95% per annum. The study area recorded 1.25% per annum, with Libertador 1.12%, Chacao 0.65%, and Sucre 1.77%. (Table 2.2.2)

2. 2. 3. Economic Structure

According to INE, the Venezuelan GDP was 82,451 million Bolivar (in 1984 constant price) in 2000, a large portion of which is derived from the exploitation of its oil resource accounting for 27.4%, and 43.8% of the GDP is derived from services sector.

Reflecting the economic characteristics of the Metropolitan District, employment in service supply (tertiary sector) of Caracas is dominant, accounting for 79% of the total employment of 1,444,360 persons in 1997as shown in Table 2.2.3.

Employment in Caracas accounts for 17.9% of the total national employment rate; employment in tertiary superior sector accounts for 48.9 % of the national total, as shown in Table 2.2.4. The other important economic activity in the metropolitan area is transport and communication. Service and manufacturing appear third in the study area.

Venezuela has been suffering from an economic depression in the last two decades that deteriorated wages, creating general impoverishment of the national population since 1983. The unemployment rate of Caracas was at 9.8% in 1997, smaller than the national average.

Another feature about Caracas economy is its unregulated informal sector, which has grown very quickly, from 35.5% in 1990 to 48.6% in 1997.[1] In the metropolitan area informal sellers are found here are there as a result of the high unemployment rate.

2. 3 Disaster Prevention Administration and Legislation

2. 3. 1. Legal Framework for Disaster Prevention

The legal structure of laws as it relates to disaster mitigation and preparedness is shown in Figure 2.3.1. Relevant articles in various laws are listed by level

2. 3. 2. National Plan for Civil Protection and Administration of Disasters

According to the "Law of the National Organization of Civil Protection and Administration of Disasters", "to elaborate and present the National Plan for Civil Protection and Administration of Disasters for the approval of the Coordinating Committee of National Civil Protection and Administration of Disasters" is the responsibility of the National Direction of Civil Protection and Administration of Disasters. (Article 13) However, this national plan is under preparation and the preparation time schedule is not clear.

As the main focus of the National Civil Protection is "emergency response" rather than "mitigation" , the national plan of them may be oriented to that direction.

2. 3. 3. National Plan for Prevention and Mitigation of Disaster Risk

The Ministry of Planning and Development is preparing a "National Plan for Prevention and Mitigation of Disaster Risk" but the time schedule of the plan preparation is not clear.

[1] Strategic Plan of Metropolitan Caracas 2010 (Plan Estrategico Caracas Metropoli 2010), "Una Propuesta para la ciudad."

2. 3. 4. Metropolitan Plan for Disaster Management

The ADMC council passed the Urban Guidelines Ordinance, (September 2003) that again establishes the responsibility for efforts in disaster prevention. These actions include: citizen education on subject of the disasters (Art. 74), Early warning systems and attention to mitigation measures (Art 75), information systems for disasters (Art. 76), and disaster prevention, especially in barrio areas (Art. 77). On March 9, 2004, the DMC council issued a decree establishing a metropolitan disaster coordination committee for civil protection and administration of disasters (CCCPAD). The CCCPAD functions are: (1) to plan, coordinate and develop activities with other governmental agencies and (2) to provide and coordinate measures for prevention, education, and administration of disasters. Thus, there is sufficient basis for the departments and agencies of the DMC to proceed with disaster mitigation and prevention activities.

Table 2.2.1 Administrative Units in the Study Area - Name of the Parroquias in the Libertador, Sucre and Chacao Municipalities

Municipality	Parroquias	
Libertador	Altagracia, Antimano, Caricuao, Catedral, Coche, El Junquito, El Paraíso, El Recreo, El Valle, La Candelaria, La Pastora,	La Vega, Macarao, San Agustín, San Bernardino, San José, San Juan, San Pedro, Santa Rosalia, Santa Teresa, Sucre, 23 De Enero
Chacao	Chacao	
Sucre	Caucagüita, Fila De Mariches, La Dolorita, Leoncio Martínez, Petare	

Source: INE

Table 2.2.2 Population of Caracas

Municipal/Parroquia	Population (1990)	Population (2001)	Population (65 years -) (2001)	Pop. Growth p.y. (1990-2001)	Area (Has)	Density (2001) (person/ha)	% (=65 yrs) (2001)
Metropolitan District	**2,685,901**	**3,090,447**	**186,470**	**1.28%**	**77,713.8**	**39.8**	**6.7%**
Study Area	**2,390,987**	**2,740,381**	**158,706**	**1.25%**	**56,874.9**	**48.2**	**6.5%**
Libertador	**1,823,222**	**2,061,094**	**118,622**	**1.12%**	**37,733.0**	**54.6**	**6.5%**
Altagracia	42,724	44,101	2,953	0.29%	186.4	236.7	7.5%
Antimano	117,179	143,343	4,304	1.85%	2,403.2	59.6	3.4%
Caricuao	141,064	160,560	7,360	1.18%	2,355.5	68.2	5.1%
Catedral	4,821	5,422	332	1.07%	79.0	68.7	6.9%
Coche	49,834	57,276	3,853	1.27%	1,254.3	45.7	7.6%
El Junquito	29,024	42,658	1,930	3.56%	5,567.6	7.7	5.1%
El Paraiso	98,647	111,354	7,902	1.11%	1,038.0	107.3	8.0%
El Recreo	96,574	107,935	11,100	1.02%	1,600.3	67.4	11.5%
El Valle	133,900	150,970	6,411	1.10%	2,116.4	71.3	4.8%
La Candelaria	51,432	60,019	5,421	1.41%	126.5	474.6	10.1%
La Pastora	82,937	90,005	5,704	0.75%	735.9	122.3	7.1%
La Vega	111,574	137,148	6,403	1.89%	1,195.1	114.8	5.2%
Macarao	40,670	48,479	1,740	1.61%	10,862.9	4.5	4.0%
San Agustin	38,527	45,840	2,225	1.59%	155.6	294.6	5.4%
San Bernardino	29,348	26,973	3,008	-0.76%	758.7	35.6	12.5%
San Jose	40,584	40,709	2,691	0.03%	308.8	131.8	7.4%
San Juan	98,009	104,471	6,158	0.58%	321.7	324.8	6.6%
San Pedro	55,967	63,274	7,249	1.12%	700.9	90.3	12.9%
Santa Rosalia	103,975	117,993	7,031	1.16%	626.7	188.3	6.7%
Santa Teresa	20,891	21,311	1,374	0.18%	68.1	313.0	7.2%
Sucre	354,012	395,139	17,542	1.00%	5,051.3	78.2	5.0%
23 de Enero	81,529	86,114	5,931	0.50%	220.1	391.2	7.7%
Chacao	**66,897**	**71,806**	**9,178**	**0.65%**	**1,886.2**	**38.1**	**14.2%**
Sucre	**500,868**	**607,481**	**30,906**	**1.77%**	**17,255.8**	**35.2**	**5.7%**
Caucaguita		55,939	1,217		6,009.0	9.3	2.4%
Fila de Mariches		29,399	647		3,194.2	9.2	2.4%
La Dolorita		**66,625**	1,729		1,320.8	50.4	2.9%
Leoncio Martinez		61,618	6,721		2,217.5	27.8	12.1%
Petare		393,900	20,592		4,514.5	87.3	5.8%
Baruta	**249,115**	**289,820**	**23,769**	**1.39%**	**8,273.9**	**35.0**	**9.1%**
El Cafetal		48,104	6,170		849.3	56.6	14.3%
Minas de Baruta		45,503	2,659		450.5	101.0	6.5%
Nuestra Señora del Rosario de Baruta		196,213	14,940		6,974.1	28.1	8.5%
El Hatillo	**45,799**	**60,246**	**3,995**	**2.52%**	**12,565.0**	**4.8**	**7.4%**

Source: INE, Census 2001

Table 2.2.3 Employment Status of Caracas, 1990 - 1997

Year	Primary sector	Secondary sector	Tertiary sector	Total
1990	17,230	346,110	1,075,312	1,438,652
1995	8,815	305,194	1,095,941	1,409,950
1997	13,814	286,527	1,144,019	1,444,360

Source: OCEI, Socio-economic Surveys, 2nd semester 1998, Population estimation, and 2001 census
Notes: Primary sector: Petroleum (crude oil) and natural gas, mining and agriculture activities
Secondary sector: manufacture, electricity & water and construction activities
Tertiary sector: financial, insurances real state and services to the enterprises, like financial assistance, administrative services, marketing investigation, quality control, publicity, commercial, transport and communication, etc

Table 2.2.4 Share of Caracas in National Employment

Economic Activity	Number	% to National total	% of National with high education
Agriculture	2,690	0.3	7.6
Mining, Oil	11,264	12.8	37.5
Manufacturing	192,365	18.6	27.9
Electricity, Gas, Water	10,727	17.6	48.9
Construction	83,435	13.0	19.3
Commerce	327,182	17.1	27.5
Transportation	119,278	23.1	38.1
Tertiary Superior*	230,853	48.9	55.5
Services	458,609	19.6	27.2
Not specified	8,097	43.0	53.5
Total	1,44,360	17.9	32.0

Source: OCEI, 1st semester, Socioeconomic Survey, 1997
Note: * tertiary superior includes Financial, Insurance, Real Estate, Service.

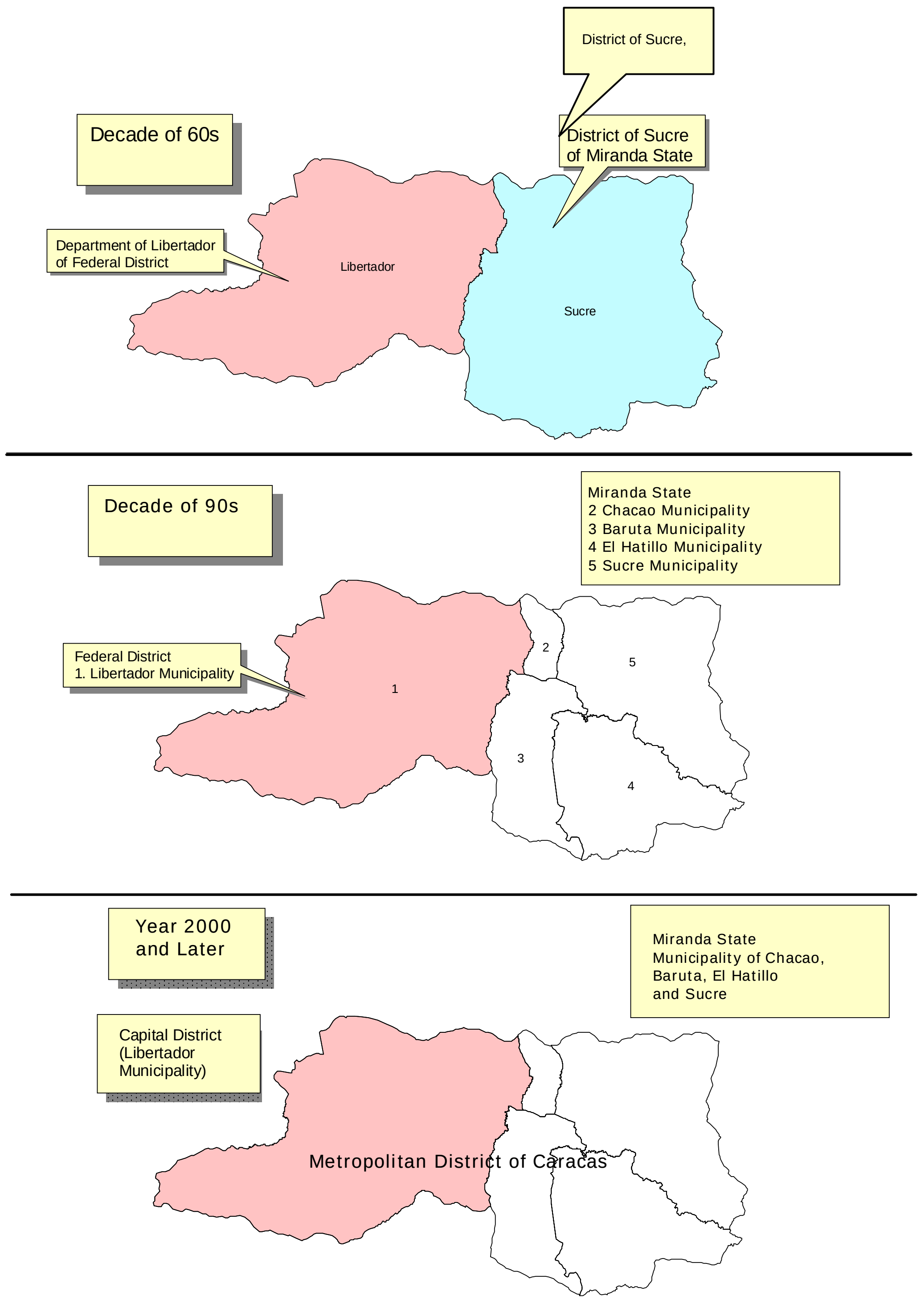

Figure 2.2.1 Recent Administrative Boundary Change of the Metropolitan District of Caracas

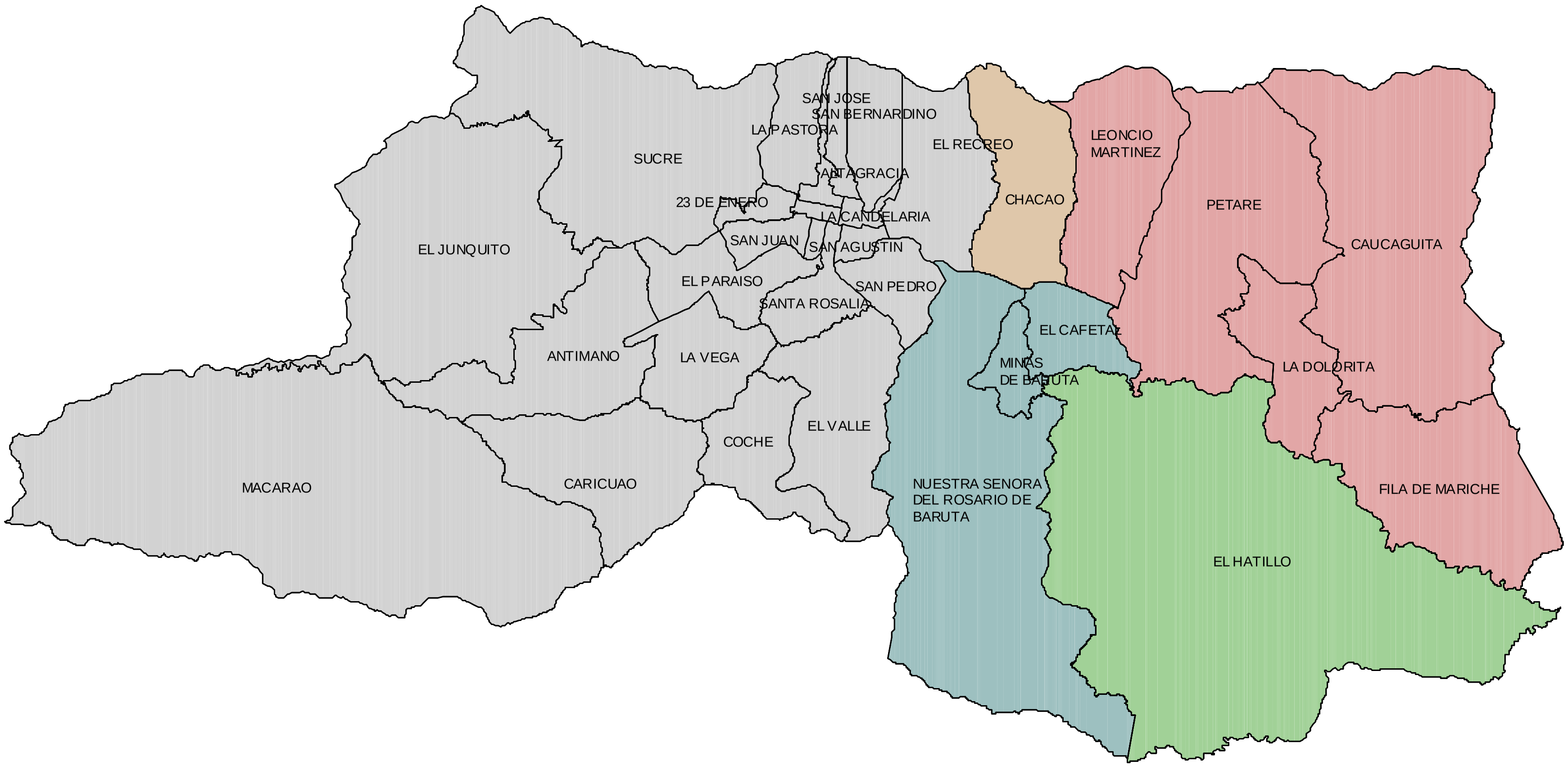

Figure 2.2.2 Political Administrative Boundary of Caracas

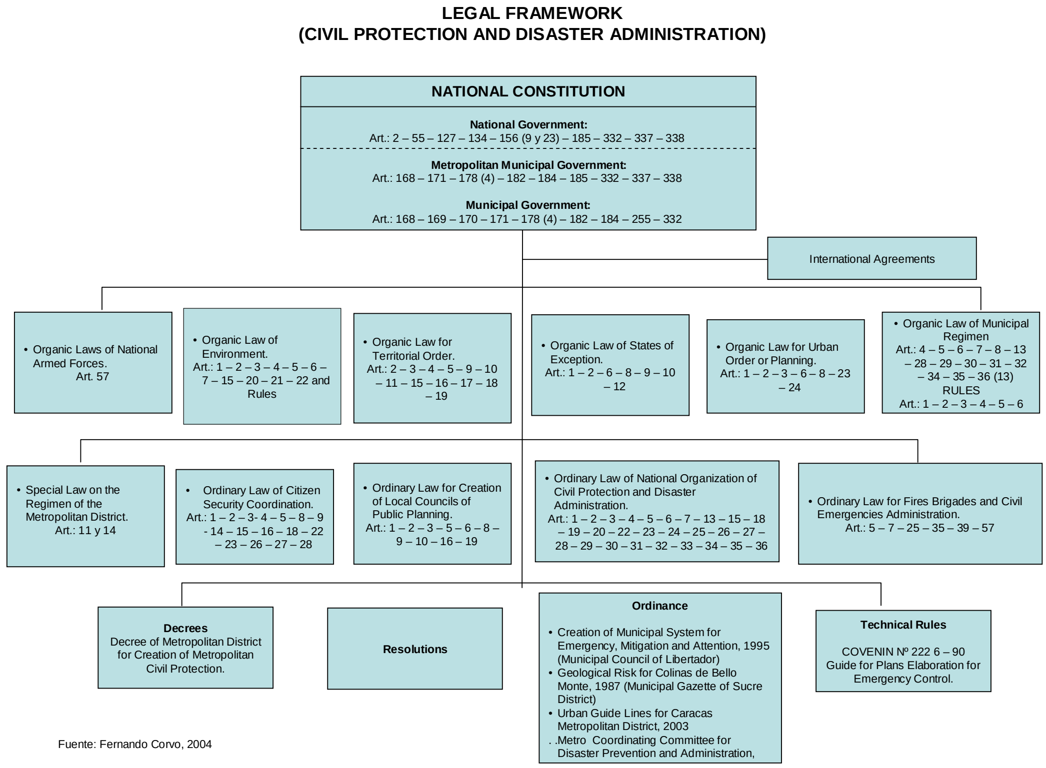

Figure 2.3.1 Legal Structure of Disaster Prevention

CHAPTER 3

EARTHQUAKE DISASTER STUDY

CHAPTER 3. EARTHQUAKE DISASTER STUDY

3. 1 Seismic Hazard Analysis

3. 1. 1. General

Northern Venezuela is located in the interaction zone between the Caribbean plate moving eastward and South America plate moving westward. This plate boundary is a 100-km-wide active deformation zone, but right-lateral motion seems to take place along the dextral faults system, and the remainder of deformation is distributed across lesser but associated faults within and offshore of Venezuela.

In Venezuela, catalogues on disastrous earthquakes can date back to 1530 (Grau (1965), Grases (1900), Grases et. al. (1999)). Table 3.1.1 shows epicenters of major earthquakes that affected Caracas in the history.

Strong motion observation in Venezuela started since 1980's. The number of records obtained to date is more than 80, with its maximum ground surface acceleration of 178.90 gal.

3. 1. 2. Definition of Scenario Earthquake

(1) Micro Zoning

The overall flowchart of seismic micro zoning study is illustrated in Figure 3.1.1. The object of micro zoning is to provide a basis to develop an earthquake disaster prevention plan for a region. This study assumes a specific scenario earthquake, which is a hypothetical earthquake.

(2) Definition of Scenario Earthquake

With the review of collect data, and through discussion with FUNVISIS, four scenario earthquakes are defined for this study. Among them, three scenario earthquakes are based on studies of historical earthquakes.

For the location of segment for the 1967 earthquake, epicenter location determined by ISC and also used in Suarez and Nabelek et. al, (1990) is used as one end, and another end is taken from Suarez and Nabelek (1990) as an epicenter of the second event, because these two events are the two major events out of four sub events studied in his work.

There are several interpretations regarding the 1812 earthquake, earlier studies regard it as three events, or two events recently. In this study, it is interpreted as two events after Grases & Rodriguez (2001), and magnitude is taken from this study. For the location of segment for the 1812 earthquake near Caracas, Grases (1990) and Isoseismal map by Altez (2000) was referred.

As for the 1878 earthquake, the fault segment is located along La Victoria Fault.

The hypothetical Avila earthquake is included, because the fault is known to be active from Quaternary fault study and seismological observation, even though there is no record of earthquake from this fault in historical documents. The magnitude of hypothetical earthquake from Avila fault for this study is defined to be 6.0, though the maximum credible magnitude is estimated to be 6.8. The segment location is taken from Quaternary fault study.

The magnitude is defined from comparative review of studies on historical earthquakes. The fault type is defined from Quaternary fault study and seismological observation. The fault size of scenario earthquake is estimated using empirical relation from fault size and possible magnitude. As a result, their parameters are defined as shown in Table 3.1.2.

3. 1. 3. Development of Ground Model

(1) Development of Ground Model for Analysis of Seismic Force Amplification

Figure 3.1.2 shows the flowchart for development of ground model for analysis of seismic force amplification. One dimensional earthquake response analysis program, named “Shake”, was used for analysis of seismic force amplification.

The densities of soil and rock were estimated based on the result of gravity survey[1] implemented at Los Palos Grandes.

The S-wave velocity of the sediment layers were estimated based on the boring data and the blow number of Standard Penetration Test data referring the relationship between the S-wave velocity and SPT number derived in Japan.

The shear modulus and the dumping factor were estimated based on equation derived in Japan as no data was available in Venezuela.

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[1] Taller Internacional “Estudio de métodos y acciones para contrarrestar los efectos producidos por terremotos en Caracas (1999-2001)” – Serie Técnica No.1, 158-165, “Modelaje Gravimétrico del Basamento de la Cuenta de Los Palos Grandes”, Sánchez R. Javier R, Nuris Orihuela, Ronny Meza, Ricardo Ambrosio.

(2) Development of Ground Model for Analysis of Liquefaction

In this Study, particle size distribution of the sediment was used to estimate the possibility of liquefaction during earthquake phenomena. Also the groundwater level information was collected from MARN and used.

3. 1. 4. Method of Ground Motion Estimation

(1) Selection of Attenuation Equation

In this study, bedrock motion is calculated using attenuation law. Various researchers had proposed attenuation laws. In order to select suitable equation among them, the study team and FUNVISIS had discussed and examined the applicability of various attenuation equations.

As a result, the study team and FUNVISIS agreed to employ formula proposed by Campbell (1997).

(2) Selection of Input Waves

During the 1967 Caracas earthquake, strong motion was not recorded. Since then, many efforts had been made to record strong motion. However, strong motion datasets in Venezuela suitable for input waves for scenario earthquake in this study are not yet available. Therefore, input wave are selected from worldwide strong motion database, which are recorded under similar conditions of each scenario earthquake.

(3) Seismic Response Calculation

For the calculation, the maximum amplitude of input waves is adjusted according to the values calculated by attenuation law, and the ground model developed for each mesh as described in 3.1.3 is used. Peak ground acceleration is then calculated for each 500 m sized square mesh .

(4) Estimation of Seismic Intensity

MMI was used to describe the shaking intensity during the earthquake. In order to correlate peak ground acceleration to ground motion, the following procedures, proposed by FUNVISIS, are employed:

- Calculate spectrum intensity (SI), according to Housner (1952), by integrating velocity response spectrum at 20 % damping over period range between 0.1 to 2.5 seconds.

- Obtain Peak Ground Velocity by V = SI/2.4 (Esteva & Rosenbluth(1964); Rosenbluth (1964)).

- Calculate Seismic Intensity by MMI = log(14v)/log(2)

(5) Estimation of Liquefaction Susceptibility

The liquefaction susceptibility for individual layer is analyzed by the FL method. The whole liquefaction susceptibility as the analyzed points is evaluated by the PL method based on the results of the FL method.

In principle, saturated sandy deposits, which satisfy the following three conditions at a same time, have liquefaction susceptibility:

- Saturated sandy deposits above the depth of 20 m with groundwater level within 10 m both from the present ground surface

- Sedimentary deposits with fine contents (Fc) less than 35%, or with plastic index less than 15% even the Fc more than 35%.

- Sedimentary deposits with mean grain size (D50) less than 10mm, and with grain size of 10% passing less than 1 mm.

3. 1. 5. Estimated Results of Ground Motion

(1) Estimated Peak Ground Acceleration

Maps of estimated seismic intensity for scenario earthquakes are shown in Figure 3.1.3 to Figure 3.1.6.

(2) Estimated Liquefaction

Liquefaction susceptibility was evaluated using PL value. Maps of estimated liquefaction susceptibility for scenario earthquakes are shown in Figure 3.1.7 to Figure 3.1.10. In general, the sedimentary deposits in Caracas valley have enough strength to resist seismic force and keep stable state about liquefaction phenomenon. The areas where have high liquefaction susceptibility are limited to several meshes even against strong earthquakes such as 1812 and Avila.

3. 2 Seismic Risk Analysis of Building

3. 2. 1. Development of Building Database

(1) Basic Concept

A Building Inventory was carried out by the Study Team to clarify the distribution of buildings in the study area. The study area is divided into tow areas. The first one is the urbanized area. The other is the barrio and rural area.

Regarding the urbanized area, the unit area is the block. The GIS data of the block was provided by the Secretary of Planning, Metropolitan District of Caracas (ADMC). In a block there are several types of buildings. Therefore, the building number of each category in a block should be estimated. To know the number of building categories, a field sampling survey was conducted. The result of the survey is summarized to estimate the ratio of building category in a block.

Regarding the barrio and rural area, the unit is an area which contains aggregated existing buildings. The area is sub-divided by the mesh of geological model. Base of GIS barrio data is provided by the Secretary of Planning, ADMC. Barrio and rural areas are divided into two areas. One is steep slope area and the other is gentle slope area. The threshold value is 20 degrees. This threshold value was decided after the discussion between FUNVISIS and The JICA Study Team.

There are a lot of factories in the rural area. The category of damage function "STEEL 1– 3F" is applied for the factories in the rural area. There are many high residential buildings in the rural area. The category of "RC-MOMENT FRAME 9-F '82-" is applied for high residential buildings in the rural area. The number of buildings in this area was counted by GIS based on the base map (Figure 3.2.14) or aerial photos.

The category of building inventory and the damage function for the barrio and rural area, that were discussed and agreed with FUNVISIS, are summarized in Table 3.2.1.

(2) Urbanized Area

Figure 3.2.1 shows the flowchart of building inventory for the urbanized area. A field sampling survey was conducted to estimate the ratio of each category in a block. The survey items were decided based on opinion of several experts during the discussion between FUNVISIS and JICA Study Team The number of sample is decided under consideration of the accuracy, term and cost. The number of the sample is 1000. The sampled buildings are selected randomly. The survey was conducted from July to middle of September, 2003.

Analyzed Vulnerability Unit (AVU) is introduced to classify the urbanized area. AVU is sub-areas of the urbanized area. AVU is proposed by Dr. Virginia Jimenez (IGSB) and Prof. Jesus Delgado (CENAMB, UCV). The urbanized area is divided into 30 sub-areas. The field sampling survey result is summarized by AVU. The same ratio is applied for all blocks in an AVU. Table 3.2.2 shows the number of buildings in each AVU.

(3) Barrio and Rural Area

Figure 3.2.2 shows the flow chart of building inventory for the barrio and rural area. The barrio and rural area is divided into two areas. One is covered by 1/5,000 working map and the other one not covered by the 1/5,000 working map. The barrio and rural area is also divided into two areas. In one the slope is steeper than 20 degrees. The other one is the area where slop is gentler than 20 degrees. The number of buildings of the barrio and rural area in the 1/5,000 working map area is summarized in Table 3.2.3. The number of buildings of the barrio and rural area out of the 1/5,000 working map area is summarized in Table 3.2.4.

(4) Information for Human Damage Estimation

The Census 2001 data, number of persons per house in the study area, was provided by INE. The data is summarized in Table 3.2.5. The figure is employed for the human damage estimation.

3. 2. 2. Method of Damage Estimation

(1) Building Damage

In agreement with FUNVISIS and Engineer Safina's proposal, the European Micro seismic Scale, EMS was applied for building damage estimation and its applicability was checked with 1967 Caracas Earthquake building damage.

These curves constitute an independent basis, so any category or structural typology of buildings can be expressed as a lineal combination of these curves applying properly weight factors to each vulnerability class.

<u>Categories of Buildings used in Caracas</u>

For classification of the different structural typologies of buildings into Vulnerability Classes the start point are the recommendations proposed by the European Macroseismic Scales EMS-98.

Table 3.2.6, summarizes the definition of the building categories used in Caracas, which were determined according to the results of the field survey and agreed on the work groups JICA-FUNVISIS.　Table 3.2.7 shows the estimated number of buildings for each category.

Damage Functions for the categories of buildings employed in Caracas

Figure 3.2.3 represents the damage functions determined by the described procedure, and will be used on the Study on the Disaster Prevention Basic Plan in the Metropolitan District of Caracas.

Calibration of the Proposed Damage Functions

In order to prove if the proposed damage function is representative, some of the registered results occurred in the earthquake of Caracas in July 29th 1967, were reviewed and compared with the calculation.

Starting form the contour map of MMI determined for the city of Caracas 1967 earthquake (Fiedler 1968), it can be observed that the macro seismic intensity in the MCS scale estimated for the sector of Los Palos Grandes and its surroundings is VIII, and in the San Jose sector the estimated intensity is VII, while the base intensity in the rock outcrops is between VI and VII.

Regarding the number of buildings heavily damaged, the comparison showed an acceptable result between the historical record and the calculation.

(2) Human Casualties

Damage function for death tolls and the number of people severely injured are derived from this analysis. Number of deaths and severe injuries is evaluated based on empirical relationships and building damage distribution.

3. 2. 3. Results of Damage Estimation

The summary of estimated damage for four scenarios is shown in Table 3.2.8.

3. 3 Inventory of Important Facilities

3. 3. 1. Seismic Evaluation Method of Important Facilities

There are no particular seismic evaluation methods in Venezuela, because the seismic evaluation is not practiced here. Accordingly, JICA Study Team and FUNVISIS adopted seismic evaluation methods developed by Federal Emergency Management Agency (FEMA) of the US government and currently applied in the US.

There are over 1,000 important buildings in the study area of three districts (Liberutador, Chacao and Sucre). In this plan, 32 buildings were selected from the whole important buildings and Rapid Visual Screening (RVS) was performed in order to determine whether detail seismic evaluation is required or not. Then, detail seismic evaluation was performed to the required buildings screened through rapid visual screening (RVS).

(1) Rapid Visual Screening (RVS) for Important buildings

RVS was designed as a procedure not requiring structural calculation. Instead, the judgment whether the building is safe or not is based on a scoring system. In RVS, the inspection, data collection and decision making process, basically, are performed at the building site.

Threshold score value “S” of this scoring system was determined by modifying the value used by FEMA after discussion with FUNVISIS.

The building is safe if, 2.0 <S / Important factor of Building (in 2001 Seismic Code)

(2) Seismic Evaluation of Important buildings

According to the results of RVS, JICA Study Team and FUNVISIS used seismic evaluation method developed by FEMA as a detail seismic evaluation for typical buildings. The detail seismic evaluation was performed with proper modeling of structural frames and analysis to which current Venezuelan seismic code and following reference books are applied.

3. 3. 2. Seismic Evaluation Results of Important Facilities

(1) Result of Rapid Visual Screening

The relation of built year and the values of S is shown in Figure 3.3.1. Out of 32 buildings, 24 buildings have smaller score than 2.0 and the detailed seismic evaluation are necessary. These 24 buildings are to be examined in the detail seismic evaluation stage .

(2) Result of the Detail Seismic Evaluation

JICA Team tried to collect the existing building information for the 24 buildings. However, JICA Team got the drawings and calculation sheets of 4 buildings only.

These 4 important buildings are: 2-hospitals, 1-Government and 1-School building.

According to the collected drawings and calculation sheets, the detail seismic evaluation for four important buildings were performed. However, since collected information is not enough, the unknown structural components without drawings were assumed by the evaluation engineer.

Out of four buildings under the detailed seismic evaluation, three building were judged that reinforcement is necessary, comparing with the Seismic Code in 2001.

3. 3. 3. Plan of Building Reinforcement

(1) Procedure for Inspection and Plan

The existing building information (such as architectural drawings, structural drawings, calculation sheets, and other specifications) is necessary for detail seismic evaluation.

If the buildings have had some expansion works, related information is also necessary. The other information will be obtained by visual check of structural components and sampling test of structural materials such as concrete and reinforcing bars on site.

Moreover, the structural engineer must discuss with building owner and operator and/or original design architect and building equipment engineer with regard to the building function and usage conditions.

Cost estimation of the strengthening plan will be submitted to the building owner and/or operator by the structural engineer.

(2) Cost Estimate for Building Reinforcement Master Plan

As one of the master plan project, building reinforcement of all the necessary buildings was selected. The number of buildings to be reinforced was estimated by the result of sampling survey during the first study in Venezuela. The total cost for this project was estimated based on the following assumptions.

1) Urban Area

- buildings built before 1967 15% of new construction cost
- buildings built between 1968 and 1982 10% of new construction cost

2) Barrio Area

- buildings on slope steeper than 20 degrees 25% of new construction cost.
- buildings on slope less than 20 degrees 15% of new construction cost

3. 4 Seismic Risk Analysis of Lifelines & Infrastructure

3. 4. 1. General

(1) Introduction

Once a disastrous earthquake occurs near the study area, the road network and lifelines may incur serious damage and may cause physical disruption of city functions.

In order to secure and maintain the city functions of Caracas Metropolitan District, it is indispensable to strengthen the vulnerable infrastructures and lifelines against earthquakes.

Seismic damage estimations for infrastructure and lifelines in the study area were carried out and the necessary countermeasures are recommended for strengthening the structure against earthquakes.

(2) Collected Data of Infrastructure and Lifeline

Data of infrastructure and lifelines of the study area were obtained from the related Agencies or Authorities; however, the collected data was quite limited due to the insufficient inventory list. Therefore the seismic damage estimations could be made only for the collected data and the information available from the investigation at the site and map in the market.

(3) Scenario Earthquake

Scenario earthquakes 1967 and 1812 are adopted for the seismic damage estimations.

3. 4. 2. Result of Damage Estimation

(1) Data

The collected data is as follows.

1) Bridge

2) Viaduct (Elevated Highway)

3) Metro

4) Water Supply Pipeline

5) Telecommunication Line

6) Hazardous Facility (Gasoline Station)

(2) Bridge

115 bridges on the express highways were selected for the seismic damage estimation in consideration of the significance of emergency activity for rescue and transportation at the time of earthquake occurrence.

Most of the bridges were constructed before 1967 and no serious damage was reported when an earthquake occurred in 1967, except one minor damage of the pier at the interchange Pulpo.

The result of damage estimation of bridges indicates the existing bridges are strong enough against the scenario earthquake 1967 and the damage estimation also shows the same result.

In the case of scenario earthquake 1812, 15 bridges are estimated as a high seismic risk and two bridges estimated as a medium seismic risk to collapse when such scale of earthquake occurs. The details of those bridges and locations are shown in Figure 3.4.1.

Among 15 bridges estimated as a high seismic risk, 10 bridges are located at the interchange Arana which consists of sedimentary deposit and susceptible for liquefaction. The interchange Arana is the biggest interchange in Caracas, which was opened to the traffic in 1966, and the height of bridge is more than 10 m at the center. This interchange plays an important role for transportation for both east-west and south-north directions. The security of this interchange is vital for social and economic activity in Caracas city.

(3) Viaduct (Elevated Highway)

Seismic damage estimation was made for the viaduct (elevated highway) referring to the experience of Hanshin/Awaji Disaster data 1995 in Japan. Due to the estimation, two locations may collapse and three locations may incur damage at interchange Arana.

Damage Estimation, earthquake intensity and each viaduct location is shown in Fig. 3.4.2.

At the interchange Arana, the flyovers were constructed in 1966 and old seismic code was applied to the design. There are three flyovers constructed at the center of interchange Arana and the height of structure is more than 10 m and the structure may be easily affected by an earthquake.

It is recommended to investigate the design code applied to the bridges, and on the basis of the design code, it is required to take a countermeasure to strengthen the structures against earthquake.

(4) Metro

There are three Metro lines in Caracas Metropolitan District and their total length is 44.3 km. The location and open cut and box type tunnel locations are shown in Fig. 3.4.3.

Line 1 : Peak Ground Acceleration (PGA) is estimated Max.581 gal at the station between Capitolio and Chacaito (about 5.8 km) in case of scenario earthquake 1812. This PGA is equivalent to Japan Meteorological Intensity 6+.

In case of Hanshin/Awaji Disaster, middle columns were collapsed due to the extra vertical force by the earthquake. Especially the weight of embankment is considered to apply to the tunnel structure vertically. It is recommended to check the design and the type of tunnel structure and strengthen the middle column in consideration of extra vertical force on the tunnel.

Line 2 : PGA is estimated Max.721 gal at the station of Antimano. The open and cut box type tunnel between Artigas and Mamera is recommended to reinforce at the middle column in consideration of scenario earthquake 1812.

Line 3 : PGA is estimated Max. 409 gal at the Box Type tunnel in scenario earthquake 1812. This PGA is equivalent to JMI 6- and no damage of middle column collapse was recorded in Hanshin/Awaji disaster. However, the damage of Metro in Caracas may be different in accordance with the embankment thickness on the box tunnel. It is recommended to check the design and strengthen the middle column to see if the middle column is not strong enough against the vertical force to the tunnel.

The damage against shield tunnel of Metro in Hanshin/Awaji disaster was not reported but the shown shield tunnel is very strong structure against earthquake.

(5) Water Supply

No information of material is available, therefore seismic damage estimation was carried out on the assumption that the material would be ductile cast iron. Recently the water supply authority is promoting the policy that the ductile cast iron is being used gradually for the water supply pipe.

The damage estimation is shown in Fig. 3.4.4 in scenario earthquake 1812.

According to the damage estimation, no damage is expected in scenario earthquake 1967. In case of scenario earthquake 1812, the maximum estimated damage number of points per mesh (500 x 500 m) is only 0.56 points.

The most affected areas are Neveri and Sanpedro and these locations are shown in Fig.3.4.4, but the estimated damage points are quite small.

However, this estimation is based on the assumption that all pipe material is made of ductile cast iron. Ductile cast iron is strong against the earthquake. It is recommended to continue to promote the policy to use the ductile cast iron.

(6) Telecommunication

In the case of scenario earthquake 1967, most of the earthquake intensity is equal to or less than 5 of Japan Meteorological Intensity (JMI) and the possible damage is only 0.07% against the total length. In case of scenario earthquake 1812, 0.25% of total telecommunication cable may be damaged.

(7) Hazardous Facility (Gasoline Station)

Total 54 gasoline stations are located in the study area and their locations are shown in Fig.3.4.5.

Scenario earthquake 1967: Estimated Max. Ground surface PGA is less than 250 gal and the probability of small spill from tank and pipe joint is only 0.14% in accordance with the study of Tokyo Metropolitan Government, 1977 and no damage anticipated.

Scenario Earthquake 1812: Estimated Max. Ground surface PGA is 400~450 gal and there are 13 gasoline stations in that area. The probability of small spill from tank and pipe joint is only 2.0% in accordance with the study of Tokyo Metropolitan Government,1977 and also the damage is quite small.

Even considering all area, the number of affected gasoline stations is less than one location.

Gasoline stations located at the high acceleration area should be improved in terms of seismic resistant structure.

3. 5 Disaster Prevention Study for Earthquake Disaster

3. 5. 1. Study on Structural Measures

Generally, the effect of structural measures is permanent once installed, but more expensive than non-structural measures. However, non-structural measures such as training or education needs to be well maintained to be effective. To maximize prevention effort, both structural measures and non-structural measures should be optimized. Structural measures can be made by following:

To reduce human casualties due to possible earthquake, structural measures to ensure building safety is the most important factor. In addition, if building damage was successfully reduced, it would save much money otherwise spent for emergency response and recovery.

- For new buildings, enforcement of latest seismic code will be effective. However, it will take time for old buildings in urban area to be replaced by new buildings, and the number of newly built building will be limited.

- Many existing buildings are built under the old seismic code, prior to the seismic code, or without engineering. Even though the seismic code has been revised, the strength of existing buildings remains the same. Since they can be a major problem if a major earthquake happens, they should be the main objects of seismic strengthening.

- Among existing buildings, socially important facilities have priority for the seismic strengthening, because they should maintain function during an emergency.

- From viewpoint of urban planning, consideration of open space and roads in disaster prevention planning is important. Open space can be used as a park during normal times, and then used as an evacuation space during an emergency period. In addition, it can prevent fire spreading, once a fire brakes out.

- The availability of roads is critical to emergency response activities, but narrower roads can be blocked by abandoned car or collapsed buildings. Therefore, preservation of main road access, together with their designation as emergency routes will be important to ensure effective transportation flow in an emergency.

In this study, feasibility of seismic reinforcement of buildings is principally investigated quantitatively in the following manners.

- As to the buildings in urban area, they are made with engineering so that technical data such as structural drawings and calculation sheets are available. Therefore, evaluation of seismic reinforcement can be made using the result of rapid visual inspection and detailed evaluations made in chapter 3.3.

- As to the buildings in barrio, there is little technical information available so far because they are made without engineering. However, considering the fact that they are the majority of the building in study area and the most vulnerable types of buildings against earthquake, it cannot be neglected to develop a disaster prevention plan. In this study, in order to understand the actual strength of houses in barrio as well as to see if it is possible to reinforce such buildings, the building breaking test using real scale houses are made.

The objectives of the field test are as follows;

- To assess the vulnerability of Barrio houses

- To assess the effect of seismic reinforcement for Barrio houses, with available techniques and affordable cost

At first, four same housing models are built as non-engineering buildings. Then seismic reinforcement for three out of four models is done as shown in Photo 3.5.1 and Photo 3.5.2, and as described in Table 3.5.1. Seismic reinforcement is provided considering the cost impact and technical effect. Horizontal loading is applied to each model to measure strength by IMME as shown in Photo 3.5.3 and seismic reinforcement is assessed. The strength of used concrete at 28 days is tested by IMME. The video of the field test is taken and is used as the public awareness material.

As a result, following are observed.

- Average strength of used concrete for column and beams was 58 kg/cm^2, as shown in Figure 3.5.1. This is about 1/3 to 1/4 of that of engineering concrete.

- Strength of frames without reinforcement is 9 to 10 ton for 4 columns as shown in Figure 3.5.2.

- Providing grade beams is effective for seismic strengthening and increases the strength by approx.40% as shown in Figure 3.5.2, and need to pay attention clear length of column, to prevent shear failure considering strength of concrete. Cost impact is 5%~7 %.

- Clay hollow brick wall is not effective for seismic strengthening. Cost impact is 10%.

- Concrete block wall will be effective, if concrete strength of block is increased, together with the use of re-bars for seismic reinforcement. Drilling and epoxy grouting method is suggested for re-bar anchorage to existing column/beam. Cost impact will be 15%.

- Video report is used to improve awareness to the public

- Other practical and economical seismic reinforcement methods are also suggested to investigate in future.

- This kind of full scale field test is done for the first time in Caracas. It is recommended strongly to continue and develop seismic assessment and reinforcement through model tests and analyses for Barrio houses in future.

3. 5. 2. Study on Non-Structural Measures

Non-structural measures, like training and education are in general inexpensive, compared to structural measures. However, they are not permanently effective if not exercised regularly. Many topics can be commonly used for both earthquake and sediment disaster systems, so that existing prevention systems and practices for sediment disaster can be used for earthquake as well.

- Institutionalization

The legal framework that supports inter-institutional coordination should be created. Since various organizations deal with the same topics, division of roles among them can be made such as assigning leading and support organizations. Identifying possible funding sources for disaster prevention is another factor to consider.

- Information dissemination

Dissemination of information on natural disasters is the first step to let the public know and motivate them to prepare for disaster in the future. Possible contents for such material are historical facts of disasters or hazard and risk maps, with different ways of representation and contents according to the different users (such as research, administration, and the public).

- Education & training

Education & training can be made for various audiences, such as administration staff, engineers, mass media, students, and the public. Contents of training are: evacuation, fire-extinguishing, search and rescue, triage, emergency gathering and communication, and desktop emergency response simulation. Training can be exercised regularly on memorial days.

- Research

Basic scientific study, as well as post-disaster scientific and engineering study is key to develop basic knowledge of disasters and to learn lessons from them. These lessons and knowledge can be reflected in revised material for education and training.

Table 3.1.1 Lists of Earthquakes That Affected Caracas (Grau (1969), Grases (1990), Grases et. al. (1999))

Year	Month	Day	Local Time	Magnitude	Seismic Intensity in Caracas	Description
1641	6	11	8:15			The earthquake destroyed the first city of Cua. The new city was founded in 1690 with a name El Rosario de Cua, 1 km north from former location. The earthquake affected Caracas where Church and other buildings collapsed.
1766	10	21	4:30	7.9	V	For the extension of the felt area and for the duration of aftershocks, this earthquake is probably the major magnitude that had affected the northeastern Venezuela. The aftershocks were felt every one-hour during 14 months. The earthquake caused damages in various cities in the eastern Venezuela and in Caracas.
1812	3	26	16:07 (Caracas) 17:00 (Merida)	6.3 (Caracas), 6.2 (Barquisimeto - San Felipe), 7 (Merida),	IX	The earthquake affected severely in distant places such as Merida, Barquisimeto, San Felipe and Caracas. From the basis of damage distribution, it is postulated to be three different events. The number of victims was about 5000 in Merida, 3000 in San Felipe, 4000 to 5000 in Barquisimeto, and 10000 in Caracas. In total, the number of victims was about 40000 from Merida to Caracas. In Caracas, northern sectors of the city were almost completely destroyed, in the southern and eastern sectors, the damage was minor. In the Avila, there were large collapses, and cracks of large dimension were formed. The ground motion lasted 48 seconds in Caracas, in the direction of west to east. The recent study reveals that about 60% buildings were heavily damaged in Caracas and death toll in Caracas could be reduced to 2,000. (Altez, 2004)
1837	9	10	14:00			Strong earthquake in Caracas. Destructive in Santa Teresa of Tuy and Santa Lucia. Destruction of some consideration, houses collapsed. There were little victims and most of them were injury.
1878	4	12	20:40	5.9	VI-VII	Destructive earthquake to the south of Caracas that ruined the city of Cua where 300 to 400 died under debris out of 3000 habitants at that time. The field work indicated that houses in the lower part of the city on alluvial plane suffered relatively little damage, while higher areas of the city in rocky hill was destroyed (Ernst 1878). Death toll estimated to be 600 (The Times, London May 18, 1878). In Caracas, buildings suffered cracks. The ground motion lasted 8 to 10 seconds in Caracas.
1900	10	29	4:42	7.6	VII	The earthquake affected Macuto, Naiguata, Guatire, Guarenas, Higuerote, Carenero, and other cities of Barlovento that suffered great damages and victims. Many buildings suffered cracked and some collapsed in Caracas. 12 deaths. The second floor of British Embassy disappeared (The Times, London, October 30 to November 2, 1900). 250 aftershocks in 3 years. In Caracas, 20 houses collapsed and more than 100 were deteriorated, 21 death and more than 50 injured.
1967	7	29		6.3	VI-VIII	The earthquake caused important damages in Caraballeda, areas in Caracas and the central coast and felt in the north central of the country. Rial (1977) concludes it was multiple earthquakes、three events in the direction of northwest to southeast, possibly Tacagua fault system. According to the Venezuelan institution, death toll was 274, number of injured was 2000, and loss of 100 million dollars. Four buildings with ten to twelve floors, constructed between from 1962 and 1966, partial damage for other similar height in Caracas. No interruptions of service. The telegraphs and telephones were saved.

Table 3.1.2 Scenario Earthquakes and Their Parameters

Scenario	Mw	Seismogenic Depth (km)	Fault Length	Mechanism	Fault system
1967	6.6	5 km	42 km	Strike slip	San Sebastian
1812	7.1	5 km	105 km	Strike slip	San Sebastian
1878	6.3	5 km	30 km	Strike slip	La Victoria
Avila	6	5 km	20 km	Strike slip	Tacagua-El Avila

Table 3.2.1 Category of Building Inventory and Damage Function in the Barrio and Rural Area

Building Inventory		Damage Function				
Area	Slope	No	Structure	Stories	Const. Year	Slope
Barrios	Less 20 degree	18	Informal (Barrio)	N. A.	N. A.	Less 20 degree
	More 20 degree	20	Informal (Barrio)	N. A.	N. A.	More 20 degree
Rural low buildings	Less 20 degree	17	Informal (Rural)	N. A.	N. A.	Less 20 degree
	More 20 degree	19	Informal (Rural)	N. A.	N. A.	More 20 degree
Rural Factory	N. A.	14	Steel	1-2 F	N. A.	N. A.
Rural High Building	N. A.	9	RC-Moment Frame	9F-	‘83-	N. A.

Source: JICA Study Team

Table 3.2.2 Counted Building Number of Analyzed Vulnerability Unit

	Physical AVU	Social AVU	Location	Number of Buildings
In Avila project area	0	N.A.	----	---
	1	1	Altamira	3.535
	2	2	Caracas Country Club	895
	3	3	Candelaria	10.813
	4	4	California	2.989
	5	5	El Bosque	2.937
	6	6	Bello Campo	7.059
	7	7	La Urbina	2.267
	8	2	San Bernardino & El Rosario	3.598
	9	N.A.	Los Ruices	2.457
	10	12	Catia & Sarria	10.957
	11	8	23 de Enero & Pedoro Camejo	2.694
	12	N.A.	A.V. Coromoto	166
Out of Avila project area	101	12	Gramoven	9.620
	102	8	La Silsa	187
	103	10	Artigas	5.903
	104	3	San Juan	1.320
	105	2	Paraiso & Washington	2.457
	106	13	La Vega	2.788
	107	7	Montalban	1.116
	108	12	Antimano	469
	109	9	SAMBIL	3.081
	110	3	Los Carmenes	7.382
	111	9	Coche & EL Valle	3.656
	112	10 & 5	Las Acacias & Santa Monica	4.877
	113	4	El Llanito	3.223
	114	7	Palo Verde	769
	115	7	Terrazas del avila	177
	116	N.A.	Miranda	484
	201	N.A.	Petare	361
			Total	98.237

Source: The JICA Study Team

Table 3.2.3 Number of Buildings of the Barrio and Rural Area in the 1/5,000 Working Map Area

	Barrio	Rural	Rral Factory	Rural High Buil.	Total	%
Slope > 20 degree	78101	5179	76	28	83384	47.4
Slope < 20 degree	85024	7384	273	32	92713	52.6
Total	163125	12563	349	60	176097	100
%	92.6	7.1	0.2	0.0	100	

Source: JICA Study Team

Table 3.2.4 Number of Buildings of the Barrio and Rural Area out of the 1/5,000 Working Map Area

	Barrio	Rural	Rral Factory	Rural High Buil.	Total	%
Slope > 20 degree	261	5887	4	81	6233	36.7
Slope < 20 degree	702	9306	34	722	10764	63.3
Total	963	15193	38	803	16998	100
%	5.7	89.4	0.2	4.7	100	

Source: JICA Study Team

Table 3.2.5 Number of House and Persons Who Dwell in it

	Num of House	Num of Person	Person/ House
Libertador	209,610	939,113	4.5
Sucre	68,033	302,620	4.4
Chacao	1,268	6,249	4.9
Total	278,911	1,247,982	4.5

Source: Census 2001, INE

Table 3.2.6 Building Categories of Damage Function Used in this Study

Type	Structure	No. Stories	Year	Slope
1	RC – MOMENT FRAME	1-3	-67	---
2			68 – 82	
3			83-	
4		4-8	-67	
5			68 – 82	
6			83-	
7		9 -	-67	
8			68 – 82	
9			83-	
10	RC – SHEAR WALL	4-8	---	---
11		9-		
12	PRECAST	1-2	---	---
13		9-		
14	STEEL	1-3	---	---
15		4-		
16	MASONRY / Brick	---	---	---
17	INFORMAL (Rural)	---	---	Less 20°
18	INFORMAL (Barrio)	---	---	
19	INFORMAL (Rural)	---	---	More 20°
20	INFORMAL (Barrio)	---	---	

Source: The JICA Study Team

Table 3.2.7 Summary of the Estimated Building Numbers

PARROQUIA	Number of Buildings				
	Urban -3F	Urban 4F-	Urban Sum	Barrio & Rural	Sum
23 DE ENERO	486	102	588	5,319	5,907
ALTAGRACIA	1,386	415	1,801	265	2,066
ANTIMANO	617	65	681	21,277	21,958
CARICUAO	805	1,129	1,934	9,240	11,174
CATEDRAL	544	160	704	2	706
CAUCAGUITA	0	440	440	7,093	7,533
CHACAO	4,703	1,547	6,250	274	6,524
COCHE	1,426	597	2,023	4,080	6,103
EL CAFETAL	2	0	2	0	2
EL JUNQUITO	0	105	105	10,279	10,384
EL PARAISO	4,587	576	5,163	4,454	9,617
EL RECREO	5,729	1,703	7,432	2,156	9,588
EL VALLE	693	266	959	16,913	17,872
FILA DE MARICHE	0	90	90	5,036	5,126
LA CANDELARIA	1,492	301	1,793	108	1,901
LA DOLORITA	0	529	529	9,128	9,657
LA PASTORA	3,514	465	3,979	7,352	11,331
LA VEGA	1,482	505	1,986	14,223	16,209
LEONCIO MARTINEZ	5,054	1,115	6,169	597	6,766
MACARAO	306	445	752	8,101	8,853
NUESTRA SENORA DEL ROSARIO DE BARUTA	40	13	53	0	53
PETARE	8,236	2,372	10,608	36,213	46,821
SAN AGUSTIN	1,122	317	1,440	3,197	4,637
SAN BERNARDINO	1,609	345	1,954	632	2,586
SAN JOSE	767	226	993	1,633	2,626
SAN JUAN	1,967	274	2,241	9,369	11,610
SAN PEDRO	3,562	1,183	4,746	429	5,175
SANTA ROSALIA	4,704	540	5,244	11,332	16,576
SANTA TERESA	657	196	853	0	853
SUCRE	10,777	1,215	11,992	42,456	54,448
Sum	66,265	17,234	83,499	231,158	314,657

Table 3.2.8 Summary of the Damage Estimation Result

Case 1967

	Building Number		Heavily Damaged Buil.		Death		Injured	
	number	%	number	%	number	%	number	%
Urban -3F	66,265	21.1	849	8.5	19	3.2	144	3.3
Urban 4F-	17,234	5.5	170	1.7	170	28.2	1,225	28.4
Urban Sum	83,499	26.5	1,019	10.2	189	31.4	1,369	31.8
Barrio & Rural	231,158	73.5	9,001	89.8	413	68.6	2,937	68.2
Total	314,657	100.0	10,020	100.0	602	100.0	4,306	100.0

Case 1812

	Building Number		Heavily Damaged Buil.		Death		Injured	
	number	%	number	%	number	%	number	%
Urban -3F	66,265	21.1	2,656	8.2	85	3.4	619	3.5
Urban 4F-	17,234	5.5	533	1.6	533	21.1	3,775	21.4
Urban Sum	83,499	26.5	3,189	9.8	618	24.4	4,394	24.9
Barrio & Rural	231,158	73.5	29,217	90.2	1,910	75.6	13,226	75.1
Total	314,657	100.0	32,406	100.0	2,528	100.0	17,620	100.0

Case 1878

	Building Number		Heavily Damaged Buil.		Death		Injured	
	number	%	number	%	number	%	number	%
Urban -3F	66,265	21.1	74	4.1	0	0.0	0	0.0
Urban 4F-	17,234	5.5	15	0.8	15	24.2	90	19.8
Urban Sum	83,499	26.5	89	4.9	15	24.2	90	19.8
Barrio & Rural	231,158	73.5	1,713	95.1	47	75.8	365	80.2
Total	314,657	100.0	1,802	100.0	62	100.0	455	100.0

Case Avila

	Building Number		Heavily Damaged Buil.		Death		Injured	
	number	%	number	%	number	%	number	%
Urban -3F	66,265	21.1	2,758	10.2	89	4.1	658	4.3
Urban 4F-	17,234	5.5	604	2.2	603	28.1	4,310	28.3
Urban Sum	83,499	26.5	3,361	12.4	692	32.2	4,968	32.7
Barrio & Rural	231,158	73.5	23,696	87.6	1,455	67.8	10,240	67.3
Total	314,657	100.0	27,057	100.0	2,147	100.0	15,208	100.0

Table 3.5.1 Method of Reinforcement and Cost Impact for Each Model

No.	Reinforcement	Cost Impact	Method of reinforcement
1	No	0 %	None
2	Yes	5 to 7 %	Grade beams
3	Yes	10%	Grade beams & brick wall
4	Yes	15 %	Grade beams & concrete brick wall

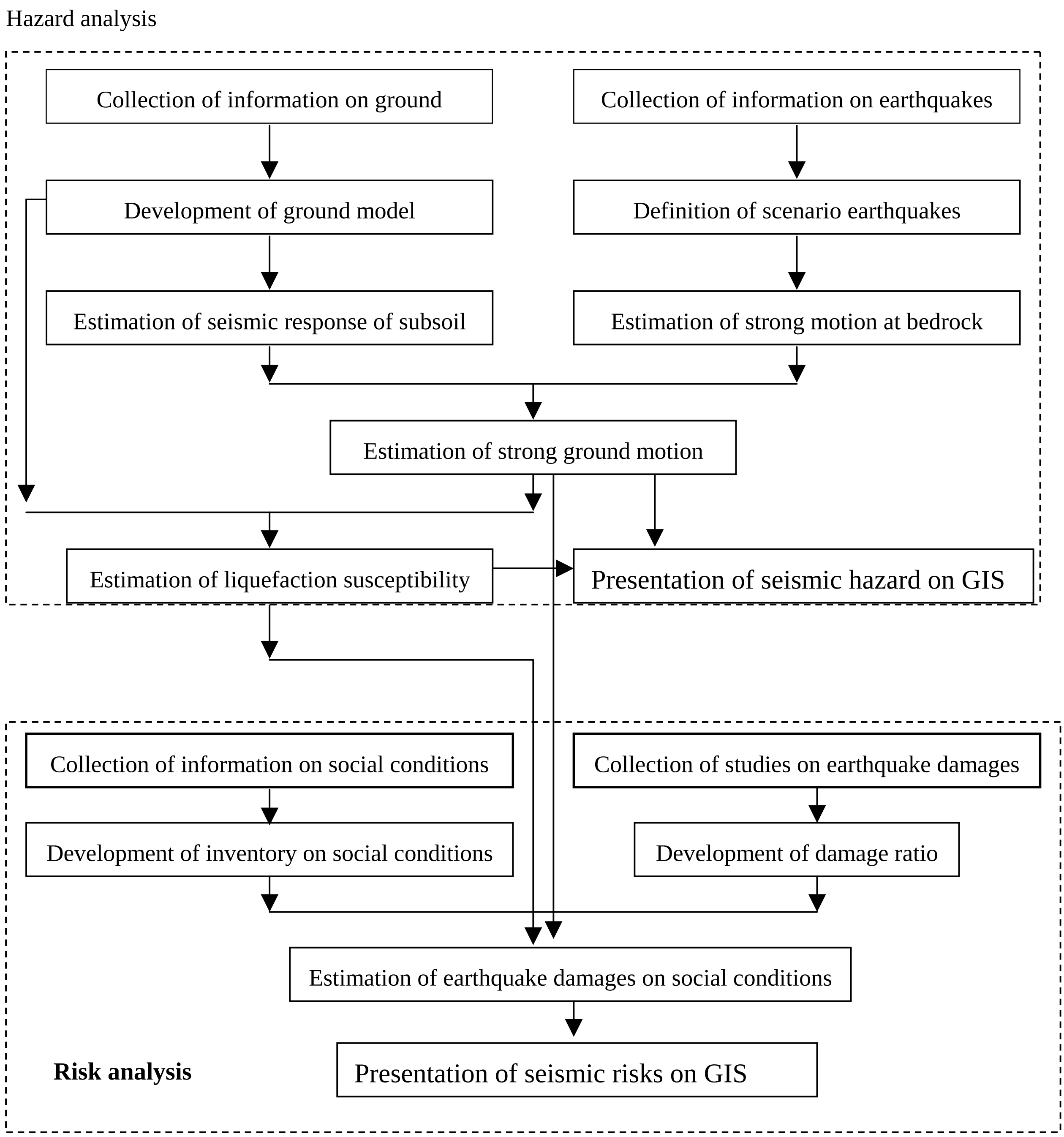


Figure 3.1.1　Flowchart of Seismic Micro Zoning Study

Figure 3.1.2 Outline of Development of Ground Model for Amplification of Seismic Force

Figure 3.1.3 Estimated Seismic Intensity for the 1967 Earthquake

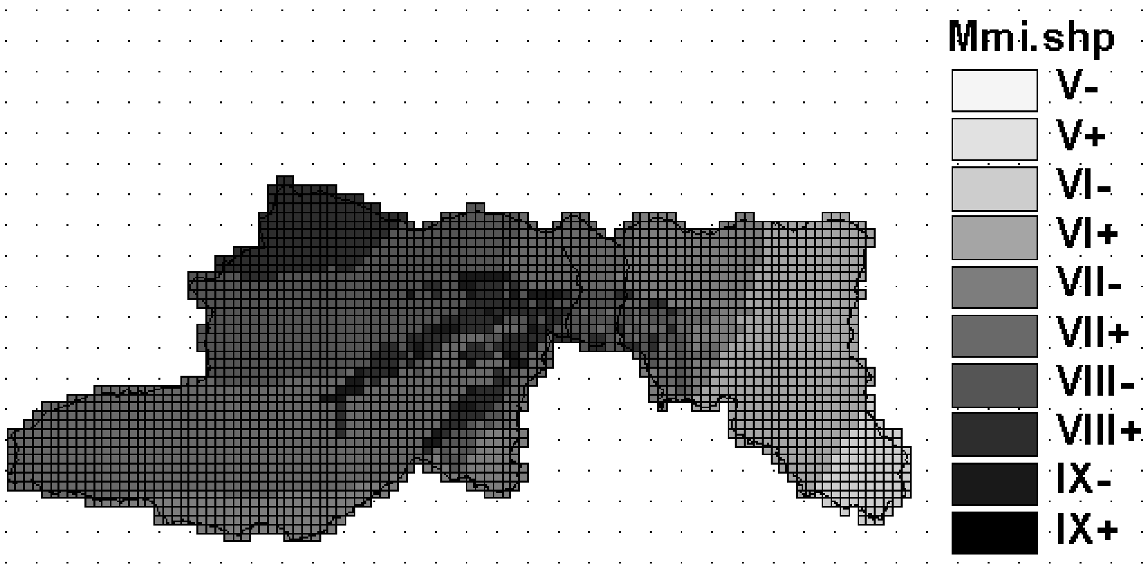


Figure 3.1.4 Estimated Seismic Intensity for the 1812 Earthquake

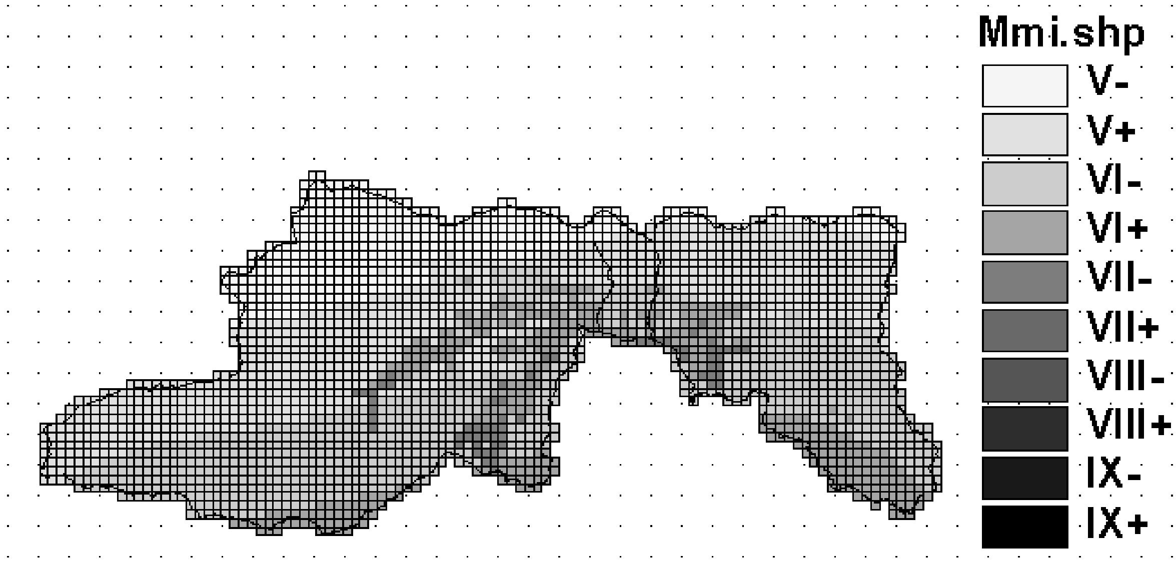


Figure 3.1.5 Estimated Seismic Intensity for the 1878 Earthquake

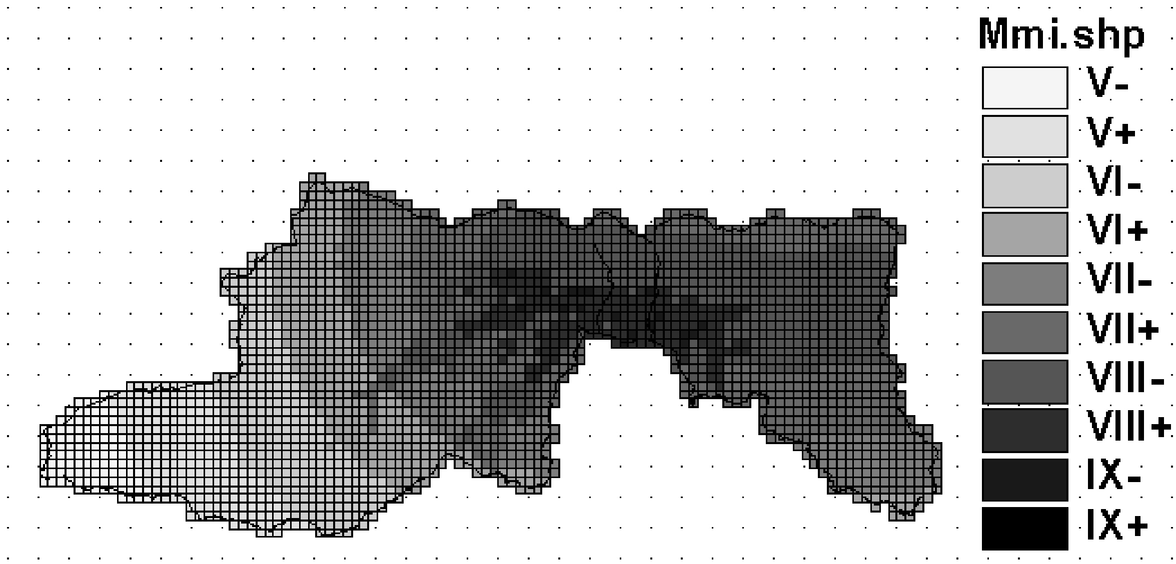


Figure 3.1.6 Estimated Seismic Intensity for Hypothetical Avila Earthquake

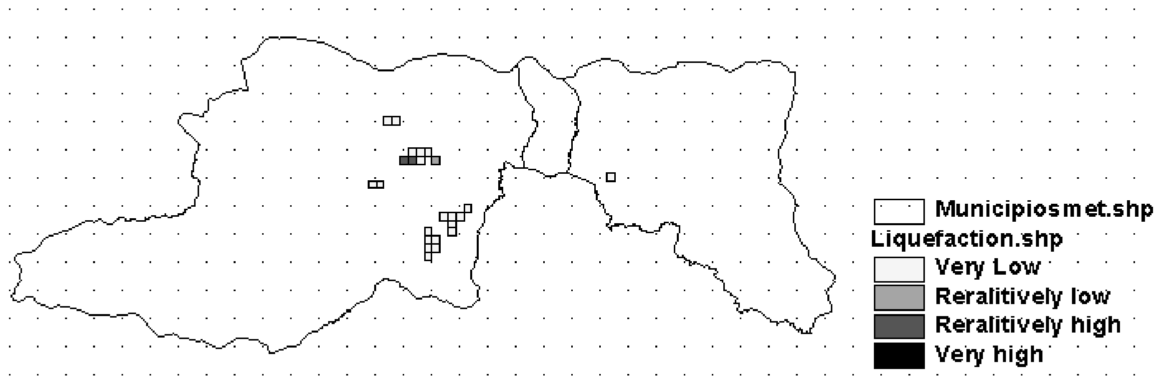


Figure 3.1.7 Estimated Liquefaction Susceptibility for the 1967 Earthquake

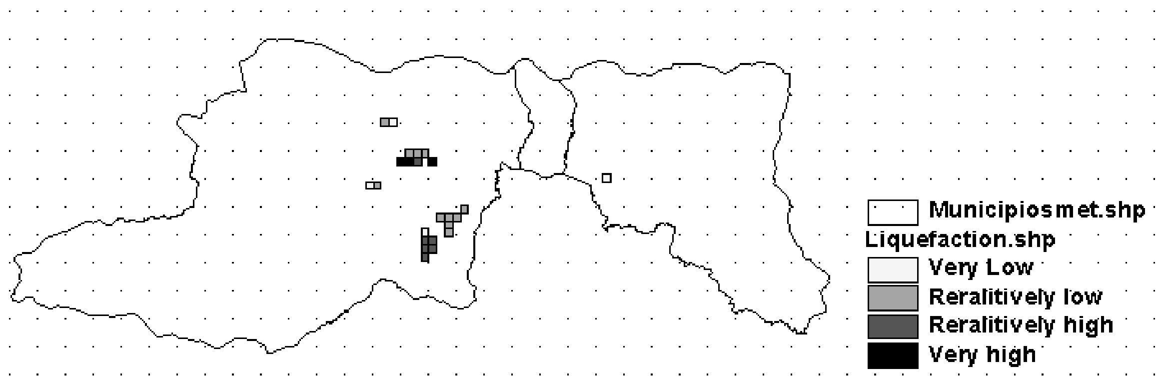


Figure 3.1.8 Estimated Liquefaction Susceptibility for the 1812 Earthquake

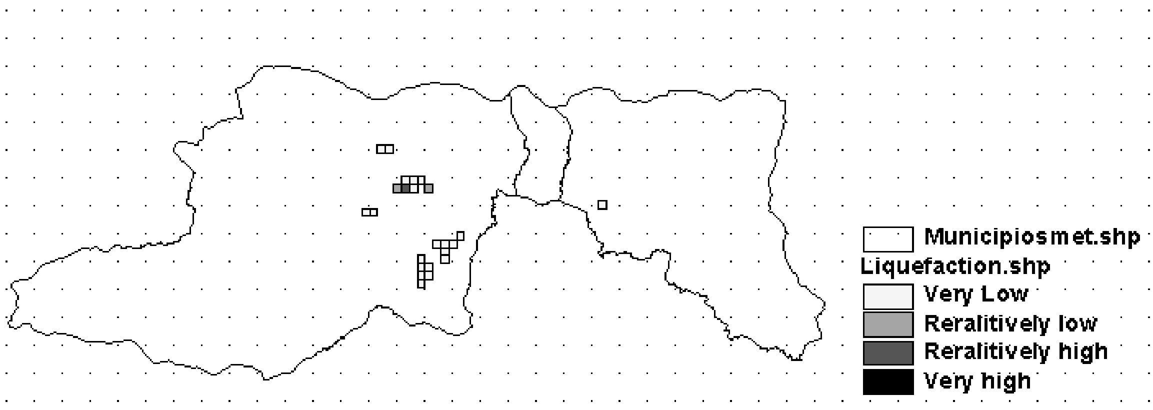


Figure 3.1.9 Estimated Liquefaction Susceptibility for the 1878 Earthquake

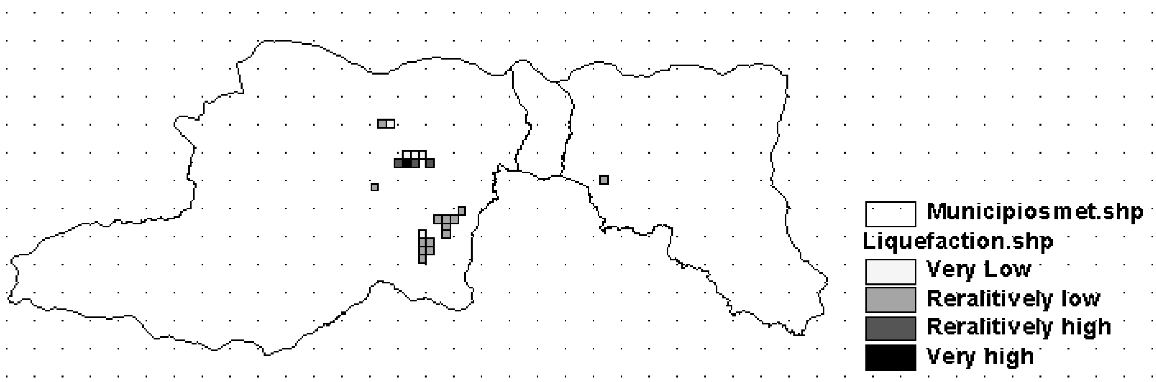
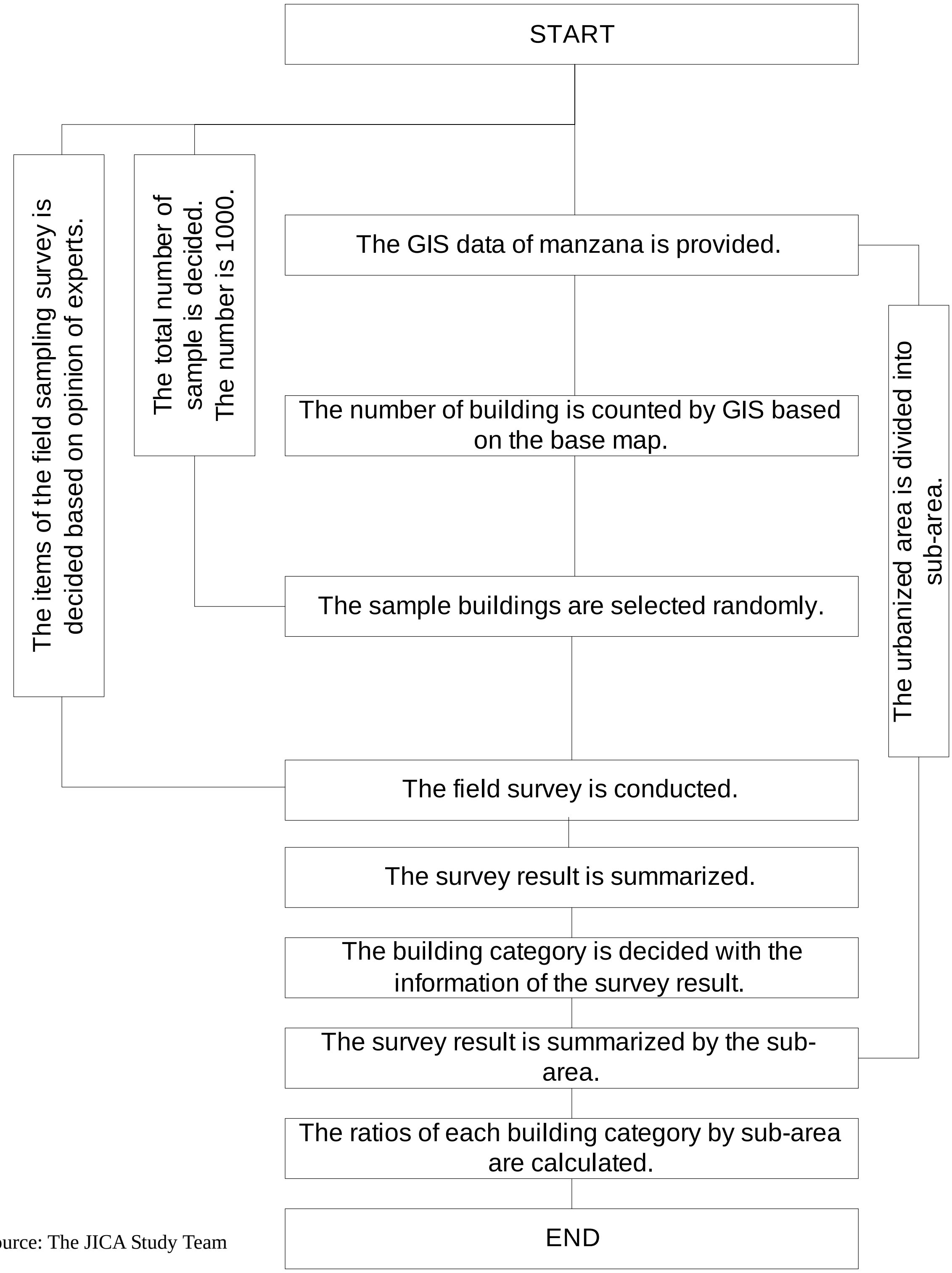
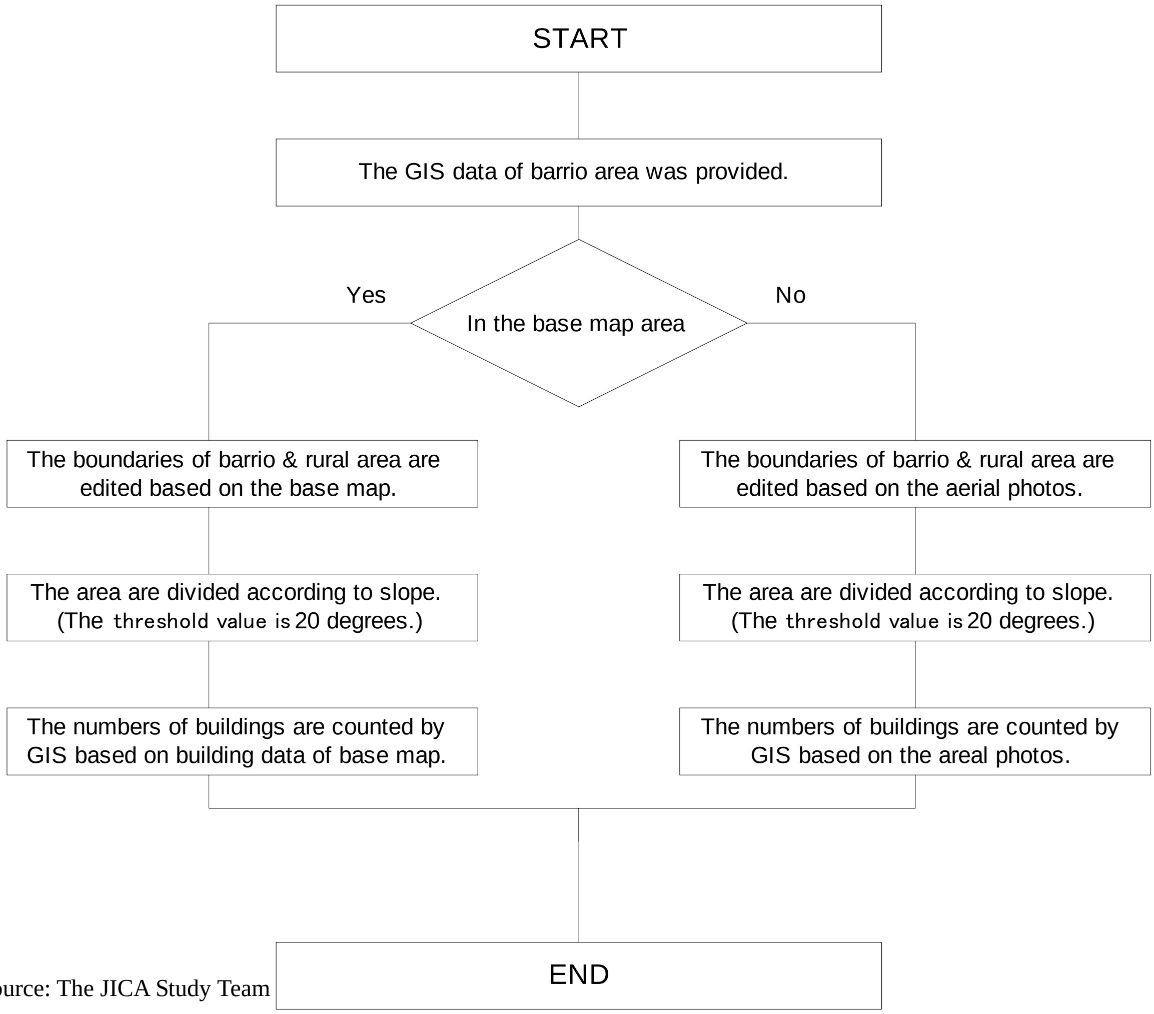


Figure 3.1.10 Estimated Liquefaction Susceptibility for Hypothetical Avila Earthquake



Source: The JICA Study Team

Figure 3.2.1 Flow Chart of Building Inventory for Urbanized Area



Source: The JICA Study Team

Figure 3.2.2 Flowchart of Building Inventory for Barrio and Rural Area

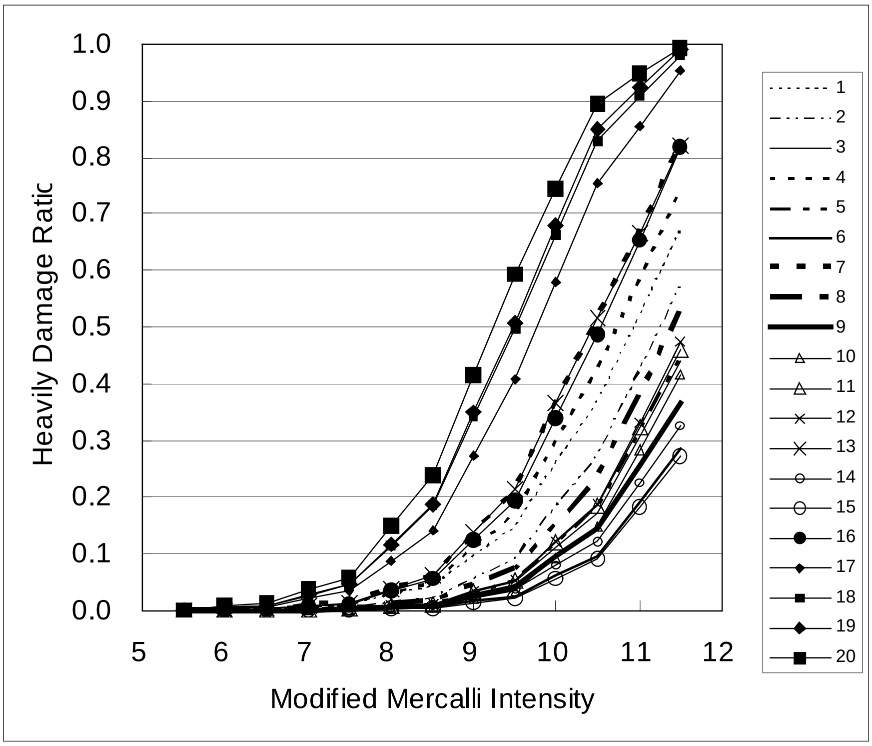
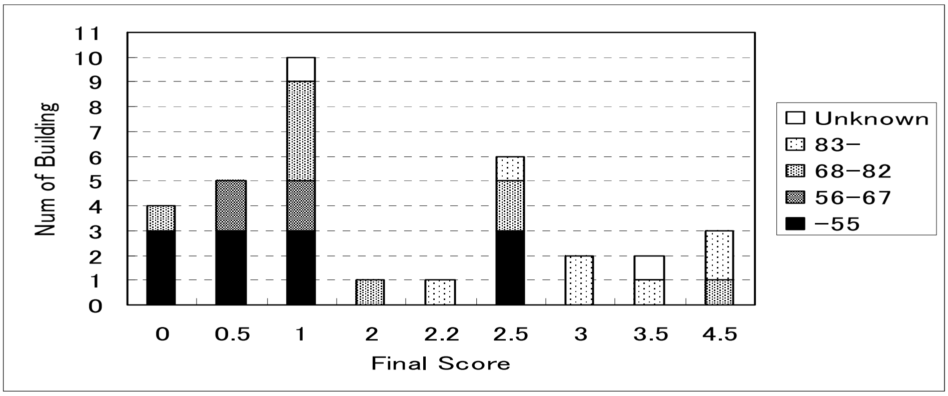


Figure 3.2.3 Building Damage Function Used in this Study



Source: The JICA Study Team

Figure 3.3.1 Result of RVS: Relation of Built Year and Final Score

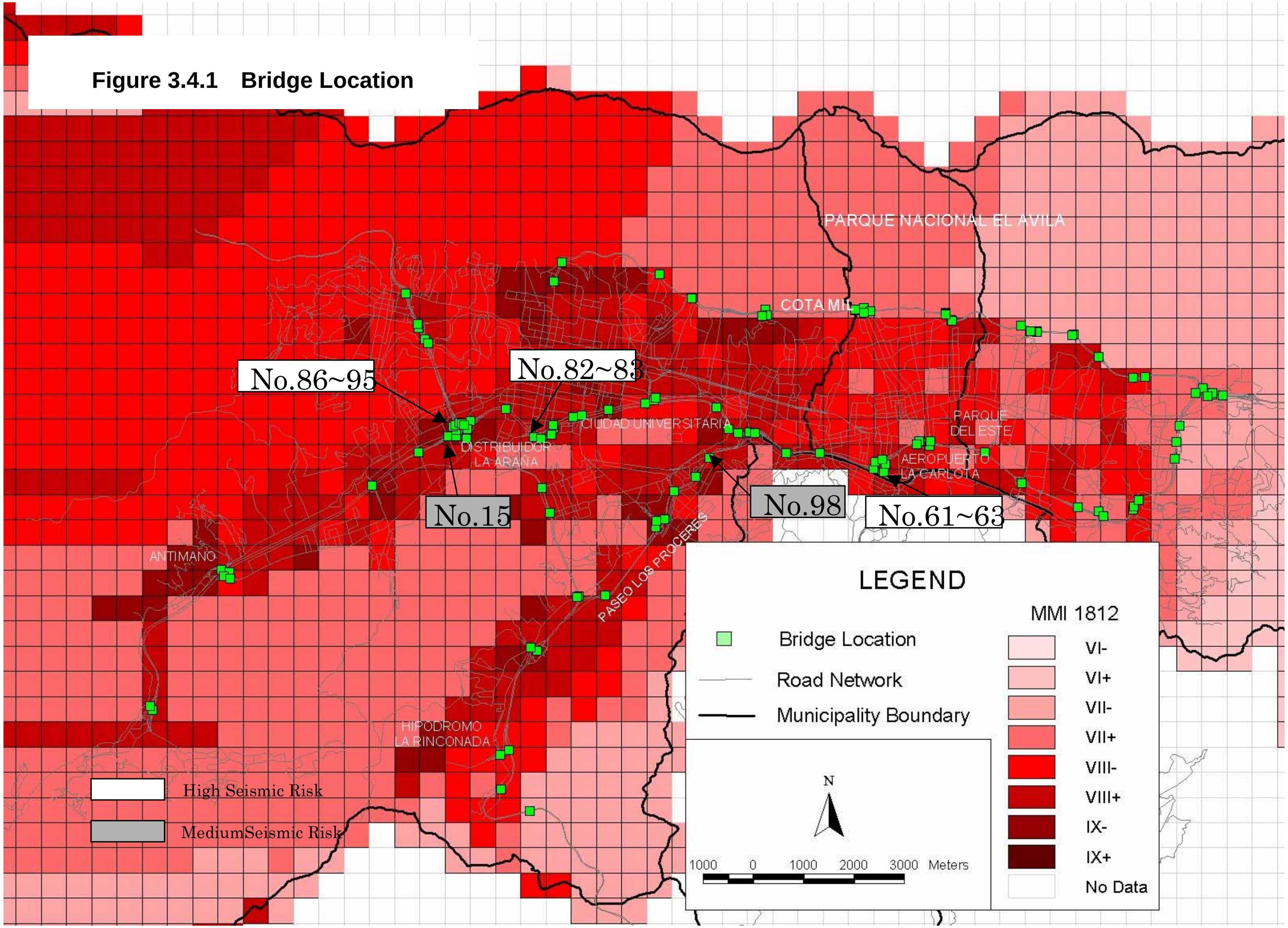


Figure 3.4.1 Bridge Location
PARQUE NACIONAL EL AVILA
COTA MIL
PARQUE DEL ESTE
AEROPUERTO LA CARLOTA
CIUDAD UNIVERSITARIA
DISTRIBUIDOR LA ARAÑA
ANTIMANO
PASEO LOS PROCERES
HIPODROMO LA RINCONADA
No.86~95
No.82~83
No.15
No.98
No.61~63
High Seismic Risk
MediumSeismic Risk
LEGEND
Bridge Location
Road Network
Municipality Boundary
N
1000 0 1000 2000 3000 Meters
MMI 1812
VI-
VI+
VII-
VII+
VIII-
VIII+
IX-
IX+
No Data

Figure 3.4.2 Viaduct Location

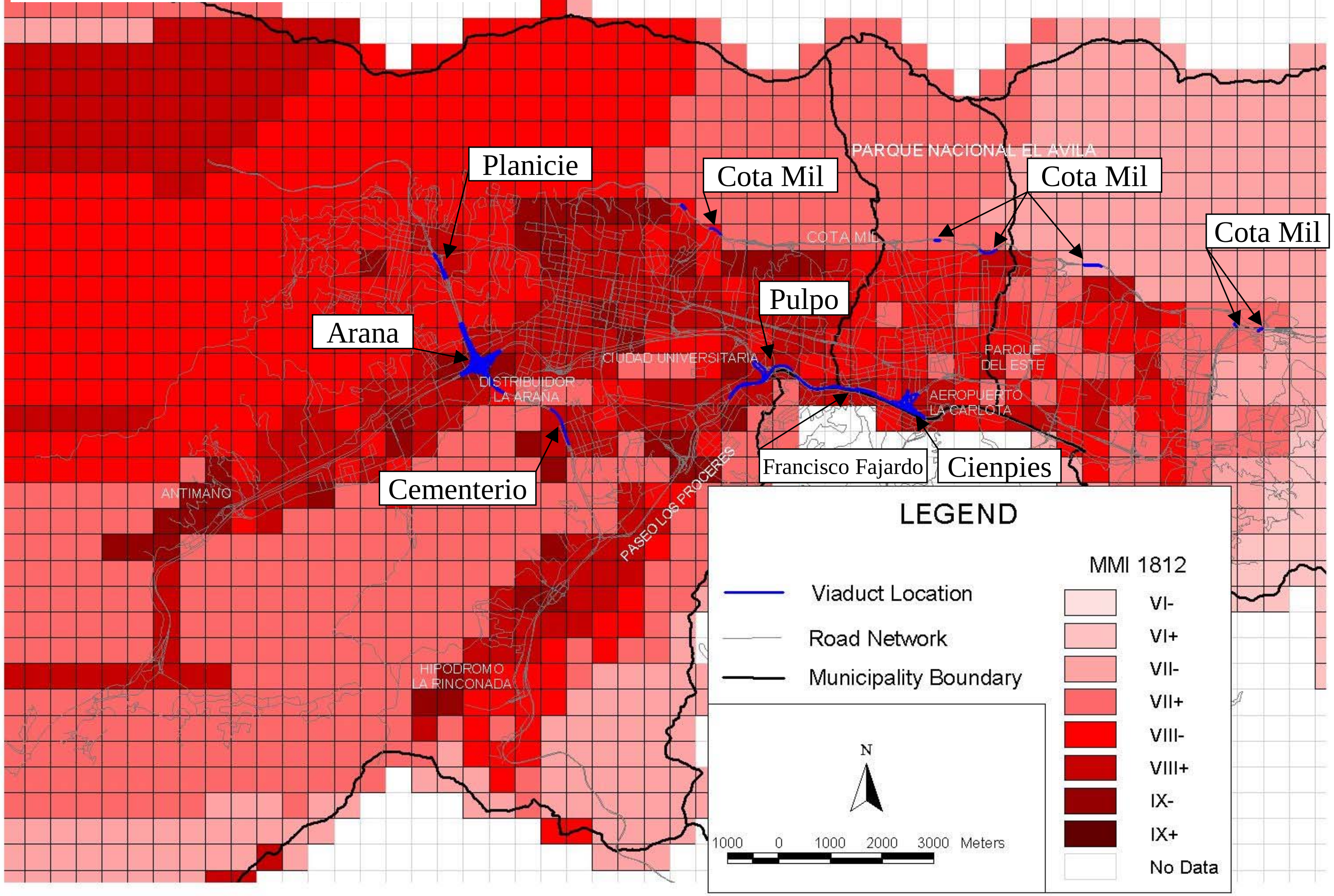


Figure 3.4.3 Metro Location

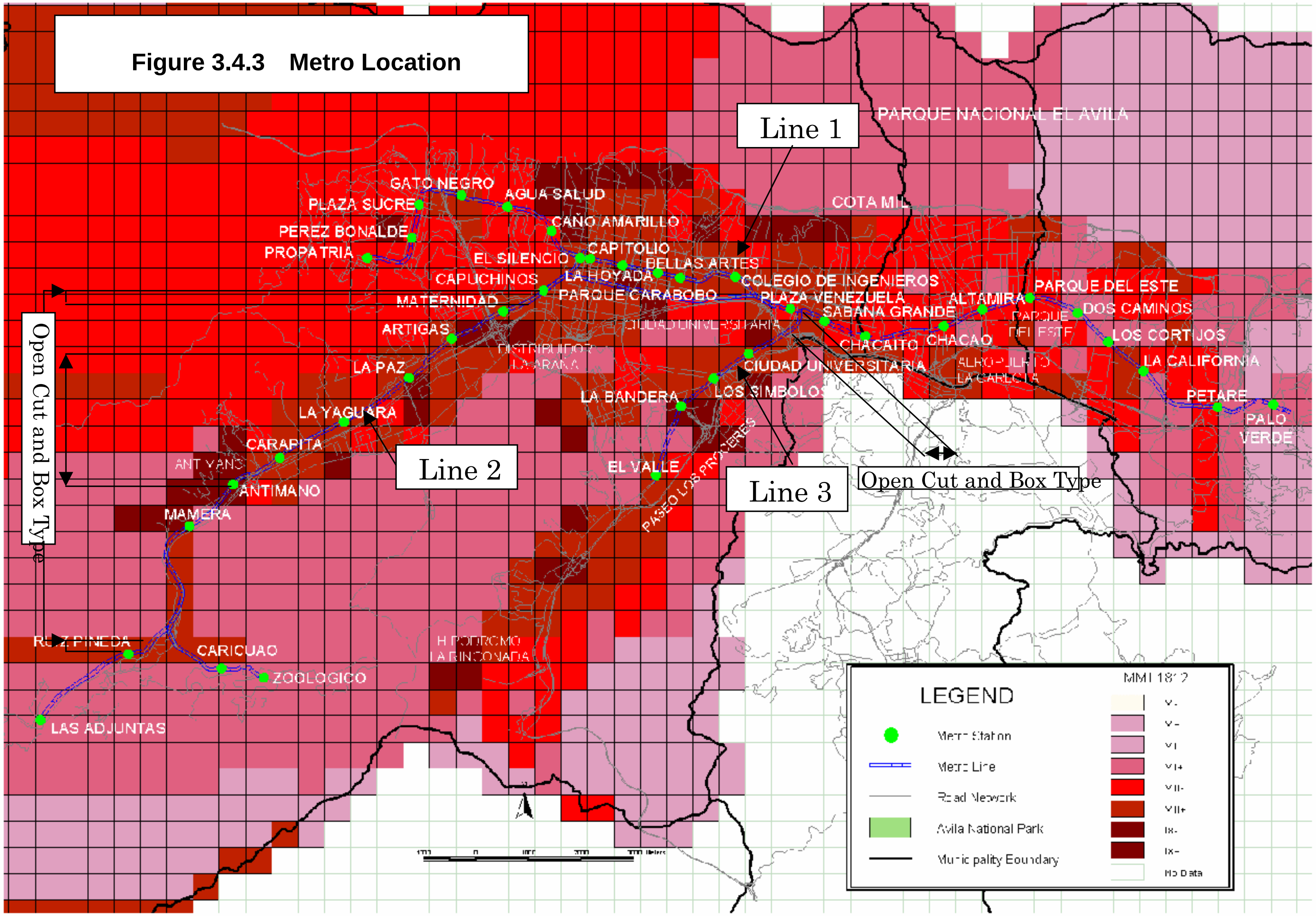


Figure 3.4.4 Water Supply Pipeline

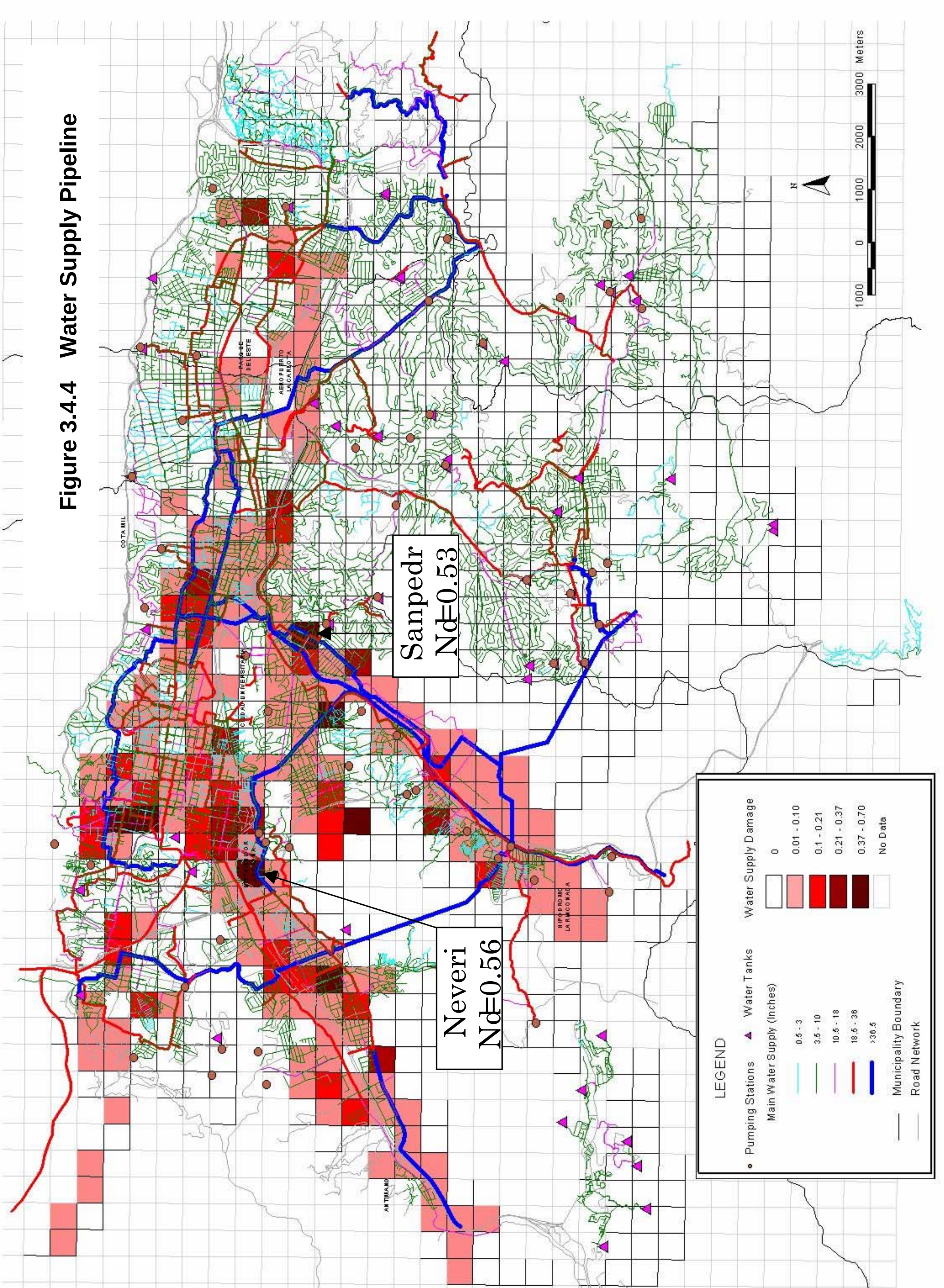
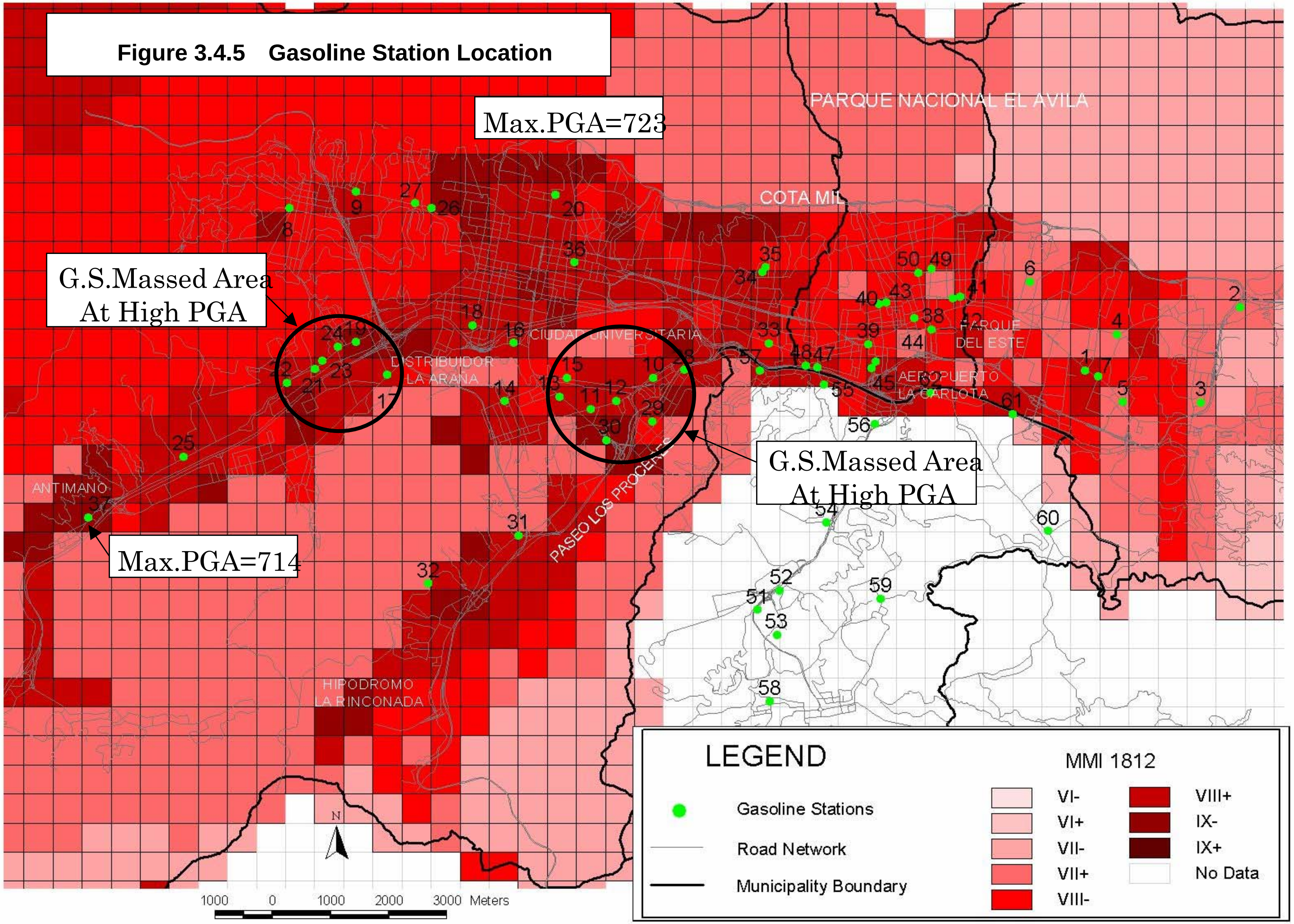


Figure 3.4.5 Gasoline Station Location



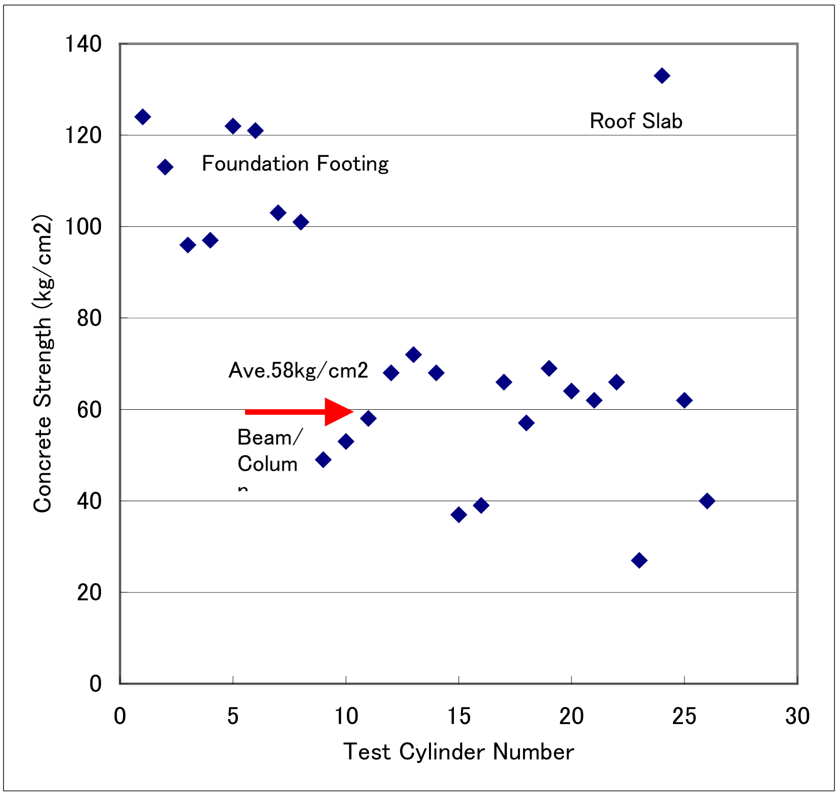


Figure 3.5.1 Distribution of Concrete Strength (Tested by IMME)

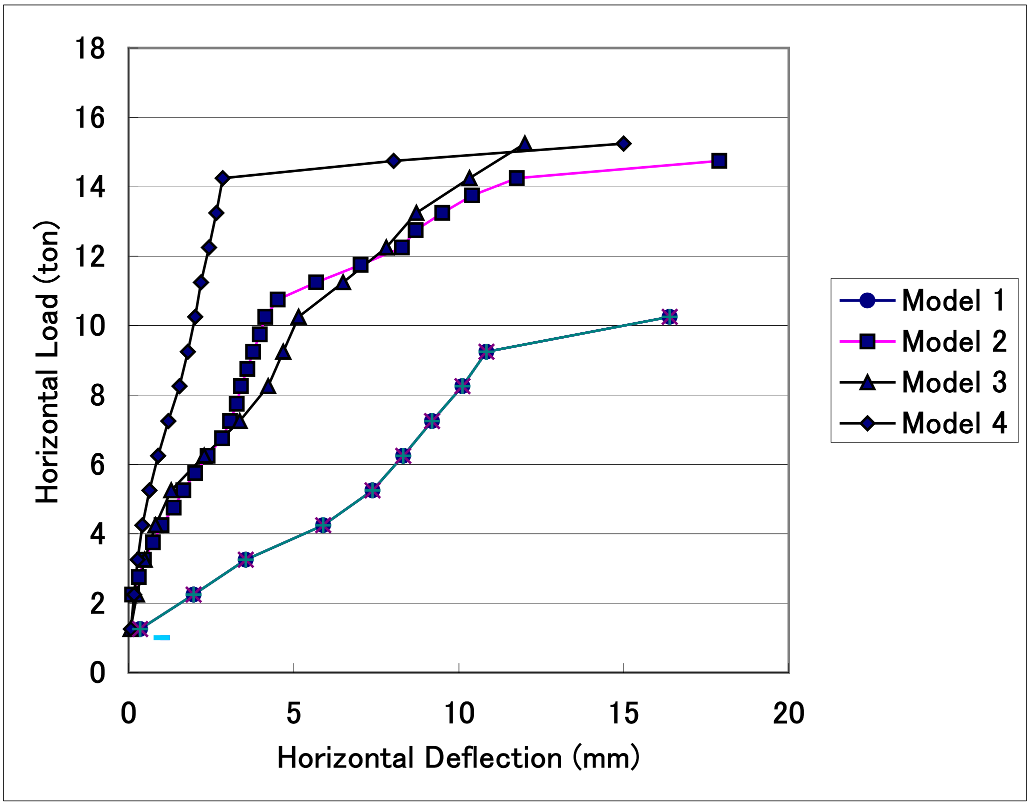


Figure 3.5.2 Horizontal Load and Deflection (Tested by IMME)

Photo 3.5.1 Four Models for the Test

Photo 3.5.2 Grade Beams

Photo 3.5.3 Horizontal Loading by Hydraulic Jack

CHAPTER 4

SEDIMENT DISASTER STUDY

CHAPTER 4. SEDIMENT DISASTER STUDY

4. 1 Sediment Disaster Hazard Analysis

4. 1. 1. Definition of Scenario Sediment Disaster

(1) Features of the Topography, Geology and Mountain Streams

1) Topography

In the Caracas Valley, thick alluvial fan deposit lies over the base rock and the maximum thickness is estimated as around 400 m. To the north of the valley, El Avila Mountain Range 8the top elevation is between 2,000 and 2,600 meters above sea level) extends west to east by around 10 km length. Between the valley and the mountain peak, there exist slopes of aroudn 30 degrees having the relative hight of around 1,000 m.

2) Geology

The Caracas Valley is composed of metamorphic and igneous rocks of Cretaceous period and Jurassic period in Mesozoic era. The higher part of El Avila is gneiss of Jurassic period and the lower part of it is gneiss of Cretaceous period. Generally, gneiss of Jurassic period is strong against weathering and it forms a steep slope while gneiss of Cretaceous period contains numerous schistosity and it is weak against weathering. According to the field survey, there is no apparent geotechnical difference between the west and the east part of El Avila.

The valley of Caracas is a deposit of many layers of un-skeletal sediment by rivers, lakes and debris flow. Along the mountain stream, which is the target of this Study, debris flow sediment in the Holocene epoch (around 10,000 years ago up to present) lies and it is apparent that this whole area is the product of repeated debris flow deposits.

3) Vegetation

The vegetation on the southern slope of El Avila has been classified into categories with elevation by various researchers. In the middle zone of the slope between EL 1,600 m and EL 2,200 m comparatively high trees grow. The reason of this is the maintenance of high moisture content because of the high activity of cloud. In the higher zone than EL 2,200 m, the vegetations fitting for low temperature and dry weather prevail. In the lower zone than EL 1,600 m, the vegetation is poor because of high temperature and low soil moisture content. This difference of vegetation density was recognized by the analysis of satellite images..

4) Meteorology

There are four (4) significant weather synopses other than the ITCZ that could bring heavy storm to Caracas, namely Wave of the East, Low Pressure Zones on High altitude, Cold front and Hurricane / Tropical depression Trail. The first three weather synopses will keep unstable atmosphere for several days even during dry seasons and they bring about rainfall with high intensity in Caracas Valley. Especially, cold front is a typical patter when a high pressure develops in Atlantic Ocean and its unstable atmosphere causes heavy rain along the northern coast. As stated later, the past large scale debris flow disasters in Caracas were both generated by unstable atmosphere of cold front. The horizontal scale of these meteorological phenomena is in the order of tens of kilometers and it is much larger than the size of Caracas Valley so that there is no significant difference of rainfall amount between the west and the east parts of the valley.

5) Mountain Streams

Table 4.1.1 shows the comparison of main mountain streams on the southern slope of El Avila from the view points of topography, geology and vegetation. There is not significant topographical or geological difference between the west and the east in the southern slope of El Avila. The vegetation in higher zone than EL 1,600 m is thick and the zone is strong in terms of erosion. This higher zone prevails in the eastern part of El Avila because the peak elevation is higher in the eastern side. On the other hand, in the western part of El Avila, this higher zone is comparatively small. In this sense, ratio of erosion may be higher in the western part than in the eastern part. However, the amount of sediment along the mountain streams is larger in the eastern part. As a conclusion, there is no significant difference in potential of debris flow between the west and the east parts of El Avila.

(2) Past Sediment Disasters in the Area

1) General

Caracas is the capital city of Venezuela with a population of 3.09 million. It lies in a west-east long valley, with the length of 25 km, the maximum width of 4 km and the average elevation of EL 900m.

In 16th century, population concentration started in the area between Catuche mountain stream and Caroata mountain stream, which are located in the western part of the valley.

Later, the town developed on the alluvial fans of main mountain streams such as Anauco, Chacaito and Tocome. Damage cause by debris flow and flood from El Avila occurred more than twenty times since 18^{th} century (PREVENE). The locations of mountain streams where damage occurred distribute from west to east unanimously. (Table 4.1.2)

Significant debris flow disasters from El Avila occurred on February 17, 1951 and December 15, 1999. During the 1951 disaster, damage was reported from Anauco, Chacaito, Sebucan and Tocome. During the 1999 disaster, when a large scale debris flows happened in Vargas State, debris flows attacked urban area of Caracas along Catuche and Anauco streams and brought about comparatively large casualties.

2) February 1951 Disaster

[Weather Condition] The cold front from the West Atlantic Ocean reached the northern part of Venezuela like in Dec.1999. But the position of the cold front in Feb.1951 was toward the south as compared to that in Dec.1999. Although the situation was very similar to the event of Dec. 1999, the cold front in Feb. 1951 caused more rain over the Caracas area.

[Rainfall] Looking at the rainfall distribution obtained by MARN, remarkable difference of the rainfall cannot be seen between western and eastern areas in the study area. Although the rainfall record in El Avila, which is the trigger of debris flow, is scarce there are some reference values of rainfall record in the coastal area and in the Caracas Valley. The maximum daily rainfall was 193.0 mm at Maiquetia in the coastal area , 72.9 mm at Cagigal and 36.2 mm at UCV in the Caracas Valley.

[Affected Area] According to Table 4.1.2, from PREVENE report, the damages produced by the February 1951 flood affected streams were widely distributed between the Anauco and the Tocome streams. The affected streams were the Anauco, Chacaito, Sebucan and Tocome.

3) December 1999 Disaster

[Weather Condition] A cold front, whose length was several thousand kilometers, was located at the West Atlantic Ocean. It had stayed on the coastal line of Venezuela for about 20 days.

[Rainfall] The rainfall observation for the event of Dec. 1999 in Caracas is only at the bottom of the valley. Figure 4.1.1 shows the location of the operating rainfall stations in Caracas at that time. At UCV station, the 63.7 mm daily rainfall was recorded on Dec. 15,

1999. Cagigal and La Carlota stations recorded minor amount than UCV data. The three (3) stations in Caracas are located on the lower Caracas Valley, so that the rainfall in El Avila Mountain was not reflected in those data. Indeed, the return periods for the data from these three (3) stations were quite low.

The United States Geological Survey (USGS) disclosed the satellite image interpretation on the total rainfall around the Avila during Dec. 14-16 in 1999 on his web site. Regarding the rainfall amount over the southern slope of the Avila, they range from 350 mm to 100 mm.

[Interview Survey]An interview survey was conducted in the 1st and 2nd week of June 2003 to obtain information on the sediment flow condition in Caracas during the 1999 event.

[Damage] The mountain streams where damage was generated are from the west, Caroata, Catuche, Anauco, Chacaito and Tocome. Among these, the damaged areas along Caroata, Catuche and Anauco are occupied by barrio. Damaged areas along the other mountain streams belong to the urban area. The total number of buildings damaged is around 2,100 and around 2,000 of them are from Catuche and Anauco streams. Because of the small area of each building, the number of buildings damaged was large. The ratios of the buildings totally destroyed along Catuche and Anauco streams were 22 % and 32 % respectively. The total loss on buildings including urban and barrio area was around US$ 1,500 million.

(3) Study on Sediment Disaster

1) Study Area and Basic Point

The study area covers the southern slope of El Avila Mountain and its alluvial fan in north-south and the area between the Caurimare Stream and the Caroata Stream catchments in east-west direction. The total area of the southern slope of El Avila Mountain is 60 km^2 as shown in Figure 4.1.2. In the cases considered by this study, most of the fan apexes of 47 mountain streams are located at the Boyaca Avenue (called “Cota Mil” in Caracas).

2) Stream Order Analysis

Figure 4.1.3 shows the sub-catchment boundary for the 2nd order stream unit catchment in the mountain streams. The delineation was conducted based on the scale 1:5,000 Topographic Map of 1984 and 1954.

The total number of unit catchment is 195. Among the 47 mountain streams, the Tocome stream catchment has 26 catchment units as the maximum.

The maximum stream order is 5 in the Tocome stream. The catchments having 4^{th} order streams are Catuche, Cotiza, Chapellin, La Julia, Galindo and Caurimare as well as Tocome.

3) Rainfall and Discharge Analysis

[Representative Rainfall Stations] According to the past study, the rainfall in the mountain stream catchment can be represented by five (5) rainfall stations. Table 4.1.3 shows the probable rainfall (Intensity-Duration and Frequency) of the five (5) representative stations.

The method of the U.S. Soil Conservation Service (herein after called "SCS method") is used to estimate the effective rainfall.

The SCS curve numbers in this study area range from 55 to 80.

[Runoff Analysis] The kinematics wave method is applied to produce the runoff hydrographs. The kinematics wave method assumes that the weight or gravity force of flowing water is simply balanced with the resistive force of bed friction.

[Probable Discharge] The study team compared the peak discharge for 100 years return period with the discharge by rational formula in order to check the discharge of Avila Project. According to the comparison, there is good correlation between the discharge in the Avila Project and the rational method. The probable discharge in the Avila Project was used in this study as water discharge.

4) Geomorphologic Survey

The Study Team conducted the geomorphologic and geological survey for the southern slope of El Avila Mountain during June and July, 2003 with the close cooperation of FUNVISIS, INGEOMIN and MARN-INPARQUES.

The survey items are "geomorphic anomalies", "trace of collapse in the basins", "lithology and geological structure" and "sediment and weathering".

5) Hydrological Evaluation of Dec. 1999 Flood in Caracas

It has been reported that during this event, the main streams affected by the rainfall were Catuche, Anauco, Chacaito and Tocome. Among them, the Catuche and Anauco streams suffered from sediment flow flooding in the urban area below the Cota Mil Ave.

According to the measurements taken by these four (4) stations, the daily rainfall amounts had an increasing tendency from east to west. This tendency corresponds to the fact that the Catuche and Anauco streams were the most seriously affected by the rainfall.

Hourly rainfall data was only available in La Carlota and in Cagigal during the event. It recorded 12.2 mm in La Carlota and 20.9 mm in Cagigal during hours 20:00 – 21:00 on December 15.

For the Caracas Valley, the maximum daily rainfall observed at Cagigal in Dec.1999 was 61.5 mm. The return period for this rainfall amount can be evaluated as less than five (5) years based on Table 3.15 from "ESTUDIO DE CRECIDAS EN LAS CUENCAS DE LA VERTIENTE SUR DEL PARQUE NACIONAL AVILA". The return periods for the daily rainfall at UCV and La Carlota are also less than five (5) years. These stations are located in the lower area of the Valley and they do not represent the hydrological conditions which occurred on El Avila Mountain during the event of December 1999. Considering the Caracas Valley sediment disaster event, the return period for the rainfall on El Avila Mountain should be much larger than five (5) years. On the other hand, the daily rainfall record at Maiquetia (revealed just after the disaster), which is around 10 km away from Chacaito stream, is 410 mm and its return period is in the order of 1,000 years.

6) Condition of Cota Mil for Sediment Disaster

For the stream section under the Cota Mil, there are four (4) types of crossing.
Bridge
Large Box Culvert
Small Box Culvert or Duct
Out of Cota Mil Route

The information on the dimension of culvert and bridge were obtained by the field reconnaissance of the Study Team and the IMF Report and the Cota Mil design drawing. However quite a few sites under the Cota Mil are difficult to access because the access routes are within private lands.

Among the 39 mountain streams that are crossing the Cota Mil, only 3 streams are going through the open channel under the Cota Mil. They are the Gamboa, Chacaito and Tocome streams. The mountain streams that are going through comparatively large culverts (wider than 2 m) is twelve (12).

7) Study on Debris Flow Potential

Sediment Balance

a) Sediment Balance in December 1999

For the event of December 1999, it is assumed that the steep slope, so-called the active collapse and new collapse, collapsed and went out to the connecting streams. Some part of the collapsed sediment and the unstable sediment on the streambed went out to the downstream urban area. The runoff sediment volume in 1999 was 50,000 m^3 in the Catuche (after the Study), 39,000 m^3 in the Cotiza after PREVENE and 31,000 m^3 in the Anauco after PREVENE.

After the December 1999 event, there has been no major sediment runoff so far, the remaining sediment deposits on the streambed.

The ratio of the runoff sediment in 1999 to the unstable sediment before 1999 can be calculated as follows,

$$R = \frac{A}{B}$$

"A" is the runoff sediment volume in 1999. "B" is the summation of the collapsed sediment in 1999 and the sediment deposit on streambed before 1999. The collapsed sediment in 1999 means here the active collapse and new collapse covered with grass. The volume A of the Cotiza and Anauco streams includes the deposition just upstream of the Cota Mil.

The resultant ratio (=R) is 0.20, 0.25 and 0.27 for the Catuche, Cotiza and Anauco streams, respectively.

Based on this result, taking a safety side, the ratio of 0.30 can be applied for the evaluation of the sediment runoff in the next rainfall event that is corresponding to the December 1999.

b) Sediment Balance for Scenario Event

Assuming the rainfall event corresponding to the December 1999 one, for the 47 mountain streams, the runoff sediment volume was estimated as follows,

"Calculation of Movable Sediment Amount"

The ratio of the area of active slope collapse to the whole catchment area was calculated as 3.7 % for the western part of the Avila, in which significant slope collapses occurred in 1999. This calculation was done based on the geomorphologic map made in the Study.

The assumed slope collapse area for the scenario event was calculated as the product of 3.7 % multiplied by each catchment area.

The sediment volume generated from the assumed slope collapse area was calculated as the product of the above collapsed area, thickness and the ratio of remaining sediment volume. The thickness was estimated according to the field survey result as 2.3 m.

Finally in order to estimate the sediment runoff volume below the basic point of each catchment, the ratio of the runoff sediment for the future event to the present unstable sediment is assumed as R = 0.3 for the major catchment whose area is larger than 1.0 km^2, while R=1.0 was applied to the catchments whose area is smaller than 1.0 km^2.

“Calculation of Transportable Sediment Amount”

The above sediment runoff volume below the basic point is a kind of potential value based on the condition in the upper part of the Avila. The runoff sediment volume below the basic point is actually affected by the topographic condition around the basic point and the hydrological condition. As it is widely done in Japan, the following sediment volume was calculated as the value possible through the basic point.

$$Vec = \frac{10^3 \cdot Rt \cdot A}{1-\lambda}\left(\frac{Cd}{1-Cd}\right)\cdot fr$$

Where A: Catchment area in km^2, Rt: 24 hours rainfall in mm for the selected return period, λ : void ratio , fr: runoff ratio, Cd: sediment concentration as a function of stream bed slope.

“Calculation of Run-off Sediment Amount”

If the calculated Vec is smaller than the assumed sediment runoff volume, the Vec is selected as the design sediment volume.

The Figure 4.1.4 shows the estimated runoff sediment for each major catchment. The catchment No.14 is at the Tocome Stream, which has the largest runoff sediment volume among all. The second largest volume is expected in the Caurimare stream (No. 4). The Catuche (No.44) and Cotiza (No.42) streams have smaller estimated sediment volume compared with the eastern part of El Avila, because the unstable sediment in those two streams already went out of the catchment in 1999.

Debris Flow Potential

In terms of the streambed slope above the basic point, they are larger than 10 degrees and there is no significant difference among the 47 mountain streams. So the amount of unstable sediment volume including new and old collapse area is one of the major factors to indicate the potential of debris flow.

As the major catchment-wise, the Tocome, Caurimare, Galindo, Chacaito and Cotiza have much sediment in this order to be generated in future as shown in Table 4.1.4.

Debris flow disaster scenario can be explained by an external force of rainfall and the potential of debris flow. The external rainfall was explained before and there the debris flow potential of 47 mountain streams on the southern slope of El Avila is summarized as follows;

- Although relatively soft rocks such as marble or serpentinite are reported in the western side, there is no major difference of geology / lithology between the east side and the west side. The density of faults and lineaments is not different between the east and the west.
- New collapses are more in the west because there were a lot of collapses in December 1999, and old collapses are scattered in the whole area. Although there were quite a few collapses in February 1951, their vegetations have already been recovered and at present they are regarded as old collapses.
- Weathered zone is thicker in the west than in the east. This may be caused by the terrain. The material of weathered zone is rich in gravel and poor in silt/clay.
- The amount of debris on streams seems larger in the east. This may be caused by that the streams in the east have steps in its profile and have trellis / angular pattern of its drainage pattern. In the west part, feather like patter prevails and there are comparatively less steps.
- Vegetation is classified from lower altitude to upper altitude of the Avila Mountains. Vegetation above 1,700m altitude is thicker than in below. Therefore, Catuche, Cotiza basins which are mostly below 1,700m have weaker vegetation.

The rainfall distribution on the southern part of El Avial during December 1999 give no significant difference between west and east according the analysis of satellite images.

However, the amount of debris flow and damage cause by it concentrated in the western part where Catuche and Anauco streams locate. This seems because the debris flow generated on the slope in the eastern part deposited in the stream beds on the slope and it did not reach the urban area.

4. 1. 2. Development of Sediment Hazard Map

(1) Steep Slope Failure and Landslide

In this study, the identified target of disasters are "landslide" and "Steep Slope Failure", and then the identified target of preservation are houses, important facilities and roads that have more than four lanes. Screening was conducted by using aero photographs that were taken in February 2002 (scale: 1/25,000), Topographical Maps that were published by in 1984 (scale: 1/5,000) and satellite pictures "Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER)" that were taken in April 2003. The slopes that were identified by the screening are considered the possibility to be landslide and steep slope failure, and also to expand to disaster.

The number of the interpreted instable steep slope and landslide is 230 and 8, respectively. Among the 230 steep slopes, there are 52 steep slopes above the road. Figure 4.1.5 shows the number by Municipality. Most of the steep slopes above house are located in Libertador and Sucre.

(2) Debris Flow

1) Methodology

Regarding the flood simulation for the Caracas Valley, the method by Japanese Law of Sediment Disaster Prevention and the FLO-2D model were used in this Study. The FLO-2D is a software developed by the Central University of Venezuela with a university of US and it has been applied in many cases including Vargas State disaster in 1999. The FLO-2D model was used to judge the effect of sabo dams in this Study.

2) Method 1: Method by Japanese Law of Sediment Disaster Prevention

The Law of Sediment Disaster Prevention, which was issued in 2001 in Japan, and the related guidelines indicate the methodology to delineate the potential area for debris flow.

a. Definition of "Red Zone"

The seriously affected area by debris flow so called "Red Zone" can be defined as the section in which the hydraulic force by debris flow is larger than the resistant force of house / building. It means that the house in the red zone can be destroyed by hitting of debris flow.

The hydraulic force in kN/m^2 is expressed as

$$F_d = \frac{\rho_d}{g} \cdot U^2$$

The resistance force of house / building is

$$P_2 = \frac{35.3}{H(5.6 - H)}$$

where P_2 : resistance force of ordinary house / building in kN/m^2, H : height of debris flow when the force is acted on the house / building by debris flow and g is gravity acceleration in m/s^2.

The above equation of P_2 has been authorized in Japan by the Law of Sediment Disaster Prevention, however, it is based on the structure of ordinal wooden house in Japan.

b. Definition of “Yellow Zone”

The normally affected area by debris flow so called “Yellow Zone” can be defined as the section in which the potentially debris flow could reach from the topographical viewpoint. The yellow zone is the basic point downstream and the slope two (2) degree upstream, in principle.

c. Hazard Map by Method –1

Figure 4.1.6 is the debris flow hazard map by the method-1. The number of affected house and the total area of the house in Yellow and Red Zones are shown in Table 4.1.5 and Table 4.1.6. From the 2,700 houses located in the red zone, 1,300 are barrio houses of which about 1,000 are built in the streams. Therefore, it is recommended that these are relocated.

3) Model 2: Method by FLO-2D Model

a. Case

The simulated cases are 10 years, 100 years in terms of return period of design rainfall under existing condition. The considered sediment conditions are no debris flow happening (Cv = 0.2 constant) for 10 years, sediment runoff volume for 100 years.

As a reference, assuming all the Sabo Dams are constructed in the Avila, one (1) case was simulated for 100 years return period.

b. Results

Figure 4.1.7 and Figure 4.1.8 are the depth and velocity for 100 years return period under the existing condition. The values of depth and velocity are the average value for each grid cell.

Figure 4.1.9 is the depth for 100 years return period assuming all the Sabo Dam constructed in the future. The peak discharge was reduced because of less sediment concentration, resulting into that the flooded area was also reduced.

The Central University of Venezuela has been working on hazard maps of debris flow by using FLO-2D since 2000. We hope the debris flow amount, which was calculated in this Study will be used in the model study of the Central University of Venezuela.

4. 2 Development of Sediment Risk Map

The risk map will be prepared based on the physical hazard in relation with the socio-economic information on the urban area.

4. 2. 1. Steep Slope Failure and Landslide

The hazard area below the slope is within the two times of the vertical height of the slope whereas the hazard area above the slope is within the one (1) time of the vertical height of the slope. This concept is based on the Japanese ordinances on sediment disaster prevention.

In the case of landslide, the affected area by a landslide is in the reach of 50 % of the slope length based on another Japanese reference, however, it should noted that the extent of the affected area is varied by the geological, topographical and vegetation.

Based on the above concept, the affected area was delineated for each potential steep slope failure and landslide. The hazard map for landslide and steep slope failure is shown in Figure 4.2.1.

The Risk map is shown in Fig 4.2.2. This is the map that is classified by the colors according to the density of houses in the hazardous area based on the hazard map.

4. 2. 2. Debris Flow

In order to create debris flow risk maps, following damage survey and property survey were conducted.

1) Affected Houses / Property

By the 1999 December disaster, the number of affected houses and property is 977 in the Catuche, 993 in the Anauco (the total of Anauco, Cotiza and Gamboa), 10 in the Chacaito, 92 in the Tocome and 37 in the Caroata basins. In terms of the affected number, most of the damage concentrated in the Catuche and Anauco basins during December 1999 disaster, whereas those areas are composed of small scale houses such as informal ones.

In the Catuche basin, the number of totally destroyed houses is 218 that is 22 % of the total. In the Anauco basin the number of totally destroyed houses is 321, which is 32 % of the total.

2) Unit Damage Price

In the Catuche and Anauco basins, the damage price for the totally destroyed house in the Non-Urban area ranges from 5 million Bs. to 15.5 million Bs., according to year 1999 reference prices. In the case of the Chacaito, Tocome and Caroata basins, the damage price for the totally destroyed house is 9.5 million Bs. These prices include the furniture.

In the urban area, the damage for the totally destroyed house was estimated based on the magazine "Reporte Inmobiliarios AKROS, Nov.1999". The magazine shows the real value for specific house items such as the floor area and the price per m^2. For commercial area, the price was set to be 140 % of that of the residential. This percentage was obtained by sample survey results in Caracas.

3) Total Damage Price

The total damage price for the five streams is as follows,

Unit: million Bs. in 1999(1US$=558Bs.)

Affected Stream in 1999	**Non Urban Area**	**Urban Area**	**Total**
Catuche	2,953(5.3)	664(1.2)	3,617(6.5)
Anauco (Cotiza, Gamboa)	2,700(4.8)	1,618((2.9)	4,318(7.7)
Chacaito	38(0.07)		38(0.07)
Tocome	199(0.36)		199(0.36)
Caroata	208(0.37)		208(0.37)

The Risk map is shown in Figure 4.2.3. This is the map that is classified by the colors according to the density of houses in the hazardous area based on the hazard map.

4. 3 Disaster Prevention Study for Sediment Disasters

Figure 4.3.1 shows the basic work flow diagram for the master plan study.

4. 3. 1. Structure Measure for Steep Slope Failure and Landslide

According to the risk map prepared preliminary in the section 4.2, the number of house / building to be protected is as shown in Table 4.2.1.

Most of the affected property belongs to the informal areas so called “barrio”. The number indicated above is the number of “house”, that means the size of house has a large variation, especially in the formal areas.

The cost of the protection works would be higher as the slope area becomes large. Since there is an upper limit of the affected area, the economical efficiency for the slope protection works in informal area (barrio) can be regarded as quite low.

However, in formal area this kind protection works could be economically possible for extremely high intensity land use such as high rises complex.

Table 4.3.1 shows the list of risk slope, where some slope protection works could be feasible based on the comparison between the cost of protection works and the protected property values.

4. 3. 2. Structure Measures for Debris Flow

(1) Conceivable Structure Measures

Figure 4.3.2 shows the work flow diagram for the selection of structure measures for debris flow from the Avila. In the figure, totally 7 types of sediment control measures are mentioned. The southern slope of El Avila is basically debris flow regime from the view point of slope gradient and three types of measures are preferable, namely ①measures to prevent large scale slope failure such as slope consolidation works and group of consolidation dams ②sabo dams to control debris flows ③sabo dams to catch debris flows. The urban area downstream is subdivided into debris flow regime and flushing regime. In the urban area downstream, the measures preferable are ④sedimentation dams or ⑤guide walls, if no measures are taken on the southern slope of El Avila. IF some measures are taken on the southern slope of El Avial, ⑥ channel works as alluvial fan measure or ⑦water channel works to release water safely, will be considered.

As the southern slope of El Avila is designated as the national park, it is unrealistic to plan measures ④or ⑤, which require large land acquisition. Therefore, in this Study, among seven alternative measures, ③sabo dams to catch debris flows on the southern slope of El Avila , ⑥ channel works as alluvial fan measure and ⑦water channel works to release water safely in the urban area are appropriate.

(2) Design Scale

The scenario for the sediment disaster is set to the level comparable to the event in December 1999 in Caracas with respect to the sediment, while set to 100 years return period for the water discharge from the Avila.

In addition to the scenario case, 25 years return period for the sediment and 10 years return period for the water channel shall be proposed as the short term case (action plan).

(3) Sabo Dam in the Avila

1) Basic Concept

The basic Layout of Sabo Dam principles in the Study are as follows

- Sabo Dam shall be proposed in the lower reach where debris flow can be deposited easily, and in the topography where the trapped sediment volume is large.
- In the case that multiple Sabo Dams are necessary because of the height limitation of 15 meter, they are located not to share the sediment deposit area. Design bed slope was set to 50 % of the original bed slope.
- Only the trapped sediment volume was regarded as the sediment capacity of a dam.

Figure 4.3.3 shows the location of each Sabo Dam.

2) Cost Estimate

The project cost for the Sabo Dam works was estimated based on the concrete volume basis. Table 4.3.2 is an actual cost for a dam constructed in Vargas in 2000. The cost is expressed by Bs. in 2000. In this case, the concrete volume for the main dam is 2,095 m^3. The partial cost only for the sabo dam works is 600 million Bs. in 2000 including the overhead cost. The project cost per 1 m^3 concrete is 286,400 Bs. in 2000. For the master plan study, 300,000 Bs. per 1 m^3 Sabo Dam concrete will be used as year 2000 price level.

(4) Channel Works and Water Channel Works

1) Basic Concept

Channel Works was proposed to stabilize the stream course on the alluvial fans for the section downstream of the basic point. The stream, whose the basic point is not crossed by the Cota Mil or is going through the bridge opening of the Cota Mil, should have the channel works downstream of its basic point. Among the 47 mountain streams, the Catuche, Chacaito, Tocome streams need the channel works. The streams west of the Catuche do not need the channel works because their fan apex is forming the clear straight V-valley.

Water Channel Works was proposed to make the flood flow safely from the downstream end of channel work section until the Guaire River. Most of the existing water channels downstream of the basic point have insufficient flow capacity against the scenario flood discharge. The Central University of Venezuela has been investigating the flow capacity of the existing channel in Caracas under the Caracas Project funded by the Venezuelan Government[1]. For the section whose flow capacity is smaller than the design discharge, the appropriate water channel works should be proposed. In this Study, the rainfall in the urban area was not considered.

3) Cost Estimate

The project cost for the Channel Works and Water Channel Works was estimated based on the concrete volume basis. The unit price for 1 m^3 concrete (80 kgf / cm^2) is 120,000 Bs. in 2000 according to the Table 4.3.2. Considering intangible cost, the unit price is set 240,000 Bs. to estimate the project cost for Channel works and Water Channel Works in Caracas.

(5) Implementation Schedule

Table 4.3.3 is the proposed construction schedule.

4. 3. 3. Non Structure Measures

(1) Components of Study on Early Warning and Evacuation

In this study, the following study components were selected,

<u>Institutional Arrangement</u>

[1] UCV-IMF,Borrador Informe FONACIT

The study on institutional arrangement covers from the national government to municipalities, which are the member of C/P of this study. The study includes the proposal on hydrological measurement system.

Critical Rainfall

The study on critical (threshold) rainfall was done considering the situation of Vargas and Maracay (Limon River). For the data collection and the study on past debris flow, the study area was extended to Vargas and Maracay (Limon River). Maracay should be included because the area has suffered from debris flow disaster and also has an advanced early warning system of MARN.

Community Activity

The study on community was conducted to select two (2) communities as a part of social survey in the JICA study (Main Report Chapter 5 and Supporting Report S24).

(2) Study on Institutional Arrangement for Early Warning and Evacuation

In terms of the rainfall forecast, the project called VENEHMET has been implemented by the lead of MARN to start the partial operation in 2005. VENEHMET has radar system over the Metropolitan District of Caracas which can be used for the rainfall forecast. The VENEHMET project will finish in 2005 and an institution called INAMEH will be created to operate and maintenance the installed equipment by the project.

At present, weather forecast is issued in the Web site twice a day in general by MARN as national and regional levels. The weather forecast includes hydro-meteorological attention ("aviso" in Spanish) and warning ("alerta" in Spanish). Actually the daily forecast is prepared by interpretation of satellite image provided from USA by three (3) Venezuelan meteorologists who are working in Caracas Office of MARN. The three (3) meteorologists are in charge of the weather forecast for the entire Venezuela.

In the 4th and 5th field study period in Venezuela, the Study Team held periodical discussion meetings with C/P and the related organizations with early warning system. Based on the findings in the discussion, evaluation of present system, limitation and recommendation for early warning and evacuation were summarized in Table 4.3.4.

Based on the above evaluation on the existing situation on early warning system in Caracas, the study team proposed a draft agreement on early warning and evacuation system among the related organizations.

The basic concept of the agreement was prepared referring to the Basic Law on Disaster Prevention in Japan. The Basic Law is covering the institutional arrangement for central government and local government as well as people to respond to anticipated natural disaster.

The main features in the draft agreement are as follows,

- to designate MARN as a primary function to monitor, analyze and distribute hydrological information and to create the Caracas Regional Office (CRO) in MARN –INAMEH. MARN will give ADMC advice on design of critical rainfall colaborating with UCV. (Figure 4.3.4)

- UCV will give ADMC advice on design of critical rainfall.(Figure 4.3.5)

- to designate ADMC (Operation Control Center) as a primary function to receive and manipulate the hydrological information from MARN and distribute it to the municipalities. ADMC is in charge of issuing of local warning in accordance with the MARN and issuing of recommendation of evacuation. (Figure 4.3.5)

- to designate municipalities as a local body closest to communities to transfer the information from ADMC to communities and to support the activities of communities.

(3) Study on Critical Rainfall

1) Methodology

It is possible to forecast the occurrence of a debris flow from the rainfall data, but its accuracy level differs largely depending on the level of data obtained. In Caracas, debris flow occurrence is very rare on record. Even in December 1999 event, the observed rainfall in the Avila does not exist. To make a practical forecast of sediment related disaster occurrence, gauging of hourly rainfall is a prerequisite.

In the area having both the hourly rainfall data and the past sediment –related disaster records, a sediment-related disaster forecast is feasible if those data are analyzed.

In Japan there are several methods to determine the critical rainfall for debris flow at present. Among them, Guideline Method called Method A was applied in this study taking into consideration of data availability and the application in Maracay (Limon River). Since the method A has been used in the Limon River in Maracay, it can be compared when the same method is applied to the Caracas.

This method is intended to forecast the occurrence of a debris flow using rainfall indexes which are obtained by combining a rainfall intensity and a total rainfall. This type of index was derived because it is known from the actual state of debris flow disasters that a debris flow tends to occur even when the total rainfall is small if the rainfall intensity is large, and that it tends to occur even when the rainfall intensity is small if the total rainfall is large.

Figure 4.3.6 is a schematic image of the critical line. The rainfall index is expressed by a combination of the rainfall intensity and the total rainfall (cumulative rainfall). As shown in the figure, the rainfall intensity is shown in the ordinate (Y-axis) and the total rainfall in the abscissa (X-axis). Debris flow causing rainfall and non-causing rainfall are plotted in the figure by the different symbols. Then, those two rainfall groups are separated with a linear line or a curved line descending to the right. This boundary line is called the Critical Line (CL) which distinguishes the occurrence and non-occurrence of a debris flow. The lower left side of this line is the safe zone where a debris flow may not be caused. The upper right side of this line is the unsafe zone where a debris flow may be caused. The definitions of plotted rainfall values are explained in Table 4.3.5.

Methods for setting the standard rainfall for issuing a warning and the standard rainfall for recommendation of an evacuation are explained below. The standard line indicating the standard rainfall for warning is called "Warning Line (WL)" and the standard line indicating the standard rainfall for evacuation is called "Evacuation Line (EL)".

Before setting the WL and the EL, it is necessary to determine the timing to give a warning issuance or an evacuation recommendation. It means that how many hours before the forecasted occurrence time a warning issuance or an evacuation recommendation should be given, so that people as well as the related organizations can take necessary actions for safety. After that the WL and EL are set in consideration of an estimated rainfall during the leading time. Table 4.3. 6 shows the conditions used in the "Method A" in Japan. In this study the conditions in Japan was used because of few historical debris flow events in Caracas. However, the timing of warning issuance and evacuation recommendation should be determined based on the conditions in Caracas.

2) Proposed Warning Level and Evacuation Level for Caracas

Figure 4.3.7 shows the proposed Warning Level and Evacuation Level for Caracas. For the detail, it was described in Supporting Report S18.

(4) Dissemination of Hazard / Risk Maps for Land use Regulation

The hazard and risk maps for steep slope failure, landslide and debris flow in this Study have cleared dangerous areas in Caracas. It is clear that the less property occupies those areas, the less disaster damage is generated in the future. Relocation is recommended on condition that the people deeply recognize their own risk in the dangerous area.

4. 3. 4. Implementation Schedule

Figure 4.3.8 shows the proposed implementation schedule of the sediment related projects in this study.

Table 4.1.1 Features of Principal Streams in the Avila

		Catuche(44)	Cotiza(42) Anauco(41) Gamboa(37)	Canoas(35) Mariperez(33)	Chacaito(25)	Seca(23) Sebucan(17) Agua de Maiz(16)	Tocome(14)	Caurimare(4) Galindo(5)
Topography, Geology and Vegetation	Top of Watershed (Elevation)	Infiernito (1,945m)	Humboldt (2,153m)		Occidental (2,478m)		Oriental (2,637m)	Naiguata (2,765m)
	Elevation Difference	872m	958-1,173m	570-767m	1,290m	440-1,635m	1,400m	1,712-1,843m
	Average Gradient	15.1 degree	17.2-19.4 degree	22.7-23.5 degree	25.1 degree	24.8-30.4 degree	25.4 degree	19.5-20.7 degree
	Stream Network System	Stream network system is fine and irregular dendritic-pattern	Stream network system is fine and irregular dendritic -pattern (Cotiza). Other stream networks show coarse and grid pattern, basically tree-leaf-pattern.	Catchment area is small. Stream network pattern is trellis-angular pattern.	Main stream course is straight. There are two (2) major bends in downstream reach.	There are trellis-angular pattern stream network. Stream course is mild and bending, however in principle straight.	Catchment area is the largest. Stream network pattern is trellis-angular pattern. Main stream network is fine and bending.	There are trellis-angular pattern stream network. Caurimare downstream and Galindo mid-downstream is straight.
	Longitudinal Profile	Mild in general. Steep in upstream and mild in downstream. The profile is convex in low ward. There is no step.	Mild in general. There are several steps.	Streams are short and steep in general. Mild in downstream. The profile is convex in low ward.	Steep in upstream and mild in downstream. The profile is convex in low ward.There is no step.	Very steep. There are several small steps.	The slope is between steep-mild. There are a few changing point of slope.	Very steep. There are a few changing point of slope.
	Geology	It is lithologically composed by rocks that belong to Ávila Metamorphic Asociation of schist and gneisses. There are marble and serpentinite distributed locally.			It is lithologically composed by rocks that belong to Ávila Metamorphic Asociation of schist and gneisses.			
	Fault、Lineament	The lineaments from north east to south west are most distinguished in the area, and from north west to south east are next, while the fault is mainly from north west to south east.			Chacaito fault is distributed along the Chacaito stream and is connecting to the Vargas side beyond the ridge.	There are few faults. The lineaments from north east to south west are most distinguished in the middle and downstream reaches.	There are few faults and lineaments. The lineaments and faults from north east to south west are most distinguished in the north-east part of the catchment.	The lineaments from north east to south west are most distinguished in the area, and from north west to south east are next. The fault and lineament are same position.
	Weathering Thickness	In general 5-10m	Upstream 1-3m Midstream 3-5m Downstream 5-10m In Cotiza 5-10m in general.	Up-mid stream 3-5m Downstream 5-10m	Upstream 0-1m Mid-downstream 1-3m		Upstream 0-1m Midstream 1-3m Downstream 3-5m	
	Streams in mountains	The elevation difference with the surrounding ridge is comparatively small, so that the gradient of the slope is mild. The valley width is wide.	In Cotiza The elevation difference with the surrounding ridge is comparatively small, so that the gradient of the slope is mild. The valley width is wide. In other streams the valley are deeper.	The valley is shallow.	In straight streams, the valley is very deep like a V shape. The west slope is very steep and the east is mild.	In the most upstream part, the dissection is not developed. In the mid-downstream the valley is very deep.	In the most upstream part, the dissection is not developed. In the mid-downstream the valley is very developed, not deeper than the Chacaito.	In the Galindo upstream, the dissection is not developed. In the mid-downstream, the dissection is developed straightly. In the Caurimare mid-downstream the dissection is developed widely and the streambed is wide.
	Streambed Deposit	Few	Few. Cotiza has more deposit than in the Anauco and Gamboa.	Few in the downstream and some deposit remains in the upstream.	Few in the right side streams. There are a lot of deposits in the left side streams and the main stream.	A lot in the downstream and few in the upstream.	A lot in the confluence points in the upstream.	A lot in the confluence points in the upstream.
	Vegetation (observation of Satellite Image)	Very dense vegetation in the area higher than 1,700m except on the cliff surround of the ridge in the west. Since the ridge elevation is higher in the east and lower in the west, the area of high elevation in entire catchment area is larger in the east.						
	Slope Collapse	There are many active collapses.	There are many active collapses in Cotiza. In Anauco there are many active collapses in the north-west side slope and there are few new collapses and old collapses in the upstream.	There are only old collapses.	There are few active collapses and not many new collapses. Old collapses are distributed evenly.			There are many old collapses in downstream and few in middle and upstream.
	Flat Area	There is lower terrace between mountain and flat area. The stream is flowing to dissect the terrace.			The alluvial fans are pushing out the eastern streams. There may be new sediment runoff here.		Erosion is more developed compared to the Chacaito.	There is a trace of deposit and erosion between Petare and Caurimare streams.
Others	Relation with Cota Mil	Not crossing	Crossing with large culvert	Crossing with small culvert	Crossing with bridge	Crossing with small culvert	Crossing with bridge	Not crossing

Table 4.1.2 Historical Event of Debris/ Sediment Flow Damage in Caracas

Year-Date	Caroata	Catuche	Anauco	Mariperez	Chacao/Chacaito	Sebucan	Tocome	Caurimare
1781		2 bridges destroyed						
1812			flooding					
1830		slope failure						
1833							railway destroyed	
1842								Road interupted
1847	1 bridge destroyed							
1866		Reservoir destroyed						
1878/10/04	1 bridge destroyed							
1932/3/9	1 bridge destroyed							
1951/2/17			100 houses inundated and 10 people died		1 person died	1 house destroyed and an old dam collapsed to wash out 15 ranchos	24 houses destroyed	
1974/10/1			Buildings damaged					
1975/10/30						buidings damaged		
1976/10/9 and 10,11			60 families affected	40 informal houses destroyed	15 houses destroyed			Damage at Hospital
1976/11/9								Damage at Hospital
1977/11/21			80 houses damaged					
1978/4/9								Damage at Hospital
1978/10/8			some informal houses destroyed		8 informal houses destroyed			
1978/11/11						3 buildings inundated		
1979/8/23						25 cars buried in debris		
1979/9/3			Bridge collapsed					
1979/9/28			Electoric Station damaged					
1980-September								California Sur near Guaire River affected
1993-August(Hurricane "Bret")					Inundation			

Source: PREVENE Informe Final pp.128

Note: Information on 1980 and 1993 was added by JICA Study Team.

Table 4.1.3 Probable Rainfall at 5 Representative Stations

Station : Caurimare

Return Period(year)	Duration Time (minute)							
	15	30	60	180	360	540	720	1440
2.33		32.6	39.9	52.5	58.3	62.3	65.3	74.3
5		41.2	48.8	64.2	74.4	78.2	80.4	90.1
10		48.1	56.0	73.7	87.5	91.2	92.8	102.9
25		57.0	65.0	85.7	104.0	107.6	108.4	119.2
50		63.5	71.8	94.6	116.2	119.7	119.9	131.2
100		70.0	78.5	103.5	128.4	131.8	131.4	143.1
500		85.0	94.0	123.9	156.5	159.7	157.9	170.7
1000		91.4	100.6	132.7	168.5	171.7	169.3	182.6

Station : Los Chorros

Return Period(year)	Duration Time (minute)							
	15	30	60	180	360	540	720	1440
2,33	24.6	36.3	47.2	62.6	68.8	70.1	72.3	80.0
5	29.6	43.2	59.7	79.5	89.3	94.9	98.8	112.2
10	33.8	48.8	69.9	93.2	105.9	115.2	120.5	138.4
25	39.0	55.9	82.7	110.5	127.0	140.7	147.8	171.5
50	42.8	61.2	92.2	123.4	142.6	159.7	168.1	196.0
100	46.6	66.4	101.7	136.2	158.1	178.5	188.2	220.4
500	55.5	78.5	123.6	165.7	194.0	222.0	234.8	276.9

Station : Teleferico

Return Period(year)	Duration Time (minute)							
	15	30	60	180	360	540	720	1440
2,33	26.9	36.6	49.4	62.1	65.0	65.3	65.9	71.7
5	32.8	46.5	67.5	90.4	95.1	95.5	95.6	98.5
10	37.5	54.6	82.3	113.5	119.6	120.1	119.8	120.3
25	43.6	64.8	100.9	142.6	150.6	151.2	150.4	147.8
50	48.1	72.3	114.7	164.2	173.5	174.3	173.1	168.3
100	52.5	79.8	128.4	185.7	196.3	197.1	195.6	188.5
500	62.8	97.1	160.1	235.3	249.0	250.0	247.7	235.4
1000	67.2	104.6	173.7	256.6	271.7	272.8	270.1	255.6

Station : San Jose de Avila

Return Period(year)	Duration Time (minute)									
	5	10	15	30	60	180	360	540	720	1440
2.33	9.1	15.1	19.5	30.6	39.1	48.4	51.9	54.5	55.1	58.7
5	10.1	18.3	22.4	36.0	47.0	59.2	64.1	68.9	69.3	73.2
10	11.0	20.9	24.8	40.4	53.4	68.0	74.1	80.6	80.9	85.0
25	12.1	24.3	27.9	46.0	61.5	79.1	86.6	95.4	95.5	100.0
50	13.0	26.7	30.1	50.1	67.5	87.3	95.9	106.4	106.3	111.1
100	14.0	29.1	35.0	54.2	73.4	95.5	105.2	117.3	117.1	122.1
500	18.0	32.0	42.0	63.7	87.2	114.3	126.6	142.5	141.9	147.6
1000	16.4	37.2	39.7	67.8	93.1	122.5	135.7	153.3	152.6	158.5

Station : Maiquetía 0502

Return Period(year)	Duration Time (minute)									
	5	10	15	30	60	180	360	540	720	1440
2.33	9.0	14.0	18.0	27.0	39.0	54.0	62.0	69.0	70.0	82.0
5	11.0	17.0	22.0	34.0	48.0	71.0	83.0	96.0	98.0	132.0
10	13.0	19.0	26.0	39.0	56.0	86.0	101.0	117.0	120.0	173.0
25	15.0	23.0	30.0	45.0	65.0	105.0	124.0	144.0	148.0	225.0
50	17.0	26.0	33.0	50.0	73.0	118.0	145.0	175.0	200.0	263.0
100	19.0	28.0	36.0	55.0	80.0	132.0	157.0	185.0	189.0	301.0
200	21.0	30.0	39.0	60.0	87.0	145.0	174.0	205.0	210.0	339.0
500	23.0	34.0	43.0	66.0	96.0	163.0	195.0	231.0	237.0	389.0

Source: MARN– UNDP, ESTUDIO DE CRECIDAS EN LAS CUENCAS DE LA VERTIENTE SUR DEL PARQUE NACIONAL AVILA, 2001

Table 4.1.4 Sediment Runoff Volume

Principal Stream	Catchment Area	Potential				Return Period 100 yr.			Return Period 25 yr.			Cota Mil Pocket Capacity
		Unstable Sediment	Slope Failure Sediment	Runoff Sediment (Ve)	Specific Runoff Sediment	Transportable Sediment(Vec)	The smaller among Ve and Vec	Specific Sediment Volume	Transportable Sediment(Vec)	The smaller among Ve and Vec	Specific Sediment Volume	
	km2	m3	m3	m3	m3/km2	m3	m3	m3/km2	m3	m3	m3/km2	m3
1	0.16	0	9,591	9,591	59,570	9,299	9,299	57,756	7,751	7,751	48,144	
2	0.99	11,596	58,796	21,117	21,396	25,318	21,117	21,396	21,105	21,105	21,383	
3	0.08	0	4,468	4,468	59,570	3,830	3,830	51,067	3,193	3,193	42,571	
Caurimare 4	6.35	726,522	378,508	331,509	52,173	101,429	101,429	15,963	84,548	84,548	13,306	
Galindo 5	3.85	484,019	229,047	213,920	55,636	58,960	58,960	15,334	49,147	49,147	12,782	
6	0.09	1,613	5,183	6,796	78,115	12,171	6,796	78,115	10,145	6,796	78,115	
7	0.36	26,018	21,445	47,463	131,842	16,314	16,314	45,316	13,029	13,029	36,190	
8	1.14	45,810	68,089	34,169	29,895	35,448	34,169	29,895	28,309	28,309	24,768	13,400
9	0.12	0	6,970	6,970	59,570	16,039	6,970	59,570	12,809	6,970	59,570	
10	0.06	0	3,276	3,276	59,570	9,792	3,276	59,570	7,820	3,276	59,570	
11	0.25	17,199	14,714	31,913	129,201	15,134	15,134	61,270	11,797	11,797	47,763	
12	2.10	403,843	125,097	158,682	75,563	62,947	62,947	29,975	49,070	49,070	23,367	
13	0.33	20,238	19,479	39,717	121,460	50,512	39,717	121,460	39,377	39,377	120,418	
Tocome 14	9.45	1,716,695	562,817	683,854	72,381	152,175	152,175	16,107	118,627	118,627	12,556	
15	1.40	67,151	83,577	45,218	32,230	45,318	45,218	32,230	35,465	35,465	25,278	
16	0.38	9,464	22,637	32,100	84,475	52,003	32,100	84,475	40,698	32,100	84,475	
17	1.57	154,682	93,525	74,462	47,428	48,669	48,669	30,999	38,088	38,088	24,260	10,700
18	0.17	8,346	9,948	18,294	109,544	31,317	18,294	109,544	24,413	18,294	109,544	
19	1.37	128,422	81,849	63,081	45,911	44,718	44,718	32,546	34,996	34,996	25,470	
20	0.11	1,085	6,672	7,757	69,258	23,398	7,757	69,258	18,240	7,757	69,258	2,400
21	0.27	15,243	16,084	31,327	116,025	24,891	24,891	92,187	19,479	19,479	72,146	4,900
22	1.97	102,990	117,532	66,157	33,531	56,156	56,156	28,462	43,948	43,948	22,275	
23	0.78	48,798	46,167	94,964	122,535	30,802	30,802	39,744	24,105	24,105	31,104	
24	0.21	2,759	12,331	15,090	72,900	36,549	15,090	72,900	28,492	15,090	72,900	
Chacaito 25	6.33	428,734	377,197	241,779	38,184	112,394	112,394	17,750	87,960	87,960	13,891	
26	0.16	647	9,412	10,059	63,662	30,085	10,059	63,662	23,453	10,059	63,662	
27	0.25	4,046	15,071	19,118	75,563	42,165	19,118	75,563	32,869	19,118	75,563	
28	1.19	95,641	71,007	49,994	41,942	67,986	49,994	41,942	53,205	49,994	41,942	1,000
29	0.07	0	4,110	4,110	59,570	14,850	4,110	59,570	11,576	4,110	59,570	
30	0.60	21,511	35,623	57,134	95,542	70,924	57,134	95,542	55,505	55,505	92,818	3,800
31	0.24	0	13,999	13,999	59,570	34,374	13,999	59,570	26,881	13,999	59,570	
32	0.06	0	3,395	3,395	59,570	10,539	3,395	59,570	8,241	3,395	59,570	
Mariperez 33	0.70	16,868	41,461	58,328	83,805	26,564	26,564	38,167	20,773	20,773	29,847	
34	0.09	0	5,480	5,480	59,570	17,010	5,480	59,570	13,302	5,480	59,570	
35	0.57	41,973	33,895	75,869	133,337	23,196	23,196	40,767	18,140	18,140	31,880	
36	0.27	1,234	15,846	17,079	64,207	30,780	17,079	64,207	24,604	17,079	64,207	
Gamboa 37	3.07	91,399	182,939	82,302	26,800	94,532	82,302	26,800	73,030	73,030	23,781	
38	0.19	0	11,437	11,437	59,570	24,398	11,437	59,570	19,503	11,437	59,570	
39	0.43	10,855	25,436	36,292	84,993	15,636	15,636	36,618	12,499	12,499	29,271	
40	0.19	0	11,378	11,378	59,570	24,307	11,378	59,570	19,430	11,378	59,570	
Anauco 41	3.69	136,514	219,813	106,898	28,970	233,670	106,898	28,970	179,110	106,898	28,970	68,500
Cotiza 42	3.80	331,373	226,247	167,286	44,046	144,514	144,514	38,050	110,771	110,771	29,166	93,000
43	0.27	3,515	16,024	19,540	72,638	11,326	11,326	42,106	9,054	9,054	33,657	
Catuche 44	4.50	203,068	268,005	141,322	31,412	95,859	95,859	21,307	73,477	73,477	16,332	
45	0.09	0	5,421	5,421	59,570	13,798	5,421	59,570	11,030	5,421	59,570	
46	0.08	0	4,885	4,885	59,570	12,434	4,885	59,570	9,939	4,885	59,570	
47	0.48	18,774	28,474	47,248	98,846	21,708	21,708	45,414	17,352	17,352	36,302	
Total	60.84	5,398,644	3,624,358	3,232,250	–		1,709,716	–		1,454,133		197,700

Table 4.1.5 Property in Yellow and Red Zones (Principal Stream Basis)

Principal Watershed		Yellow Zone						Red Zone					
		Building Count			Building Area			Building Count			Building Area		
No.	Name	Barrio	Formal	Total	Barrio	Formal	Total	Barrio	Formal	Total	Barrio	Formal	Total
		nos.	nos.	nos.	m2	m2	m2	nos.	nos.	nos.	m2	m2	m2
02_1		46	0	46	2,272	0	2,272		0			0	
02_2		231	168	399	11,312	55,591	66,903		0			0	
02_3		195	96	291	10,348	48,343	58,691	9	27	36	339	10,272	10,610
4	Caurimare	316	271	587	20,981	121,969	142,950	109	103	212	6,107	79,994	86,101
5	Galindo	0	18	18	0	5,702	5,702		0	16		4,733	4,733
6		0	198	198	0	46,569	46,569		0			0	
7		0	90	90	0	21,377	21,377		0	41		5,741	5,741
8	Pasaquire	0	233	233	0	54,548	54,548		0	60		7,355	7,355
9		0	171	171	0	51,812	51,812		0			0	
10		0	336	336	0	141,091	141,091		0			0	
11	Gamburi	0	246	246	0	66,192	66,192		0	12		1,937	1,937
12	La Julia	10	696	706	888	187,272	188,159	8	397	405	838	97,416	98,255
13		0	92	92	0	29,800	29,800		0	9		3,803	3,803
14	Tocome	0	638	638	0	160,183	160,183		42	42		11,909	11,909
15	Tenerias	0	92	92	0	24,275	24,275		0			0	
16	Agua de maiz	115	247	362	5,487	64,580	70,068		0	2		610	610
17	Sebucan	0	742	742	0	255,255	255,255		0			0	
18		0	507	507	0	152,338	152,338		0			0	
19	Pajarito	0	517	517	0	210,755	210,755		1	1		503	503
20		0	805	805	0	352,716	352,716		0	1		460	460
21		0	900	900	0	389,840	389,840		0			0	
22	Quintero	9	1,157	1,166	62	454,710	454,772		0	184		37,703	37,703
23	Seca	24	529	553	683	186,530	187,213		57	57		7,639	7,639
24		69	397	466	6,355	140,453	146,808		0	1		548	548
25	Chacaito	63	454	517	5,487	162,209	167,696	39	209	248	2,635	55,814	58,450
27		303	484	787	23,016	127,160	150,176		4	4		781	781
28	Chapellin	255	139	394	18,325	30,036	48,361		0	2		152	152
29		278	143	421	19,247	26,440	45,687		0			0	
30	Cuno	248	106	354	17,581	21,626	39,207		0	10		1,700	1,700
31		259	105	364	17,843	21,796	39,639		0			0	
33	Mariperez	0	106	106	0	23,550	23,550		3	32		6,545	6,545
34		920	154	1,074	61,584	45,133	106,717		0	1		1	1
35	Canoas(Sarria)	551	341	892	34,297	69,282	103,578	5	5	163	4,471	7,132	11,602
36		463	755	1,218	20,953	174,237	195,190		0			0	
37	Gamboa	83	315	398	11,277	68,997	80,274		2	17		2,179	2,179
38		191	433	624	22,346	99,098	121,444		0			0	
39	Beatas	184	169	353	15,849	28,282	44,131		0			0	
40		319	255	574	28,308	40,941	69,249		8	8		815	815
41	Anauco	339	340	679	32,774	58,615	91,389	290	188	478	26,218	23,045	49,263
42	Cotiza	64	69	133	3,636	12,680	16,316		0			0	
44	Catuche	659	696	1,355	59,691	194,692	254,383	660	399	1,059	59,967	111,363	171,330
45	St. Isabel	224	0	224	13,050	0	13,050		0			0	
46		299	275	574	20,588	26,812	47,400	23	10	33	828	443	1,271
47	Agua Salud	158	224	382	11,774	23,590	35,364	134	0	299	8,665	13,071	21,736

Note: The count and area of building/house were calculated based on the topographical map of scale 1:5,000.

Table 4.1.6 Property in Yellow and Red Zones (Alluvial Fan Basis)

Watershed System	Yellow Zone							Red Zone						
	Building Count			Building Area			Zone Area	Building Count			Building Area			Zone Area
No.	Barrio	Urban	Total	Barrio	Urban	Total		Barrio	Urban	Total	Barrio	Urban	Total	
	nos.	nos.	nos.	m2	m2	m2	m2	nos.	nos.	nos.	m2	m2		m2
Caurimare	458	965	1423	27,800	370,200	398,000	1,784,800	118	130	248	6,400	50,000	56,400	595,200
Tocome	10	1,303	1313	900	331,300	332,200	997,500	8	440	448	800	100,000	100,800	394,000
Agua de Maiz	115	415	530	5,500	111,700	117,100	459,800		0	0	0	0	0	4,200
Sebucan	0	1,525	1525	0	524,000	524,000	1,643,600		0	0	0	0	0	22,100
Seca	30	879	909	700	337,100	337,900	1,088,500		50	50	0	38,500	38,500	148,500
Chacaito	483	1,063	1546	37,000	312,200	349,200	1,285,700	39	215	254	2,600	55,000	57,600	353,900
Mariperez	0	106	106	0	23,600	23,600	124,600		3	3	0	600	600	53,800
Canoas	1,270	592	1862	83,300	127,200	210,600	556,600	5	5	10	4,500	700	5,200	36,600
Anauco	688	1,006	1694	56,200	226,100	282,300	867,900	290	190	480	26,200	22,000	48,200	168,300
Catuche	659	502	1161	59,700	164,500	224,200	559,200	660	394	1,054	60,000	111,100	171,100	393,900
Caroata	596	433	1029	39,100	40,800	79,900	172,900	157	10	167	9,500	1,000	10,500	57,200
51	0	4	4	0	300	300	600		0		0	0	0	0
55	0	38	38	0	17,200	17,200	71,300		0		0	0	0	0
57	0	284	284	0	86,500	86,500	268,400	0	1	1	0	0	0	0
64	207	517	724	9,000	104,400	113,400	270,900		0		0	0	0	700
68	0	201	201	0	27,800	27,800	62,500		0		0	0	0	0
Total	4,516	9,833	14,349	319,300	2,804,800	3,124,100	10,214,800	1,277	1,438	2,715	110,100	378,900	489,000	2,228,400

Note: The count and area of building/house were calculated based on the topographical map of scale 1:5,000.

Table 4.2.1 Affected Number of Houses by Steep Slope Failure and Landslide

	Number of houses located on the interpreted slope		Number of houses affected by the failure		Total	
	Formal Area	Informal Area	Formal Area	Informal Area	Formal Area	Informal Area
Steep Slope Failure	49	6,797	304	5,197	353	11,994
Landslide	2	383	16	139	18	522

Table 4.3.1 List of Risky Slope in Urban Area

Slope Code	Municipality	Area of Slope(m2)	Area of House on Slope(m2)	Number of House on Slope	Area of House on Affected Area(m2)	Number of House on Affected Area
40 091	Libertador	5,655	1235	1	12,404	5
40 148	Libertador	932	664	1	3,742	4
40 149	Libertador	563	773	2	2,016	5
40 161	Sucre	4,130	58	4	3,663	10
40 162	Sucre	2,953	107	4	6,052	6
40 225	Sucre	1,412	131	4	1,774	9
40 226	Sucre	1,361	507	3	3,457	7
40 228	Sucre	1,365	271	1	1,485	5
40 230	Sucre	2,123	18	2	4,129	10
40 232	Sucre	2,537	65	3	3,505	8
40 233	Sucre	1,890	391	1	10,616	7
40 272	Libertador	3,330	143	3	5,510	32
43 172	Sucre	868	79	2	886	11

Table 4.3.2 Actual Cost for Sabo Dam constructed in Vargas in 2000

FONTUR Prpject: Qda. Guanape (Vargas State)

Main Work Item	Description	Unit	Quantity	Unit Price (Bs. in 2000)	Total	Total for only related with Dam Works
Excavation	Removal of Vegetation	m3	1,200	1,775	2,130,492	2,130,492
	Excavation for Common Works 1	m3	66	5,034	332,227	332,227
	Excavation for Common Works 2	m3	2,317	5,034	11,663,176	11,663,176
	Excavation for Dam Works	m3	10	19,291	192,912	192,912
	Excavation for Channel Works 1	m3	50,000	3,185	159,270,000	–
	Excavation for Channel Works 2	m3	100,000	4,666	466,604,000	–
	Temporary Works	m3	15,000	2,590	38,844,750	38,844,750
	Sub TOTAL				**679,037,557**	**53,163,557**
Concrete Works	Concrete (80kg/cm2) for Closed Dam	m3	1,100	120,697	132,766,216	132,766,216
	Concrete (80kg/cm2) for Open type Dam	m3	995	120,697	120,093,077	120,093,077
	RC Concrete (250kg/cm2) for Closed Dam	m3	80	187,111	14,968,917	14,968,917
	RC Concrete (250kg/cm2) for Open type Dam	m3	250	190,322	47,580,485	47,580,485
	RC Concrete (250kg/cm2) for Channel Works	m3	4,130	176,793	730,153,768	–
	RC Concrete (250kg/cm2) for Channel Transition	m3	800	192,232	153,785,632	153,785,632
	Sub TOTAL				**1,199,348,095**	**469,194,327**
TOTAL					**1,878,385,652**	**522,357,884**
Overhead (15% of TOTAL)					281,757,848	78,353,683
Ground Total					**2,160,143,500**	**600,711,566**

Table 4.3.3 Proposed Implementation Schedule

No. of Catchment		Sabo Dam Works: Nos.	Concrete Volume	Construction Cost	Construction Period	Channel Works: Length	Concrete Volume	Construction Cost	Construction Period	DB/year	Annual Construction Cost: 2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	sum
		(-)	(m3)	×10³(Bs)	(year)	(m)	(m3)	×10³(Bs)	(year)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)	×10³(Bs)
17	[illegible]	8	18,480	5,544,000	6.5					888,077	888,077	888,077	888,077	888,077	888,077	888,077	416,538									5,544,000
						450	2,610	3,136	8.0	392								392	392	392	392	392	392	392	392	3,136
25	Chacalto	4	9,300	2,790,000	4.0					697,500	697,500	697,500	697,500	697,500												2,790,000
						1,200	3,760	7,716	11.0	701					701	701	701	701	701	701	701	701	701	701	701	7,716
44	Catuche	3	7,470	2,241,000	3.0					747,000	747,000	747,000	747,000													2,241,000
						1,600	3,420	1,010,400	12.0	84,200				84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	1,010,400
4	Caurimare	6	21,260	6,378,000	7.5					880,400	880,400	880,400	880,400	880,400	880,400	880,400	880,400	425,200								6,378,000
42	Cotiza	5	15,900	4,770,000	6.0					795,000	795,000	795,000	795,000	795,000	795,000	795,000										4,770,000
30	Guno	4	13,700	4,110,000	5.0					822,000	822,000	822,000	822,000	822,000	822,000											4,110,000
37	[illegible]	6	13,360	4,008,000	5.5					728,727		728,727	728,727	728,727	728,727	728,727	364,364									4,008,000
20	Chapellin	4	10,490	3,147,000	4.0					706,750					706,750	706,750	706,750	706,750								3,147,000
41	Anauco	4	9,370	2,811,000	4.0					702,750						702,750	702,750	702,750	702,750							2,811,000
17	[illegible]	5	8,990	2,697,000	3.5					770,571							770,571	770,571	770,571	385,286						2,697,000
19	Pajaro	3	9,330	2,799,000	3.5					799,714							799,714	799,714	799,714	399,857						2,799,000
5	Catlindo	2	8,460	2,538,000	3.0					846,000								846,000	846,000	846,000						2,538,000
12	[illegible]	2	6,580	1,974,000	2.5					789,600								789,600	789,600	394,800						1,974,000
22	Quintero	3	7,290	2,187,000	2.5					874,800									874,800	874,800	437,400					2,187,000
8	Pasaculre	2	5,140	1,542,000	2.0					771,000										771,000	771,000					1,542,000
15	[illegible]	2	4,900	1,470,000	2.0					735,000										735,000	735,000					1,470,000
21		3	4,520	1,306,000	2.0					653,000										653,000	653,000					1,306,000
27		2	5,260	1,578,000	2.0					789,000											789,000	789,000				1,578,000
10		2	3,940	1,182,000	2.0					591,000											591,000	591,000				1,182,000
47	Agua Salud	3	3,930	1,179,000	2.0					589,500											589,500	589,500				1,179,000
2		1	2,280	684,000	1.5					456,000											456,000	228,000				684,000
7		1	3,180	954,000	1.5					636,000												636,000	318,000			954,000
11	Gambur	1	3,120	936,000	1.5					624,000												624,000	312,000			936,000
16	Agua de maiz	1	4,080	1,224,000	1.5					816,000												816,000	408,000			1,224,000
28	Seca	1	3,860	1,158,000	1.5					772,000												772,000	386,000			1,158,000
29		1	3,120	936,000	1.5					624,000													624,000	312,000		936,000
31		1	2,720	816,000	1.5					544,000													544,000	272,000		816,000
33	Mariches	1	3,790	1,137,000	1.5					758,000													758,000	379,000		1,137,000
6		1	2,070	621,000	1.0					621,000													621,000			621,000
9		1	2,050	615,000	1.0					615,000													615,000			615,000
10		1	1,700	510,000	1.0					510,000													510,000			510,000
13		1	1,810	543,000	1.0					543,000														543,000		543,000
18		1	2,570	771,000	1.0					771,000														771,000		771,000
20		1	2,590	777,000	1.0					777,000														777,000		777,000
24		1	1,750	525,000	1.0					525,000														525,000		525,000
34		1	1,140	342,000	1.0					342,000														342,000		342,000
35	Carmen	1	1,900	570,000	1.0					570,000														570,000		570,000
36		1	2,190	657,000	1.0					657,000															657,000	657,000
38		1	2,570	771,000	1.0					771,000															771,000	771,000
39	[illegible]	1	2,570	771,000	1.0					771,000															771,000	771,000
45	St Isabel	1	2,190	657,000	1.0					657,000															657,000	657,000
46		1	1,680	504,000	1.0					504,000															504,000	504,000
sum		87	[illegible]	[illegible]	[illegible]	3,250	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
										Nos. of stream	5	7	7	7	9	9	9	10	9	11	11	11	10	12	9	

Note: BS is the Bolivar Currency in 2005

Table 4.3.4 Evaluation of Present System, Limitation and Recommendation for Early Warning and Evacuation

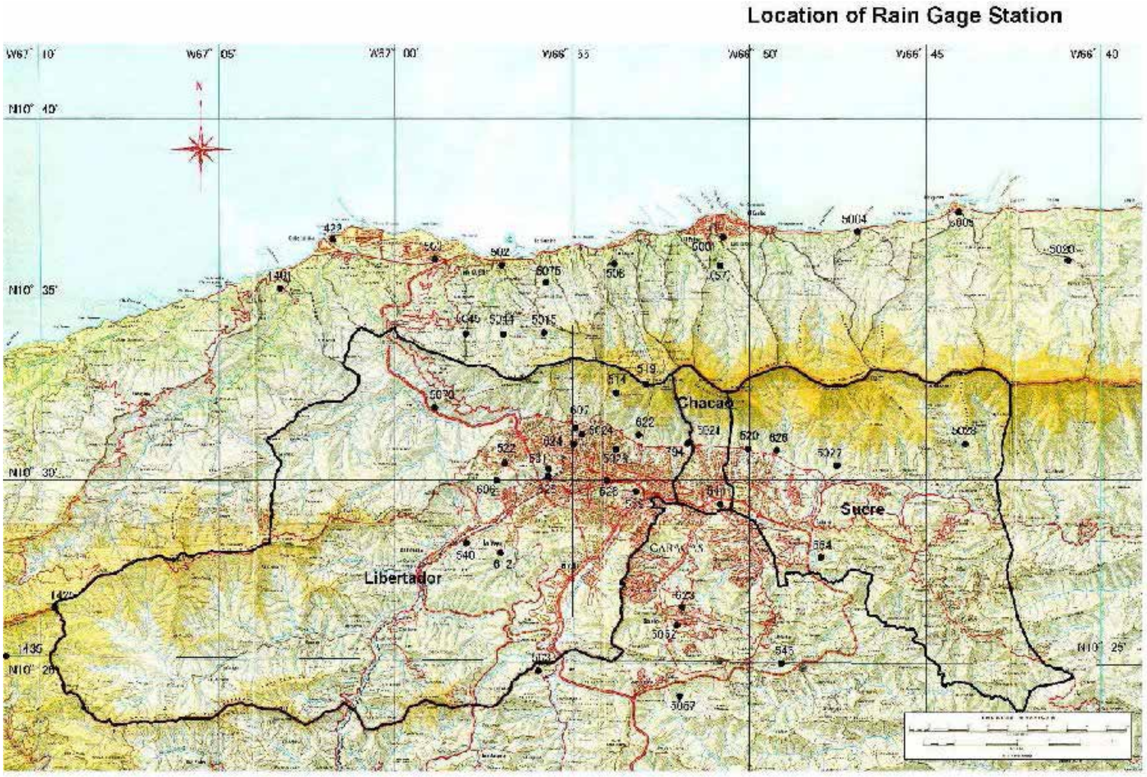
Organization	Evaluation of Present System	Limitation	Recommendation
MARN	● MARN is satisfying its responsibility as a national level in terms of monitoring, providing hydro-meteorological information to the public. ● The rainfall monitoring and measurement system of MARN is not appropriate to respond the needs of local government who will be in charge of early warning system.	● Since MARN is a national level organization, there is a limitation to execute more local and precise activity such as issuing of local warning or evacuation order. ● In reality it seems that there is insufficiency of number of engineer who can do hydrological and hydraulic modeling to make hazard map and meteorological forecast.	● Promoting of VENEHMET Project further with sustainability ● Establishment and strengthening of regional branch with MARN for the purpose of precise activity for Caracas and Vargas area to unite the present rainfall monitoring system and to update hazard map and to study hydrological features of Caracas such as critical rainfall. ● Assembling and normalization of all the protocols on early warning system in Venezuela
ADMC	● There have been human channels to receive meteorological information from MARN and others, however, there is no system to translate the information and taking action when necessary for early warning and evacuation. ● There is no access in real time to rainfall data measured by MARN and other organization.	● It is not practical to do the monitoring, providing hydro-meteorological information to the public.	● Construction, and operation / maintenance of Emergency Command Center ● Establishment of Operation Control Center to manage the disaster from the viewpoint of entire Caracas. ● Dispatch of human resources to IMANEH training program for hydrometeorology.
Municipalities	● They have high capacity for the emergency operation after a sediment disaster, however, they have few experiences of early warning and evacuation (pre-disaster).	● In reality, the operation for early warning and evacuation and the operation for emergency could be done at the same time in Caracas depending on the time line progressive of the disaster. It is difficult for a municipality to grasp condition of the other municipality.	● Issuing of recommendation of evacuation to community based on the information from ADMC and MARN. ● Education of community group

Table 4.3.5 Definitions of Rainfall Indexes

	X axis (abscissa)	Y axis (ordinate)
Causing Rainfall	Working rainfall up to 1 hour before the occurrence of debris flow	1 hour rainfall immediately before the occurrence of debris flow
Non-causing Rainfall	Working rainfall up to before the start of a maximum hourly rainfall	Maximum hourly rainfall in a series of rain

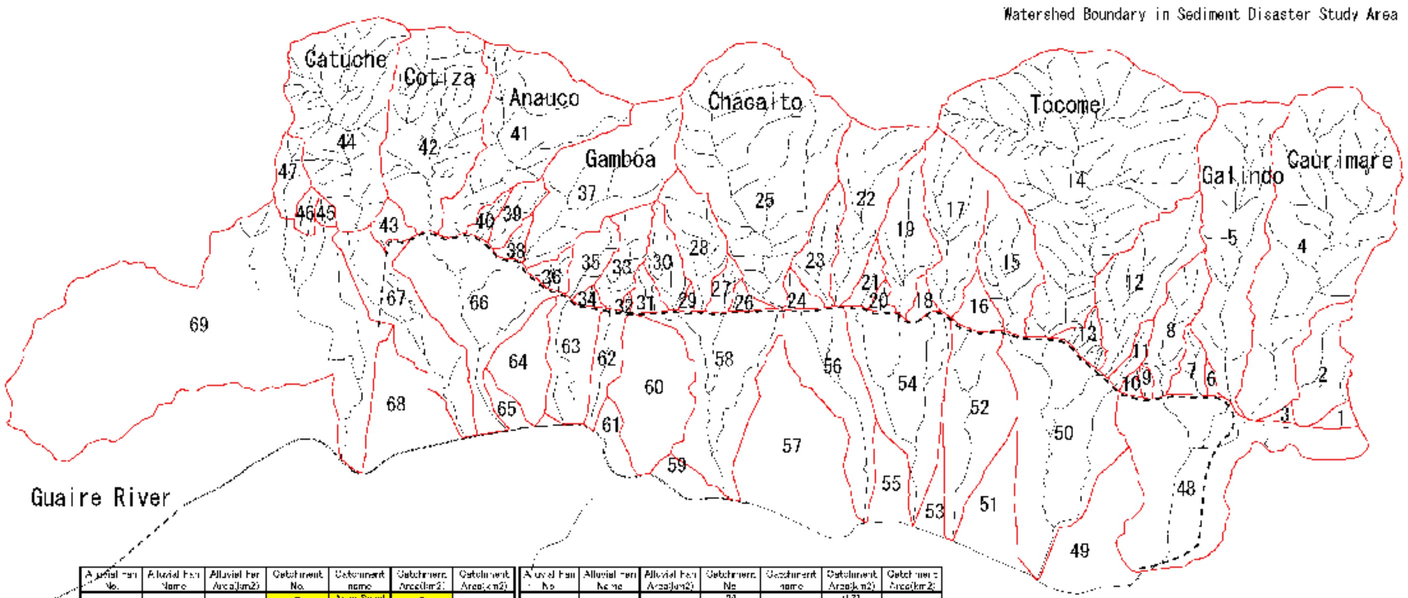
Table 4.3.6 Definitions of Timing for Warning and Evacuation

	Timing of Issuance / Recommendation	Forecasted Rainfall during leading time
Issuance of Warning	2 hours before reaching the CL	Past maximum 2 hours rainfall (R_{H2M})
Recommendation of Evacuation	1 hours before reaching the CL	Past maximum 1 hour rainfall (R_{H1M})



No	Code	Station	Organization	Altitude (m)	Latitude	Longitude	Period Daily Hourly	No	Code	Station	Organization	Altitude (m)	Latitude	Longitude	Period Daily Hourly
	422	Carla La Mar						18	612	Ces-Circulo Militar	MARN	920	102800	665700	67-82
1	502	Maiquetia (MARN)	MARN	75	103600	665700	[illegible]	19	625	Ces-Teleférico	MARN	1150	103110	665315	68-91
2	503	Maiquetia-Aerop (FAV)	FAV	43	1031	6659	[illegible]	20	623	Ces-La Trinidad	MARN	962	102634	665158	68-99
3	505	Macuto	MARN/UCV	53	103601	665347	[illegible]	21	624	Ces-Urb Miranda	MARN	1000	103150	665500	78-92
4	514	Ces-Los Venados	MARN	1540	103219	665341	[illegible]	22	626	Los Chorros	MARN	1000	103000	664925	67-81
5	519	Hotel Humboldt	MARN/UCV	2129	103240	665254	[illegible]	23	628	[illegible]	MARN	920	103040	665540	66-99
6	520	Ces-La Salle	MARN	1097	103046	665000	49-63	24	794	Ces-Edif. La Paz	MARN	900	103129	665200	62-91
7	522	Ces-Catia	MARN	970	103029	665648	53-63	25	1072	Tacamahaca	MARN	1200	105700	663500	78-91
8	526	Ces Torre Sur	MARN	1060	103000	665400	[illegible]	26	1510	de Turgua	MARN	1107	102320	664534	67-99
9	531	Cagigal	Armada	1042	103025	665539	1951-	27	5005	Naiguata	MARN	49	103725	664108	[illegible]
10	539	UCV	MARN/UCV	884	103941	663312	[illegible]	28	5011	Los Caracas	MARN	15	103732	663722	[illegible]
11	540	Ces-Had. Montalban	MARN	937	102822	665803	[illegible]	29	5021	Ces-Chacaito	MARN	1205	103127	665149	[illegible]
12	544	La Carlota	FAV	835	1030	6653	[illegible]	30	5024	Ces-Subida Avila	MARN	1000	103121	665455	67-94
13	546	El Hatillo	MARN	1132	102500	664900	[illegible]	31	5025	Ces-San Bernardino	MARN	-	103052	665347	75-83
14	555	Ces-Petare-Caurimare	MARN	700	102800	664800	[illegible]	32	5027	Ces-Caurimare	MARN	965	102510	665320	[illegible]
15	563	Ces La Mariposa	MARN	980	[illegible]	665535	[illegible]	33	5028	[illegible]	MARN	1207	103100	664100	77-83
16	606	Ces Cuartel Urdaneta	MARN	970	103000	665700	66-77	34	5057	Ces USB	MARN	1225	102507	665248	71-98
17	607	Ces-San José Avila	MARN	999	103121	665455	[illegible]	35	5070	Ojo De Agua	MARN	508	103156	665833	76-96

Figure 4.1.1 Location of Rain Gauge Station



Alluvial Fan No.	Alluvial Fan Name	Alluvial Fan Area(km2)	Catchment No.	Catchment name	Catchment Area(km2)	Catchment Area(km2)
69	Caracas	12.45	–	Agua Salud	–	
			47	Agua Salud	0.46	
			48		0.08	
			45	St. Isabel	0.05	0.65
67	Catuche	2.2[illegible]	44	Catuche	1.50	
			43		0.27	[illegible]
66	Anauco	3.30	42	Cotiza	0.80	
			41	Anauco	3.09	
			40		0.19	
			39	Bestas	0.49	
			38		0.16	
			37	Gamboa	3.07	
			36		0.27	11.84
63	Canoas	1.23	35	Canoas	0.57	
			34		0.09	0.66
62	Mariperez	0.80	33	Mariperez	0.70	
			32		0.05	0.75
60	Chacaito	2.96	31		0.24	
			30	Cuno	0.80	
			29		0.07	
			28	Chapellin	1.19	
			27		0.25	
			26		0.16	
			25	Chacaito	6.99	8.64
58	Seca	2.07	24		0.21	
			23	Seca	0.73	
			22	Quintero	1.37	2.30
54	Sebucan	2.72	21		0.27	
			20		0.11	
			18	[illegible]	1.37	
			19		0.17	
			17	Sebucan	1.37	3.49
52	[illegible]	[illegible]	16	[illegible]	0.33	[illegible]
50	Tocome	[illegible]	15	[illegible]	1.40	
			14	Tocome	9.45	
			13		0.33	
			12	La Julia	2.11	
			11	Gamburi	0.25	13.52
48	Caurimare	[illegible]	10		0.05	
			9		0.12	
			8	Pasaquire	[illegible]	
			7		0.28	
			6		0.09	
			5	Galindo	3.33	
			4	Caurimare	6.35	
			3		0.03	
			2		0.92	
			1		[illegible]	13.18
	Total	38.75			60.84	60.84

Figure 4.1.2 Sediment Study Area

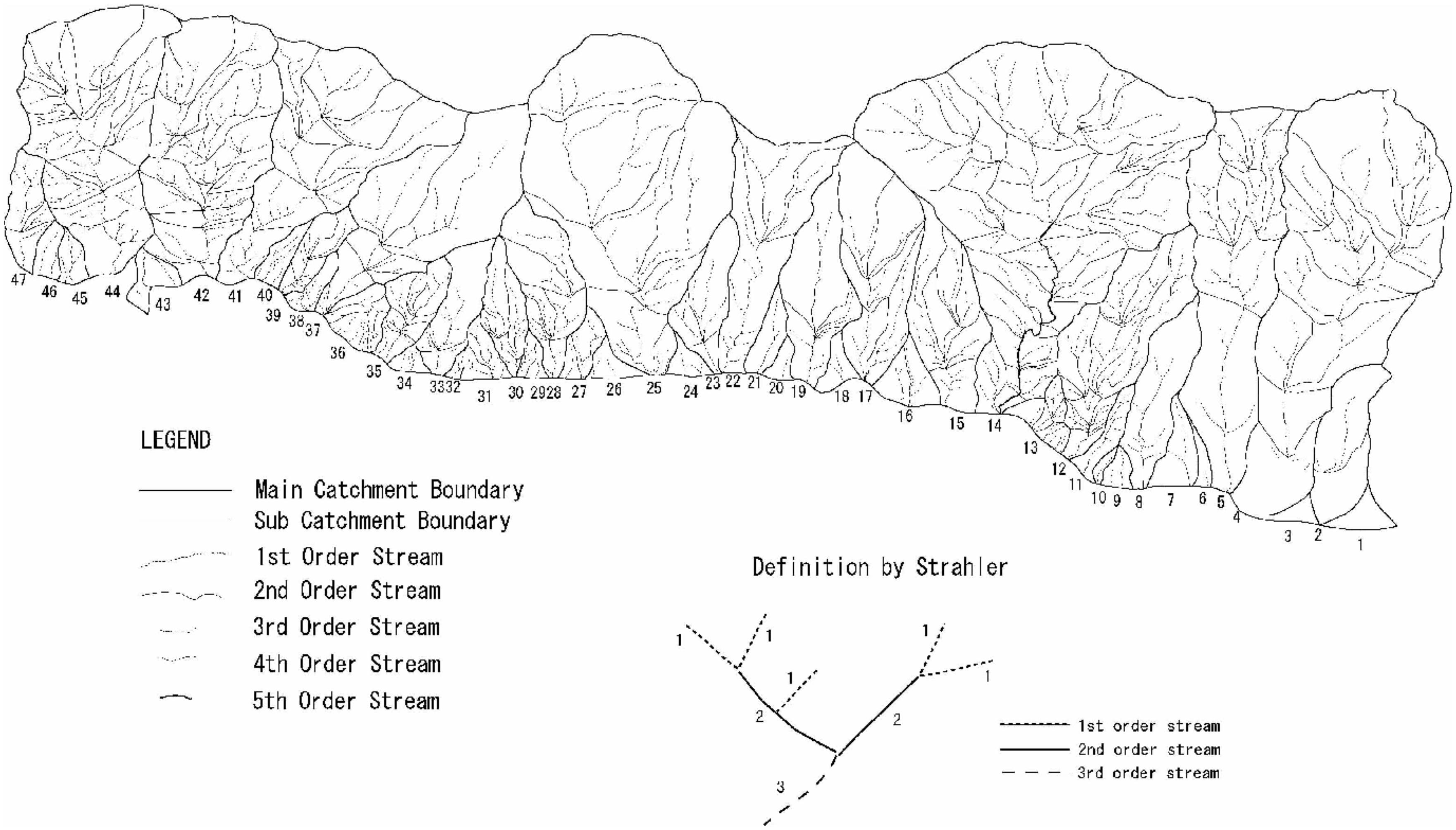


Figure 4.1.3 Sub-catchment and Stream Order in the Mountain Streams

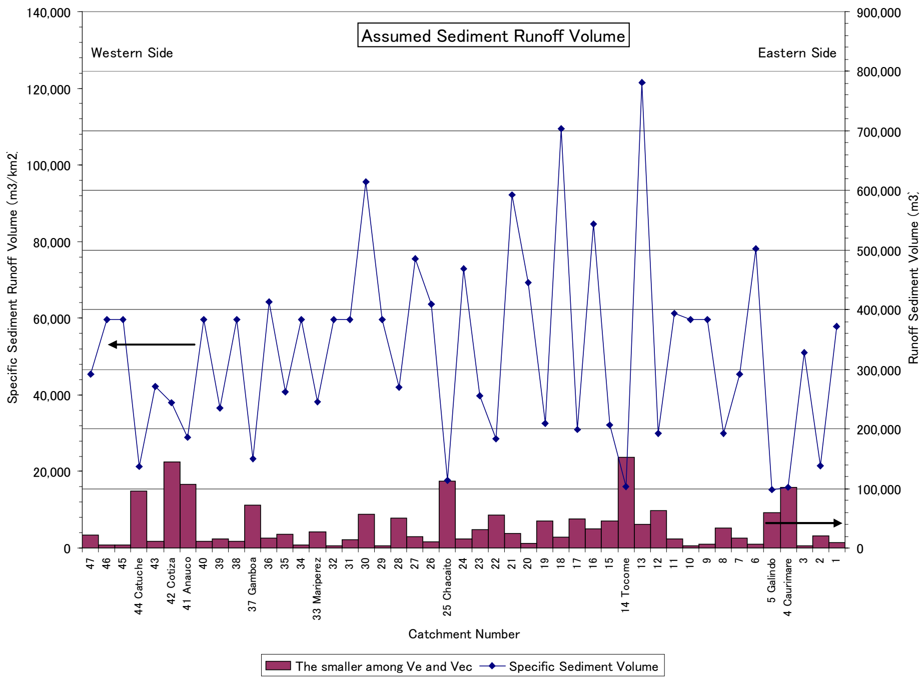


Figure 4.1.4 Estimated Sediment Runoff Volume for Scenario Flood

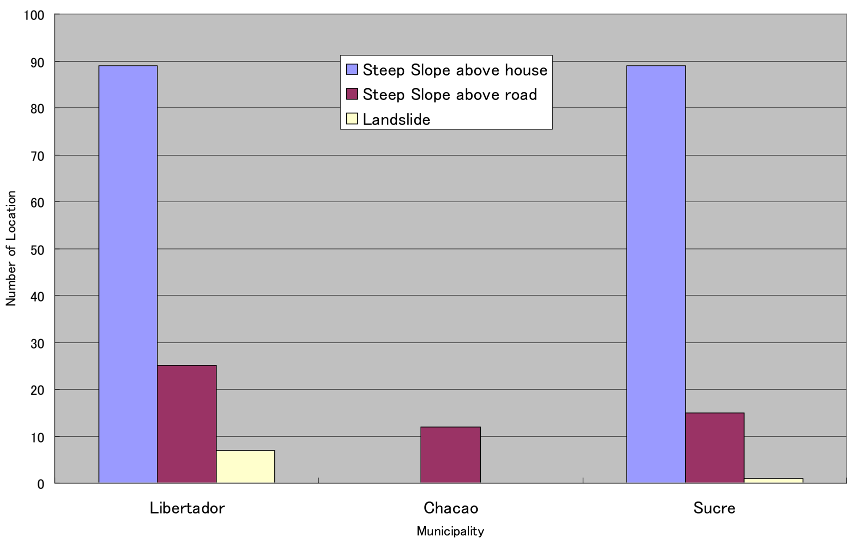


Figure 4.1.5 Number of Unstable Steep Slope and Landslide

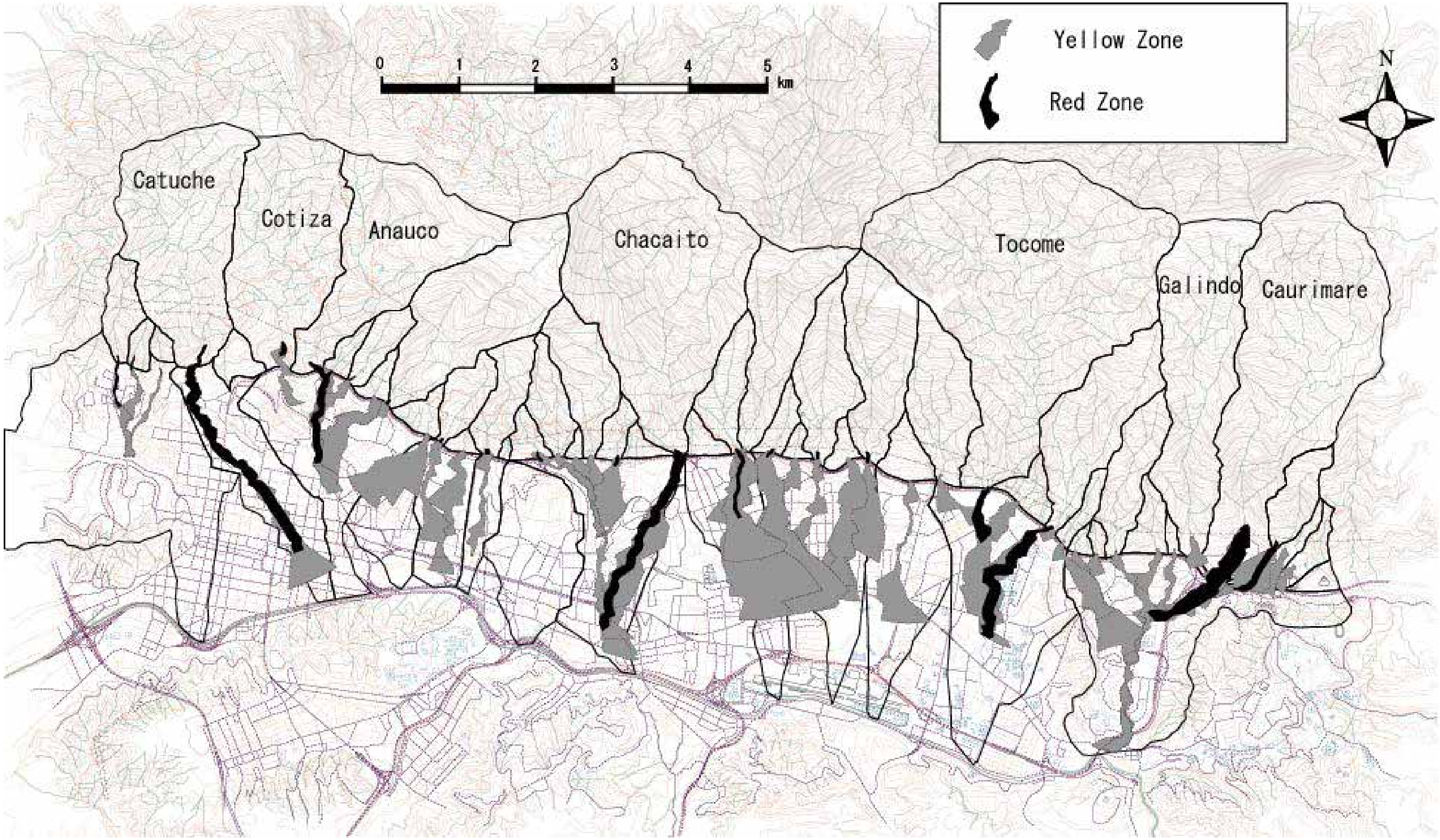


Figure 4.1.6 Debris Flow Hazard Map by Method-1

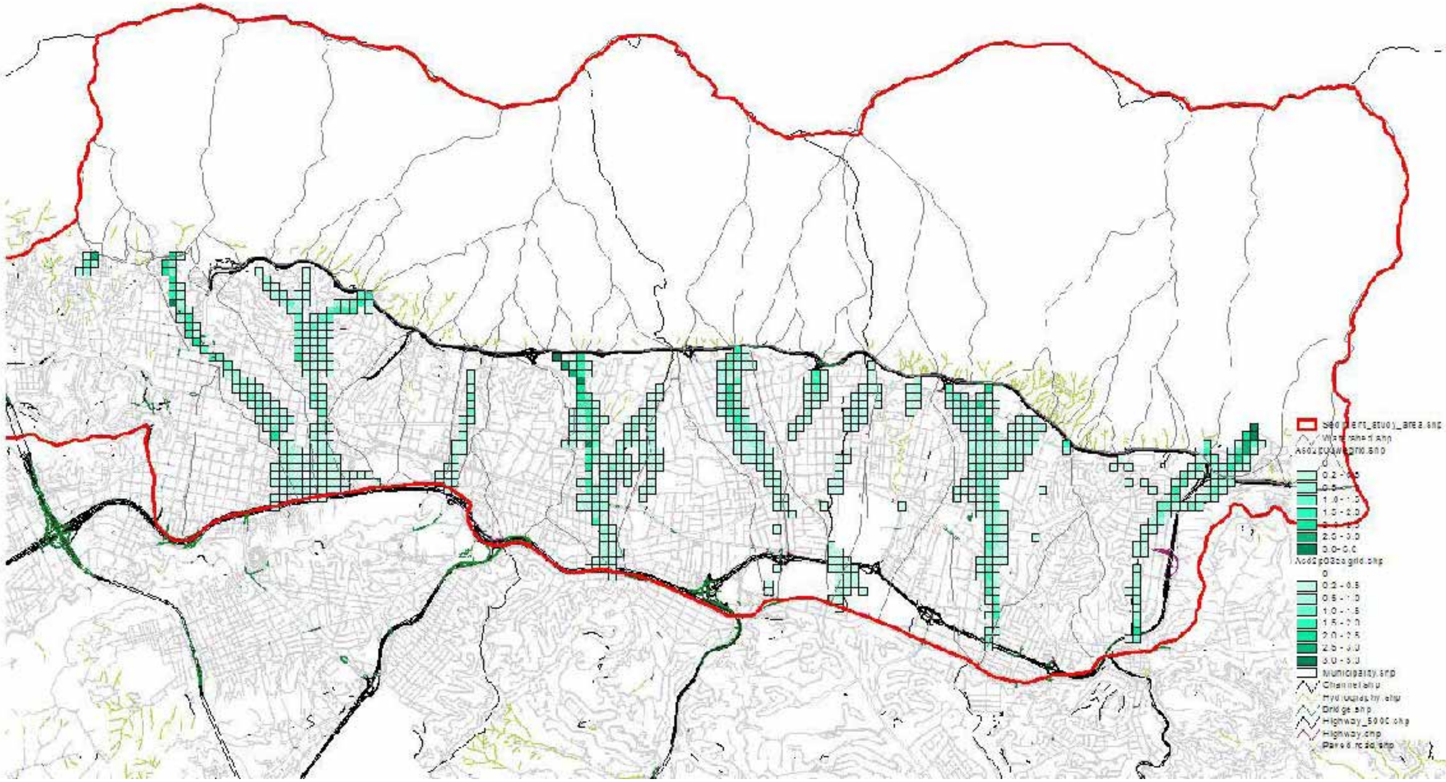


Figure 4.1.7 Depth for 100 Years Return Period Under Existing Conditions

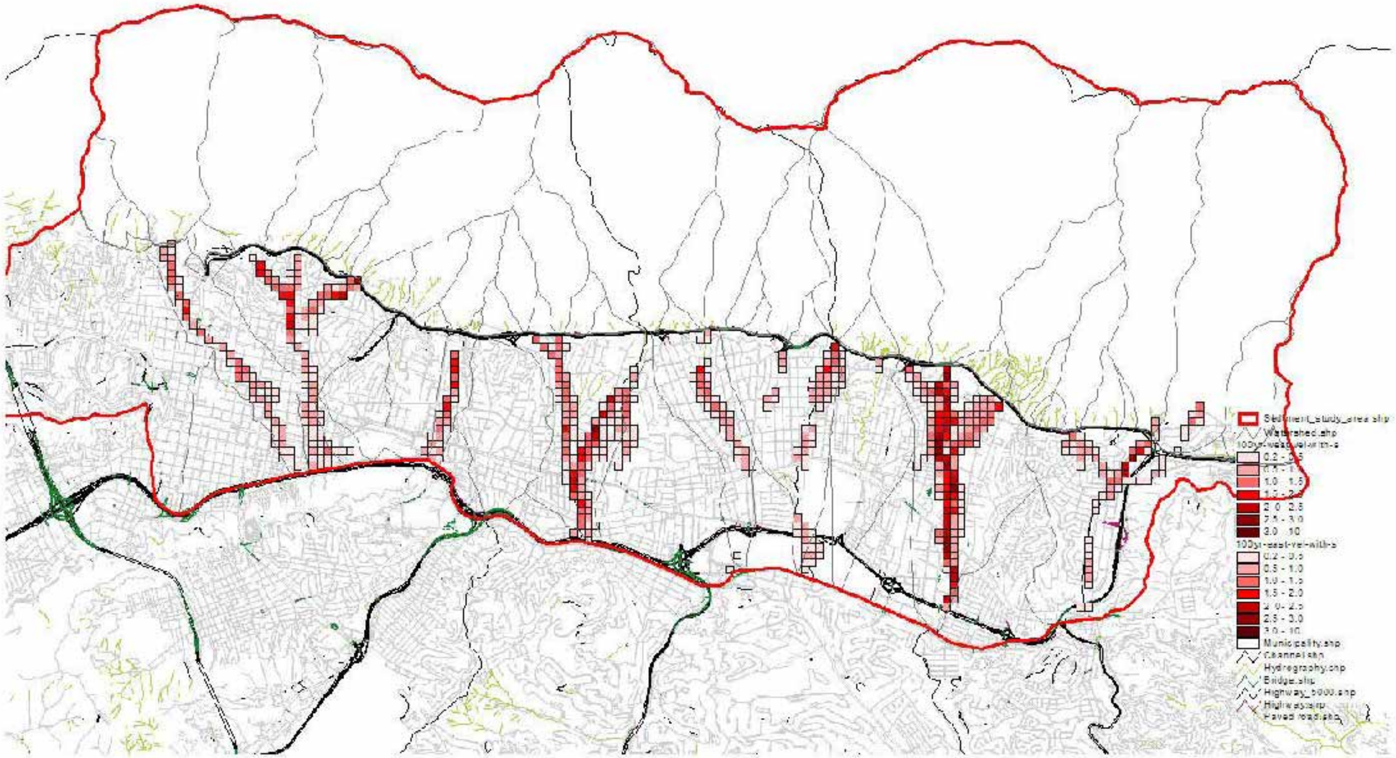


Figure 4.1.8 Velocity for 100 Years Return Period Under Existing Conditions

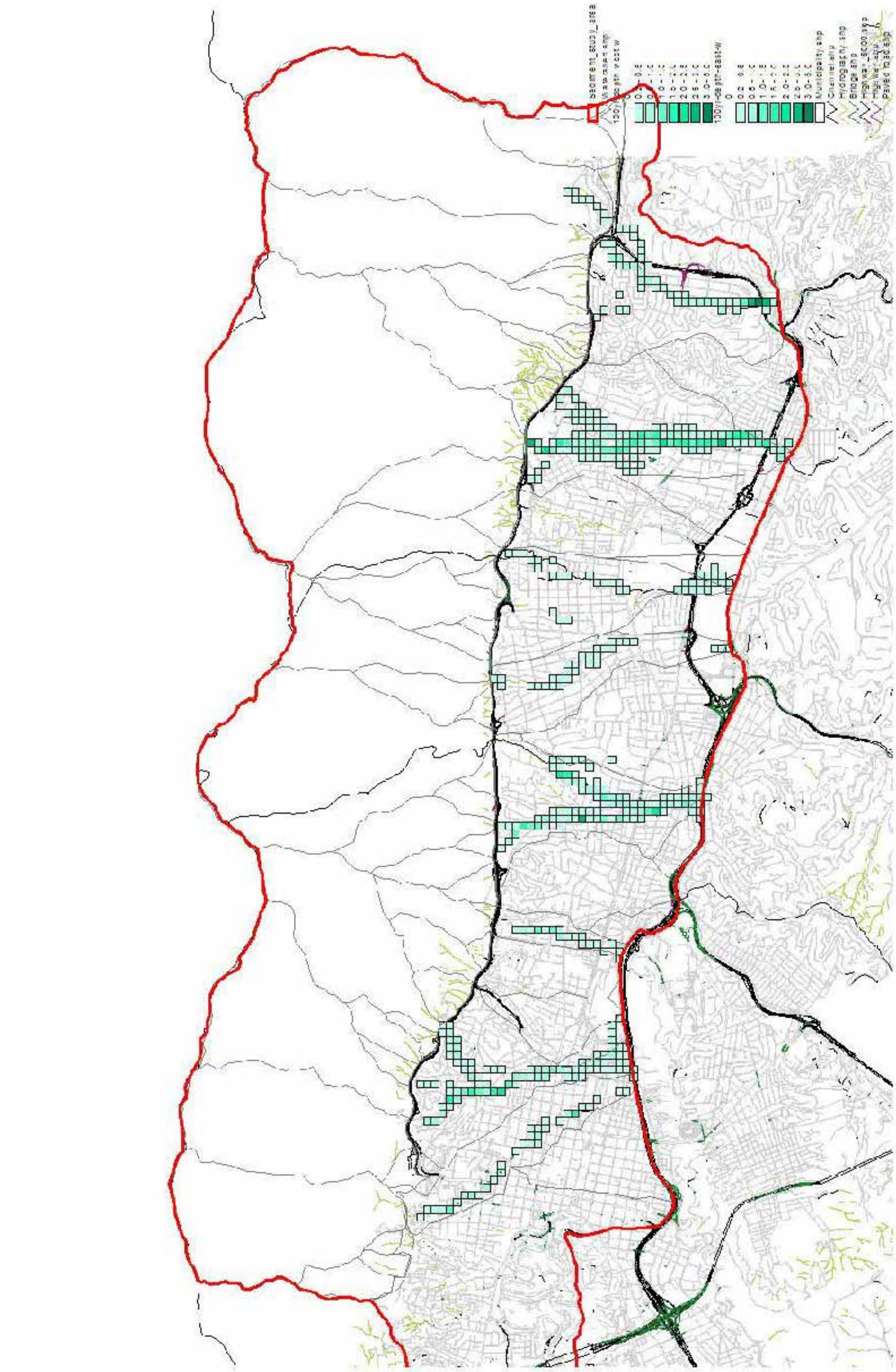


Figure 4.1.9 Depth for 100 Years Return Period Under with-Sabo Dam Conditions