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Capital District of Bogotá and Soacha Municipality
The Republic of Colombia

# THE STUDY ON MONITORING AND EARLY WARNING SYSTEM FOR LANDSLIDES AND FLOODS IN SELECTED AREAS IN THE CAPITAL DISTRICT OF BOGOTÁ AND SOACHA MUNICIPALITY IN THE REPUBLIC OF COLOMBIA

## FINAL REPORT

### VOLUME 1 SUMMARY

MARCH 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

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PACIFIC CONSULTANTS INTERNATIONAL
OYO INTERNATIONAL CORPORATION


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The exchange rate applied in this Study is
US$ 1.00=Colombian Peso 2014.76
(T.R.M. for January 1, 2008)

# PREFACE

In response to a request from the Government of Colombia, the Government of Japan decided to conduct a development study on Monitoring and Early Warning System for Landslides and Floods and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Colombia a study team headed by Mr. Kimio Takeya of the joint venture of Pacific Consultants International and OYO International Corporation, between June 2006 and March 2008. In addition, JICA set up a Monitoring Mission which examined the Study from specialist and technical point of view.

The Study Team held discussions with the officials concerned of the Government of Colombia, and conducted field surveys at the study area. Upon returning to Japan, the Study Team conducted further studies and prepared this final report.

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

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Colombia for their close cooperation extended to the Study Team.

March, 2008

Ariyuki MATSUMOTO
Vice-President
Japan International Cooperation Agency

March 2008

Mr. Ariyuki MATSUMOTO
Vice-President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to submit the final report entitled the "The Study on Monitoring and Early Warning System for Landslides and Floods". This report compiles the results of the Study in accordance with the contracts signed on June 16, 2006 and May 1, 2007 between the Japan International Cooperation Agency and the joint venture of Pacific Consultants International and OYO International Corporation.

In the Study, the Study Team presents the plan on monitoring and early warning system based on the analysis of the existing conditions and problems. The report consists of the Summary, Main Report, Supporting Report and Data Book.

All members of the Study Team wish to express sincere appreciation to the personnel of your Agency, Monitoring Mission, and the Embassy of Japan in Colombia, and also to the officials concerned of the Government of the Republic of Colombia, the Government of Bogota City, the Government of Soacha Municipality and the Government of Cundinamarca Prefecture for their cooperation extended to the Study Team. The Study Team sincerely hopes that the results of the Study will contribute to the disaster prevention for Bogota and Soacha.

Yours Faithfully

Kimio Takeya
Team Leader
The Study on Monitoring and Early Warning System for Landslides and Floods
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Composition of Final Report

English

Volume 1 : Summary

Volume 2 : Main Report

Volume 3 : Supporting Report

Volume 4 : Data Book 1,2 and 3

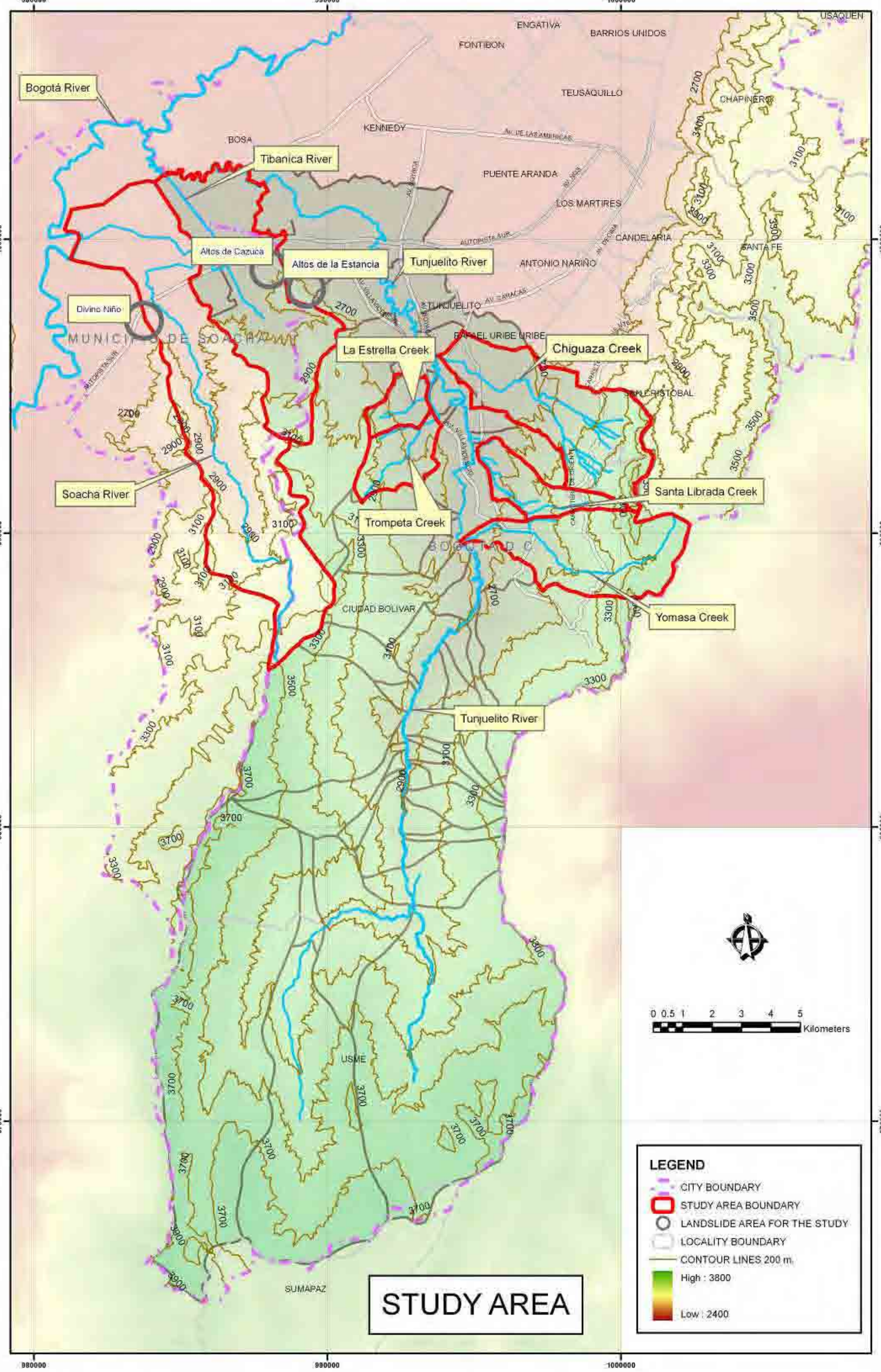
Spanish

Volumen 1 : Resumen

Volumen 2 : Reporte Principal

Volumen 3 : Reporte de Soporte

Volumen 4 : Libro de Datos 1,2 and 3


Bogotá River
Tibanica River
Altos de Cazuca
Altos de la Estancia
Tunjuelito River
Divino Niño
La Estrella Creek
Chiguaza Creek
Soacha River
Trompeta Creek
Santa Librada Creek
Yomasa Creek
Tunjuelito River
MUNICIPIO DE SOACHA
BOGOTA D.C.
ENGATIVA
BARRIOS UNIDOS
FONTIBON
TEUSAQUILLO
CHAPINERO
USAQUEN
BOSA
KENNEDY
PUENTE ARANDA
LOS MARTIRES
CANDELARIA
SANTA FE
ANTONIO NARIÑO
TUNJUELITO
RAFAEL URIBE URIBE
SAN CRISTOBAL
CIUDAD BOLIVAR
USME
SUMAPAZ
0 0.5 1 2 3 4 5 Kilometers
LEGEND
CITY BOUNDARY
STUDY AREA BOUNDARY
LANDSLIDE AREA FOR THE STUDY
LOCALITY BOUNDARY
CONTOUR LINES 200 m.
High : 3800
Low : 2400
STUDY AREA

Study on Monitoring and Early Warning System for Landslides and Floods

# Outline

## 1 Background of the Study

The Study Areas are landslide area and river/creeks catchment located on the southern part and edge of the Bogota city, the capital of the Republic of Colombia. The ground elevation is 2,500 m in the low area and 3,600 m as the highest point above mean sea level. The study area has been developed quite rapidly since 1970's as a marginal area of the Bogota city, where in poor condition's area such as steep slope around abandoned quarries and used to be wet land, people started to live densely, forming low income neighborhood (barrio). On the other hand, the area has suffered from landslides, steep slope failures and floods due to the topography and meteorological conditions. The Bogota city has already conducted a lot of studies and implemented some relocation. In the Tunjuelo river basin, along the main river course the monitoring and early warning system has been established, however, the system within some tributaries catchment has not been established yet, which is not enough from the viewpoint of saving people's life. The Soacha Municipality has a disaster prevention organization, however does not have any monitoring system.

Under the above situations, the Government of Colombia requested the Government of Japan to make a plan of monitoring and early warning system for landslides and floods for a part of Bogota city and Soacha Municipality. Responding to this request, Japan International Cooperation Agency (JICA) dispatched the Study Team headed by Mr. Kimio Takeya on June 2006.

## 2 Objectives of the Study

The objectives of the Study are:

- To prepare a Plan for monitoring and early warning system for the Study area for landslides and floods for the target year 2020.
- To establish, operate and maintain the monitoring and early warning system for landslides and floods for the selected areas through pilot projects relying on the initiative of community people in order to enhance the capacity on disaster prevention of the counterpart organizations and communities.
- To transfer technologies and knowledge to the Colombian personnel involved in the Study.

## 3 Study Area

The Study Area is one (1) landslide area and four (4) creek catchment located in the southern part of Bogota, and two (2) steep slope areas and two (2) river basins of Soacha city which is next to Bogota.

## 4 Plan on Monitoring and Early Warning System

### 4.1 Landslides of Bogota

Present Status of the Landslide

There is only one place for the landslide study area in Bogota and it is designated commonly by Altos de La Estancia, and is located southwest of Bogota, north of the Bolivar Locality. In Chapter 5, the landslide in the Sector Altos de La Estancia is referred to as "the Landslide". The Landslide includes two major masses, namely La Carbonera in the south and El Espino in the north, displaces hundred of thousand of cubic meters, and forces hundreds of families to resettlement in an approximate area of 100 ha. The type of the Landslide is related to a mass movement accompanied by some small different types of movement. DPAE divided the Landslide area in 3 zones, namely high alert, middle alert and low alert [or Phase I area, Phase II area and Phase III area] with the purpose of relocation program. There were no residential houses in Phase I area, but still there were a lot of houses in Phase II area in Year 2007.

Table Areas in the Landslides

| Area | Condition | Relocation program by Bogota |
|---|---|---|
| Phase I area | Surfaces of the land are deformed. Most active area in the landslide. | Relocation program has been completed |
| Phase II area | The areas locate above and below Phase I. The areas were not affected by the landslide, but recently some cracks and deformation on the ground were found in the areas. | Relocation program is being in progress. |
| Phase III area | The areas locate upper and lower part of the Phases I area and II area. The areas are regarded as safe. | Out of relocation program |
| Out of the Landslide Area | Out of the Landslide. | Out of relocation program |

Target

Enhancement of capacity of DPAE on disaster prevention by implementation of the proposed plan in this study

Purpose of the Project

The purpose of the monitoring as the pilot project is to verify that the residential areas as for its safety. This concerns only the object areas of the monitoring of the residential area (Phase III area and the areas outside the landslide area) only as follows.

a. boundaries between Phase II and III areas
b. the areas above the heads of the main landslide in Phase II area
c. the house in which cracks and distortions were found.

With reference to “b” above, new collapses occurred recently near the heads of the main landslide blocks may show expanding of the landslide upward (toward Phase III area). In order to ascertain the movement of the ground above the main landslide blocks, the monitoring is carried out in the area above heads of the main landslide blocks in Phase II area. With reference to “c” above, some cracks and deformations of a house in safe area were found recently.

Monitoring

The following five kinds of monitoring works are carried out. Extent of the monitoring is shown below.

Table Extent of Monitoring

| Location | Monitoring | Item | Quantity |
|---|---|---|---|
| Boundary between the Landslide and the Residential Area | Survey Point | Survey Points | 15 |
| | | Fix Points (Bench Marks) | 5 |
| Phase II area | Crack Gauge | Crack Gauges | 3 |
| | | Pegs (4 pegs for 1 set) | 3 set |
| Uplift and Deformed House | Level Survey | Survey Points | 3 |
| | Tiltmeter | Sensor | 1 |
| | | Logger | 1 |
| | Distance Meter | Laser Distance Meter | 1 |
| | | Target Plate | 2 |

The survey Points were installed along the boundary between the residential area and the Landslide in order to confirm the safe areas are still in safe. In case any movements on some survey points are observed by the monitoring, the area around the survey points might be affected by the landslide. Exploration of the area is necessary to find any damages, distortions and cracks on the ground, houses or structures. A total of 15 the survey points were installed, and 5 fix points were installed as bench marks.

The movement of the cracks monitored by simple crack gauges can be summarized in graphs which show relations between time and movement. The graphs can show the movement of the head of landslide block, and then the velocity of the landslide movement may be estimated.

In the house which is object of the monitoring, some cracks were found by residents of the house in October 2006. The house locates in the safe area (outside the landslide) close to the boundary between relocation area, and at the place close to the uplift by the landslide movement. The following equipments were installed in and around the house to monitor the slow progress of tilting of the house and slow movement of uplift.

a. Tiltmeters on the basement floor of the house

b. Laser distance meter to monitor the distance between the house and the uplift

c. Logger which connected to the tiltmeters in the house

d. Level survey points to monitor uplifting of the uplift

For the monitoring of distance between the house and the uplift, laser distance meter is employed instead of extensometers which required wires on the ground.

Data Processing

Any significant movement has not been seen on all the monitoring during the pilot project. The results may show that the landslide has not reached the safe areas, and the residential areas may be still in safe status. However, the period of the monitoring is too short to judge the safety of the areas, the monitoring should be continued and accumulate the data to confirm the safety of the areas.

Hazard Map

DPAE did an area division in three areas named Phase I area, Phase II area and Phase III area based on available information and especially in the study of INGEOMINAS (2003) in order to relocate the population of all areas, and issued the map to public as Hazard Map. Almost all of the inhabitants in Phase I area actually have been relocated, and relocation of inhabitants in Phase II area is progressing. The Phase III area, which is counted as stable area and out of relocation plan, corresponds to the high slope part.

Early Warning and Evacuation Plan

The early warning systems using the automatic monitoring systems are not required in the Landslide in terms of saving human loss in the area, because of existing resettlement program and the movement speed of landslide. The most recommendable thing is to observe the ground conditions by the engineers with regular patrol or by the communities in their ordinary lives. This observation survey is performed to examine the extent, direction of movement, and the mechanism of landslides in detail when any sign of landslide motion such as slide scarps or cracks are found or when there is any possibility of the occurrence of landslides in the future.

## 4.2 Flood in Bogota Target Creeks

Past Floods in Target Creeks

The target creeks in Bogota are Chiguaza creek, Santa Librada creek, Yomasa creek and La Estrella Trompeta creek. The largest catchment area is that of the Chiguaza, 18.7 $km^2$. The bed slopes of these creeks are quite steep whose main reach is steeper than 3 degree.

The interview survey was undetaken by the Study team about the past floods in the 4 creeks. In the Chiguaza, a flood disaster took place in May 19, 1994 which caused 4 victims, 800 people affected. In this flood, the Juan Rey rainfall station of EAAB located in the upstream of the creek catchment recorded the daily rainfall 22.9 mm and the maximum 30 minutes rainfall 19 mm. The flood damage was caused by the flooding on the street of the right side of the creek due to the clogging of culvert crossing the creek. In the study area, that is only flood disaster associated with victims and a lot of affected according to the survey during the study.

Also in the Chiguaza the inundation occurred in the most downstream reach near the Tunjuelo river confluence in the end of May 2002. This flood is considered that caused by runoff from the Chiguaza itself as well as high water of the Tunjuelo river. In the upstream of the Tunjuelo river EAAB's Cantarrana Dam (flood control purpose) was constructed in 2007. The Chiguaza downstream reach has been improved by EAAB, so that the safety level is increasing in the Chiguaza. However, since there is few monitored data, especially waterlevel data, the safety level is not confirmed yet based on the relationship between monitored rainfall data and waterlevel.

Objectives of the Plan

By implementing of the plan proposed in the Study, the capacity on disaster prevention of DPAE will be enhanced.

Planning Principle

The above-mentioned plan was prepared for short, middle and long term. The target year of the plan is set up in 2020, assuming that the implementation of the plan starts in 2007 and fourteen (14) years would be required for the completion. The reason for starting the said plan in 2007 is that the pilot project(s) in this Study was undertaken as a part of the proposed plan.

Definition of Short, Middle and Long Term Plan

| Plan | Year | Definition |
|---|---|---|
| Short | 2007-2008 | It is urgently required and should be implemented as pilot projects which will become the basis of middle and long plan. |
| Middle | 2008-2012 | This is an extension for a short term plan in order to secure the target creeks. |
| Long | 2013-2020 | This is a fully advanced system based on the experience of short and middle plans. |

The purpose of the proposed plan is to prevent the people in the previously affected area from the same flood damage in near future, or mitigate the future damage by the plan. Thus, as a tool for the above, monitoring of hydro-meteorological conditions by equipment and preparation of early warning system based on the monitored data are required. Therefore, it should be pointed out that the people who should evacuate in an event of flood understand the meaning of the early warning system and they take necessary actions are quite important. In this sense, unless the people understand the importance of the system and can make use of the system actually, any expensive equipment for the monitoring and early warning is meaningless.

Based on the purpose, the monitoring system of DPAE should be proceeded as following phases,

Monitoring and Data Gathering System

Phase 1 ： data accumulating and people's training phase

The Chiguaza creek catchment is defined as the most important monitoring area and the following station were setup.

List of Station to be monitored for DPAE (Short –Team)

| Location | Monitoring item | Purpose of Monitoring | Equipment | Person in charge of Monitoring |
|---|---|---|---|---|
| Moralba (school) | 10 minutes rainfall | The short duration rainfall upper art of the affected area in 1994 will be monitored. | Rain gauge(tipping bucket), data logger with external display, solar panel, battery, cabinet and earth | Security guard of school Hourly monitoring |
| La Gloria | Waterlevel in upper reach | The affected people in 1994 flood should start the monitoring (waterlevel). | Staff gauge, waterlevel simple alarm device | 3 times day monitoring by local people and recording time and waterlevel at high water. |
| Molinos (foot bridge next to school ) | Waterlevel in middle reach | The affected people in 1994 flood should start the monitoring (waterlevel). | Staff gauge, Non-touch stage sensor (ultrasonic type), data logger with external display, solar panel, battery, cabinet and earth. | 3 times day by people and security guard of the school |
| El Hoyo | Waterlevel in downstream | The affected people in 2002 flood should start the monitoring (waterlevel). | DPAE staff gauge | 3 times day by Civil Defense |

In this phase, the following thins should established.

- Accumulation of waterlevel monitoring experience of the downstream people and rainfall monitoring experience of upstream people. The collaboration between upstream and downstream is enhanced.
- Accumulation of data regarding the short duration rainfall in the upstream and the waterlevel response in the downstream
- Downstream people's understanding on the phenomena of waterlevel response by upstream rainfall(understanding on false alert)

Phase 2 ： Rainfall and waterlevel measurement in Yomasa creek catchment

The Yomasa creek has not suffered from flood damage like Chiguaza 1994, however, the present condition of the creek bed has remarkable unstable sediment deposit.

List of Station to be monitored for DPAE (Mid –Team)

| Location | Monitoring item | Purpose of Monitoring | Equipment | Person in charge of Monitoring |
|---|---|---|---|---|
| Alemana | Rainfall | Measurement of upstream rainfall in the Yomasa creek | Rainfall gauge(automatic with external display) | 3 time a day monitoring by people |
| Ave. Usme downstream (Monte Blanco) | waterlevel | Measurement of waterlevel response by the upstream rainfall | Staff gauge | 3 time a day monitoring by people |

Data Analysis and Processing

By measuring of waterlevel at Molinos continuously, the data on response of waterlevel for the upstream rainfall will be accumulated, as well as discharge measurement (by floating during flood) will be conducted to confirm the runoff from the upstream and analyze effective rainfall, which could improve the warning criteria. The velocity measurement by float should be arranged by the people who monitored the staff gauge at Molinos in the Short Term.

Also, the waterlevel at Molinos and rainfall at Moralba will be transferred by telemeter system to DPAE, whose system will be included in the existing Tunjuelo River early warning system of DPAE.

Warning Criteria and Susceptibility Map

The flood map in May 1994 flood was made by the Study Team based on the flood interview survey for the affected people in 1994 in the Chiguaza creek. Also the probable flood area for 25 years return period was prepared for the Chiguaza downstream area.

The flood alert of the Study area was proposed to be daily rainfall 10 mm tentatively. This is based on the statistical analysis of rainfall and some kind of flood events in the study area from DPAE recent 5 years data. In the Chiguaza creek catchment, in recent 5 years, 38 flood events were reported to DPAE. The detailed phenomena of such flood was not recorded, however, it is a sum of various flood events such as overflow from ditch and inland flood based on people's information. Among them, 20 events (50 %) happened at the time of daily rainfall 10 mm. It means that in the Chiguaza creek catchment, when the daily rainfall is 10 mm, some kind of flood would occur with possibility of 50 %, so that this rainfall should be set as alert tentatively. In other 3 creeks, when the daily rainfall is 10 mm, the flood event possibility is lower, however, considering the small size of catchment, more detailed alert by area (catchment) can not be proposed.

The tentative warning criteria for the Chiguaza creek based on the monitoring and hydraulic study is as follows,

In the downstream reach between Caracas Avenue and Molinos street, there is critical section whose flow capacity is only 10 years return period. The discharge for 10 years return period can be brought by about 20 mm per 30 minutes. Therefore, the warning criteria is set as follows, alert level 6 mm per 10 minutes and warning level 20 mm per 30 minutes.

In the reach from middle stream to upstream of the Chiguaza, basically the channel capacity is quite high, however, as they can experienced in May 1994 flood, if crossing structure such as culvert is clogged, over flow could take place easily and unexpectedly. Six (6) locations were pointed out because they need periodical maintenance.

In the upstream, there is possibility that crossing structure will be clogged up by garbage and sediment deposition as they saw in May 1994. The warning criterion in terms of rainfall for this kind phenomenon is difficult because of lack of data. Tentatively based on the measured rainfall amount in May 1994, the past 15 days rainfall 78.1 mm and daily rainfall 22.9 mm are proposed as the first criteria. If the rainfall exceeds this value, patrol along the creek is recommended.

Information Transfer Plan

DPAE is in charge of information transfer to community based on the monitored data. The modification of warning criteria should be done by DPAE.

### 4.3 Landslides in Soacha Municipality

Status of Landslides

Landslides, mostly classified into rock fall and surface collapses, in the study areas occur frequently at abandoned quarries in Altos de Cazuca area where houses gathered in the upper and lower area close to steep slopes and landslide hazard areas. Also, houses gathered in landslide hazard area formed by a quarry in El Divino Niño area. According to the statistic record, the number of residential houses suffered from landslides especially in El Divino Niño area and La Capilla area of Altos de Cazuca area is the highest in Soacha Municipality. Prompt measures should be taken to save people in these areas.

Steep slopes in the abandoned quarries are the most critical conditions among many disasters in Altos de Cazuca area. In this study, only steep slopes in the abandoned quarries are the object of the studies.

Target

Enhancement of capacity of Soacha Municipality on disaster prevention by implementation of the proposed plan in this study

Purpose of the Project

Even some landslide disasters occur in dry condition, many landslide disasters have occurred during or after heavy rain in Altos de Cazuca area and El Divino Niño area in Soacha Municipality. It may be true that the rainfall causes many landslides in Soacha Municipality, but not certain without any support data. The information collection of precipitation and disasters are most important to take action against the landslide disasters. Accumulating the information about precipitation and occurrence of landslides, the relation between rainfall and occurrence of landslides should be studied.

In order to install the rain gauges as many as possible for the purpose, the simple gauges which are low cost and easy to be read were installed in the pilot project area. To monitor many rain gauges constantly, the monitoring works are left to the community in where the rain gauges are installed. It is expected also that community's awareness of disaster prevention becomes higher with the monitoring works. The record of landslide is being carried out by Soacha municipality, since recording of landslides requires more expertise.

Monitoring

Precipitation monitoring was carried out in the pilot project area where is Altos de Cazuca area and El Divino Niño area in Soacha Municipality. Five rain gauges were installed in five schools in the pilot project area.

The rain gauge consists of funnel and Cylinders and sub cylinder for reading minutely is attached. It is very simple rain gauge without any mechanical parts and electric power.

Basically, the monitoring works are carried out by a person in each school who is assigned by the principal of the school. The values indicated by the rain gauges are read three times a day at 6:30, 14:00, and 18:00. The records are submitted once a week to the Soacha municipality. In the case the accumulate rainfall is more than 20mm/24h, the person who read the rain gauge should call the firefighter station in Soacha Municipality.

All of landslides in Soacha Municipality should be recorded immediately after occurrence of the landslide using the record format. Especially, the pilot project areas, Altos de Cazuca area and El Divino Niño area, are emphasized. The formats are filled by the engineer immediately after he visited the landslide site. The report of monitoring contains an analysis of the relation between the rain fall and the landslide disasters. Record format which has been recorded should be filed in the engineer's office in Soacha Municipality.

Data Processing

Though the precipitation monitoring has been carried out for five months in 2007, the precipitation data must be accumulated for longer periods in order to have information on rainfall. At the moment, the following situation is observed in the monitoring.

a) Monthly precipitation in August is more than in September. It shows different trends from average normal year.

b) Monthly precipitation is different in each point in August, and is not different in each point in September.

c) Maximum monthly precipitation was observed with RG-4 by 141.8 mm in October 2007.

d) Maximum daily precipitation was observed with RG-4 by 58.2 mm on 13th October 2007.

e) The lower the altitude of the rain gauges is, the more it tends to rain both especially in August.

Three landslide disasters occurred in the period from 13th October to 15th October 2007 in Los Robbles, Terranova and La Capilla in Altos de Cazuca area. Rain continued intermittently from 6th October 2007 to 14th October 2007 in Altos de Cazuca area. Nearest rain gauge points to Los Robbles is RG-4, to Terranova is RG-3 and to La Capilla is RG-1. According to Figure 8-3 in Main Report, excess 20 mm of accumulate precipitation may be appropriate for Alert Level 1 and excess 50 mm of accumulate precipitation may be appropriate for Alert Level 2.

Hazard Map

Disaster inventory survey in Altos de Cazuca area and El Divino Niño area was carried out by aero photo analysis and site reconnaissance. The results of the disaster inventory survey are seen in Disaster Inventory Map. Steep slopes in the abandoned quarries are the most critical conditions among many disasters in Altos de Cazuca area. In this study, only steep slopes in the abandoned quarries are the object of the studies.

In the study area, Critical Zones has been set to verify the critical area in the “barrios”. In barrios La Capilla in Altos de Cazuca area and El Divino Niño area where houses are dense, slopes are high and landslides occur frequently. The Critical Zones are set above and below the steep slopes. Critical Zone is defined as the area within the distance of twice the slope height (2h) from toe of the slope and the area within the same distance as the slope height from top of the slope. Critical Zone in El Divino Niño area and La Capilla is shown in Figures attached.

The Soacha Municipality introduced a scheme for relocation of houses from high risk areas in a disaster prevention program. The Critical Zone maps could provide useful information for the Soacha Municipality’s relocation scheme. It is obvious, however, that the early relocation of houses in the Critical Zones in El Divino Niño area and La Capilla area is difficult, since many houses are settled in the Critical Zones. The Emergency Zone is set in the Critical Zones in El Divino Niño area where is found the most serious area in Soacha Municipality. It is imperative that the houses in Emergency Zones be relocated urgently. The criterion of Emergency Zone should be within the limits of 10 m or 2 houses from toe of the slope.

For the relocation program in El Divino Niño area, the relocation of all people from Critical Zones and even Emergency Zones may take a long time. Therefore, it is important to protect the people who stay in the Emergency Zones and Critical Zones until they are relocated. To this end, the people should know whether they are settled in the zones or not using by Critical Zone map (Hazard maps).

Early Warning and Evacuation

The steep slopes are covered by clayey material which was created in process of weathering of sandstone and mudstone. The surfaces of the steep slopes are sensitive. In addition, open cracks observed on the slopes indicate that the entire bodies of the slopes have been continuously moving from the past. Therefore, the steep slopes are delicate state and further cutting on steep slopes is equal to removal of toe of the slope and this activity increase the risk of mass movement. Any protection and stabilization works on steep slopes in abandoned quarries in El Divino Niño area and Altos de Cazuca area is impracticable to implement from the technical viewpoints.

It is recommendable to relocate from the Critical Zones as measures against slope disasters on steep slopes in abandoned quarries. The houses close to the steep slopes should be relocated to safe areas, out of Critical Zones.

## 4.4 Flood for Soacha

Flood Problems in Soacha

The study area for flood in Soacha is the Soacha river basin (a tributary of the Bogota river) and the Tibanica river basin (a tributary of the Tunjuelo River).

The Soacha river has 24 km length from the Bogota river confluence to the San Jorge in its origin. The river suffered from the most serious flood damage on recent 20 years on May 11, 2006. The most seriously affected areas were the left bank floodplain between 7K+877 and 9K+000. This reach used to be the floodplain (wetland) in 1940's and the urbanization was proceeded. The barrio called Llano Grande suffered from damage most seriously where the inundation depth was over 1 meter. The damage in the Tibanica river next to the Soacha river was comparatively small. The plan was focused on the Soacha river for the monitoring and early warning system.

The rainfall in may11, 2006 was observed only at San Jorge IDEAM station located 18km upstream from the Bogota river. The observed rainfall was only 7.5 mm (8:40AM to 9:40AM) while the daily rainfall was 20 mm.

According to the people in Llano Grande, the overflow started at 11:30 in the morning, which means the flood in Llano Grande took place 2 hours after the rainfall in San Jorge. The distance from Llano Grande to San Jorge is about 8 km, while the rainfall distribution in area is not clear, according to the people, the rainfall concentrated on the middle basin of the Soacha river.

The Firefighter Station started to monitor the rainfall from December 2006 in this Study. The correlation between the Firefighter Station and IDEAM San Jorge is quite low in terms of daily rainfall.

Objectives of the Plan

By implementing of the plan proposed in the Study, the capacity on disaster prevention of Soacha Municipality will be enhanced. Also it is expected that Soacha Municipality will train other municipalities in the Cundinamarca Government, which would enhance the capacity of the Government.

Planning Principle

The plan above was prepared with short, middle and long term plans. The target year of the plan is set up in 2020, assuming that the implementation of the plan starts in 2007 and takes fourteen (14) years for the completion. The reason why the said plan starts in 2007 is that the pilot project(s) in this Study was undertaken as a part of the proposed plan.

Definition of Short, Middle and Long Term Plan

| Plan | Year | Definition |
|---|---|---|
| Short | 2007-2008 | It is urgently required and should be implemented as pilot projects which will become the basis of middle and long plan. |
| Middle | 2008-2012 | This is an extension of short term plan in order to secure the target creeks. |
| Long | 2013-2020 | This is a fully advanced system based on the experience of short and middle plans. |

The purpose of the proposed plan is to prevent the people in the previously affected area from the same flood damage in near future, or mitigate the future damage by the plan. Thus, as a tool for the above, monitoring of hydro-meteorological conditions by equipment and preparation of early warning system based on the monitored data are required. Therefore, it should be pointed out that the people who should evacuate in an event of flood understand the meaning of the early warning system and they take necessary actions are quite important. In this sense, unless the people understand the importance of the system and can make use of the system actually, any expensive equipment for the monitoring and early warning is meaningless.

Based on the purpose, the monitoring system of Soacha should be proceeded as following phases,

Monitoring and Data Gathering System

Phase 1 : Waterlevel measurement by affected people in May 2006 flood and rainfall measurement in the upstream by local residents

The Soacha river basin is defined as the most important monitoring area and the following station were setup.

List of Station to be monitored for Soacha (Short –Team)

| Location | Monitoring item | Purpose of Monitoring | Equipment | Person in charge of Monitoring |
|---|---|---|---|---|
| San Jorge (ICA) | Hourly rainfall | To monitor the upstream local rainfall at representative position in the upper part of the catchment. | Rain gauge(tipping bucket), data logger with external display, solar panel, battery, cabinet and earth | Three times a day monitoring by security guard and reporting to Firefighter Station by radio |
| Fusunga | Waterlevel | In order to assure the accuracy of warning, waterlevel is monitored. | Staff gauge | Three times a day monitoring by people and reporting to Firefighter Station by radio. The person in charge is quite cooperative to the monitoring activity in entire basin. |
| City Prison | Rainfall and waterlevel | Monitoring rainfall and waterlevel in middle part of the basin and issuing of alert to downstream target area. | Staff gauge, waterlevel simple alarm device and simple rainfall gauge | Three times a day monitoring by security guard and reporting to Firefighter Station by radio |
| Ladrillera Santa Fe(brick factory) | waterlevel | Monitoring waterlevel at most downstream as long as the security is assured and issuing of alert to downstream target area. | Non-touch waterlevel sensor(ultrasonic), data logger with external display, solar panel, battery, cabinet and earth | Three times a day monitoring by security guard and reporting to Firefighter Station by radio |

| | | | | |
|---|---|---|---|---|
| Llano Grande | Waterlevel | The affected people in May 2006 flood should start waterlevel monitoring. | Staff gauge | Three times a day monitoring by people and reporting to Firefighter Station by radio |
| Firefighter Station | 10 minutes rainfall | As a Monitoring Centre of Soacha, the rainfall measurement should be started. | Rain gauge(tipping bucket), data logger with external display, solar panel, battery, cabinet and earth | Hourly monitoring by Firefighter |
| Firefighter Station | Web site monitoring for rainfall and waterlevel | All information from Monitoring station will be input into Data Base. | Desktop PC, Laptop PC and data download software | |

In this phase, the following thins should established.

- Accumulation of waterlevel monitoring experience of the downstream people and rainfall monitoring experience of upstream people.
- Establishing of information transfer system between Firefighter station and monitoring stations and communities by radio, in order to let the Firefighter confirm the current status of the Basin.
- Accumulation of data regarding the short duration rainfall in the upstream and the waterlevel response in the downstream
- Downstream people's understanding on the phenomena of waterlevel response by upstream rainfall(understanding on false alert)

Phase 2 : Telemeterizing of San Jorge (rainfall) and automatic measuring of Ladrillera Santa Fe(waterlevel) and conducting of discharge measurement at Ladrillera Santa Fe

<u>Data Analysis and Processing</u>

By measuring of waterlevel at Ladrillera Santa Fe continuously, the data on response of waterlevel for the upstream rainfall will be accumulated, as well as discharge measurement (by floating during flood) will be conducted to confirm the runoff from the upstream and analyze effective rainfall, which could improve the warning criteria. The velocity measurement by float should be arranged by the people who monitored the staff gauge at Ladrillera Santa Fe in the Short Term.

After telemeterizing of San Jorge and Ladrillera Santa Fe, the Soacha monitoring system will be integrated into IDEAM system. An agreement between Soacha Municipality and IDEAM regarding future maintenance and data exchange has been discussed. The discussion should be continued after the study in order that the Soacha will receive technical support from IDEAM.

<u>Warning Criteria and Susceptibility Map</u>

The flood map in May 2006 flood was made by the Study Team based on the flood interview survey for the affected people in 2006 in the Soacha river.

The flood alert of the Study area was proposed to be daily rainfall 10 mm tentatively. This is based on the statistical analysis of rainfall and some kind of flood events in the study area from Soacha Municipality recent 10 years data. In Soacha Municipality, in recent 10 years, 101 flood events were reported to Municipality. The detailed phenomena of such flood was not recorded, however, it is a sum of various flood events such as overflow from ditch and inland flood based on people's information.

Among them, 56 events (55 %) happened at the time of daily rainfall 10 mm. It means that in Soacha Municipality, when the daily rainfall is 10 mm, some kind of flood would occur with possibility of 50 %, so that this rainfall should be set as alert tentatively.

The warning waterlevel and rainfall was tentative setup based on the actual waterlevel on May 2006 flood and monitoring and hydraulic analysis.

Information Transfer Plan

The Soacha Municipality is in charge of transfer of warning to communities based on the monitoring data. The firefighter station will collect all monitoring data and manage them, and provide information with CLOPAD for warning issue.

The updating of warning criteria will be done by Soacha Municipality receiving of support from IDEAM.

Evacuation Plan

The evacuation plan for the pilot project area was formulated based on the actual inundation in May 2006 flood. People should evacuate to their 2nd floor or community center outside of the inundation area.

Institutional Aspects

The proposed plan will be implemented basically by CLOPAD of Soacha Municipality. CREPAD of Cundinamarca Government which is the upper level organization of the Municipality, is in charge of Bogota river committee whose members are municipalities along the Bogota river. The monitoring data which will be accumulated in Soacha river and experience of community activities will be a model for other municipalities. In this sense, CLOPAD in Soacha Municipality and other municipalities and CREPAD should coordinate more and contribute to the activities of the committee.

## 4.5 Community-based Disaster Prevention Plan in Soacha

(1) General

Regarding community organizations of Soacha Municipality, quite a few international organizations have been studying, however, the study on disaster prevention activities was done first in this Study.

(2) Community Survey

According to the communities' awareness survey in the Study area, a lot of people are interested in participation to disaster prevention activities, however, they did have few training on disaster prevention.

(3) Focus Group

Based on the survey on communities' awareness, some barrios were selected in which they have experiences on past disasters (landslides and floods) and have high awareness on participation to disaster prevention activities, and also have leaders who can actually participate into the activities. Inviting of those communities leaders, focus group meetings were held and some barrios for the pilot project were selected.

(4) Community Workshop

In the course of the Study, a series of workshops were held to invite community's organizations called JAC and to formulate community based disaster prevention plan in the pilot project area.

(5) Community-based Disaster Prevention Plan

| Main Component | Outline |
|---|---|
| Rainfall and waterlevel Monitoring System | Rainfall and waterlevel stations which were installed in Soacha river and Altos de Cazuca area and El Divino Niño area will be monitored by communities and related entities. The monitored data will be reported to Firefighter station by radio. |
| Information Transfer System | Communities will receive information (alert and warning, etc.) from Firefighter station through speaker system installed in JAC leader's houses. |
| Early Warning System | The proposed system is based on collaboration among upstream people and downstream people. The upstream people will participate in the rainfall and waterlevel monitoring. The person in charge of monitoring at each station will report the data to firefighter station. The Firefireghter station will inform communities by radio information (alert and warning) based on warning criteria. |
| Operation and Maintenance | The radio and speaker system necessary for information transfer will be maintained by communities. However, advanced equipment such as automatic rainfall gauge and waterlevel gauge will be maintained by Soacha Municipality with support from IDEAM. |
| Consideration of Lead time for early warning criteria | The necessary lead time for evacuation in communities including time for information transfer, preparation and moving) was assumed to 50 to 105 minutes according to communities' leaders, which will be revised in the course of the drill. |
| Evacuation Plan | The evacuation plan for the pilot project area was formulated based on the actual inundation in May 2006 flood. People should evacuate to their 2nd floor or community center outside of the inundation area. |
| Community Disaster Prevention map | In the course of repeated community's workshops, necessary information were compiled in maps for each barrio in the pilot project area. |
| Meeting Point and shelter for evacuation | In the community disaster prevention map, evacuation route and meeting points are indicated. At present, the capacity of evacuation center is not enough for emergency situation, and the Soacha Municipality and Communities should discuss to improve the situation. |

# 5 Implementation of Pilot Projects

The pilot project was conducted in the study as the first step of the plan on monitoring and early warning system formulated for DPAE and Soacha Municipality.

## 5.1 Landslides in Bogota

Pilot Project for landslide in Bogota is to execute the monitoring works mentioned in Section 4.1. The monitoring equipments were in stalled in July 2007, and the monitoring works are still in progress.

Any significant movement has not been seen on all the monitoring at the moment. The results may show that the landslide has not been reached to the safe areas, and the residential areas may be still in safe status.

## 5.2 Flood in Bogota

The pilot project for flood in Bogota is the implementation of Phase I area proposed in section 4.2. DPAE already started to monitoring activities using installed equipment in the Study.

### 5.3 Landslides in Soacha

Pilot Project for landslide in Soacha Municipality is to execute the monitoring works mentioned in Section 4.3. The monitoring equipments were installed in July 2007, and the monitoring works are still in progress.

Reading of rain gauges has been done by school teachers and security guards. In the first stage of the monitoring, some mistake like the unit wrong can be seen in record sheets. Reliable monitoring can be done after workshop which held after one month monitoring.

Three landslide disasters were recorded in the period from 13th October to 15th October 2007 in Altos de Cazuca area. Rain continued intermittently from 6th October to 14th October 2007 in Altos de Cazuca area.

Precipitation monitoring was carried out for five months in 2007, still the precipitation data must be accumulated for longer periods to have information on rainfall.

### 5.4 Floods in Soacha

The pilot project for flood in Soacha is the implementation of Phase 1 proposed in section 4.4. This is the establishment of system that resident or security guard monitor the rainfall gauge and waterlevel staff gauge and report the data by radio to the firefighter station at least 3 times a day.

Also in the case of Sacha Municipality, for the seriously affected area in May 2006 of the Soacha river left bank between Autopista Sur (7+877) and upstream 9+000, information transfer system was established among 4 barrio leaders in those areas and one administrator of El Silo downstream of the Autopista Sur. The Firefighter station will inform those leaders by radio alert and warning about floods. In this Study, speaker system was installed in those barrio leaders house and handy radio receivers were provided for the communication with firefighter station. By this system, people in communities will take action based on the instruction of leaders who receive message from the firefighter station.

In the last phase of this Study, the drill for the information transfer between monitoring stations and the firefighter station, and for the process that the firefighter station sends message to community leaders based on the warning criteria and the leaders prompt proper action to their community people was conducted, receiving of support of the Municipality, Red Cross and Civil Defense.

## 6 Temporary Works in Soacha Municipality

### 6.1 Background

In the Territorial Ordering Plan (POT) Soacha Municipality, the municipality classifies the area of El Divino Niño area as a “Hazard Zone by Landslide”, and the municipality is going to implement a relocation program of houses which are located in the hazardous zone. At the preparatory stage of this study (September 2005), Soacha municipality requested the study and implement emergency measures of slope protection against the landslide in El Divino Niño area. As a result, the it was concluded that the relocation of houses is the only way to assure the safety of residents and any other measures are impractical even some measures have possibility to induce further dangerous situation.

The Study Team examined and decided in concrete form the Critical Zone in El Divino Niño area. The Critical Zone is signified by the criteria of; slope angle is not less than 30 degree and slope height is not less than 5m, and distance from the slope toe is within twice of height of slope. Since there are many houses to be relocated in the Critical Zone, the Critical Zone was classified into two zones; Emergency Zone (the area within 10m or 2 rows of houses from the toe of the slope) and the remaining. And the priority for the relocation of houses was given to the relocation program by the Municipality.

Although the relocation of houses in the Emergency Zone is implemented by Soacha municipality, there are many remaining houses facing critical situation in the Critical Zone. Therefore the Study Team planed to implement temporary works in the Emergency Zone after the relocation of houses to reduce the damages to remaining houses by small-scale slope failures and rockfalls.

### 6.2 Design of the Temporary Protection Wall in El Divino Niño

(1) General

From the background as mentioned above, the objectives of temporary works are 1) to reduce the damages to remaining houses in the Critical Zone by small-scale slope failures and rockfalls, 2) to inform that the Critical Zone is a risk zone to the neighbors, and 3) to be a symbol of a emergency measures to avoid new settlement in the risk zone.

(2) Area for the Temporary Works

The temporary works is installed in the area of 5,100m$^2$ (0.51ha) defined as the Emergency Zone; the area within 10m or 2 rows of houses from the toe of the slope.

(3) Temporary Works

The temporary works is consisted of four items, which are a) temporary gabion wall for rockfalls, b) drainage channel at the house side of the wall, c) conventional drainage channel at the top of slope and 4) hazardous sign board.

## 7 Recommendations

### 7.1 General

The Study Team proposed the above plan on monitoring and early warning system to DPAE and Soacha Municipality and desires the system on landslides and floods will be made use of by them in the future in order to enhance the safety of people and early warning system on flood will be improved. Therefore the Study Team would like to recommend the following.

### 7.2 Recommendations for DPAE (Landslide)

<u>Continuous of Monitoring Works</u>

The results of the monitoring works as the pilot project may show that the landslide has not been reached to the safe areas, and the residential areas may be still in safe status. However, the period of the monitoring is too short to judge the safety of the areas, the monitoring should be continued and accumulate the data to confirm the safety of the areas. When significant movement is found in the monitoring result, the following steps should be taken to make sure that the landslide reaches the place.

1. Increasing of frequency of the monitoring at the place where the movement was found. Frequency of the monitoring may be about once a week.
2. Conducting of visually observations around the place to find the landslide reaches the place. This observation survey is performed to examine the extent, direction of movement, and the mechanism of landslides in detail.
3. If it is concluded with the result of the monitoring and observations that the landslide affect the place, the phases should be reconsidered.

<u>Recommendation for Stabilization Works in Altos de Estancia</u>

DPAE is planning stabilization works in the Landslide, however the details are not confirmed yet at the moment. Generally stabilization works are classified into two major categories, works for reduction of driving forces and works for increase in resistance force. In a large scale landslide like the Landslide in Altos de Estancia, method for reduction of driving forces is given to priority, since cost effectiveness for a large scale landslide is normally better than method for increase in resistance force. As remarkable thing in Altos de Estancia, surface water which comes from inadequate drainage system in Phase III area flows into the Landslide area at all over the place of heads of the Landslide. Water flow into the Landslide makes many channels and pools in the Landslide. The most important and effective stabilization works for the Landslide is to reduce the groundwater level, and prevent water penetration into the ground especially from sewer and rainwater.

## 7.3 Recommendations for Soacha (Landslide)

It is recommendable to relocate from the Critical Zones as measures against slope disasters on steep slopes in abandoned quarries. The houses close to the steep slopes in abandoned quarries should be relocated to safe areas. However it may take a long time to relocate from Critical Zones because there are many steep slopes in abandoned quarries and houses in the Critical Zones. The following non-structural measures are recommended.

1. People in Critical Zones should be relocated. Priority of relocation should be given to the people in most danger in Critical Zones.
2. Until all the people in Critical Zones relocated, Soacha Municipality should take care of safety of people remaining in Critical Zones.
3. People remaining in Critical Zones should be informed that they are in Critical Zones and always are at risk even in fine weather.
4. In heavy rain, Soacha Municipality should be on the alert for people in Critical Zones
5. To obtain the basic information about alert level of rain fall, Soacha Municipality should collect rainfall data.

As it could take a long time to complete the plan, relocation from more dangerous area with the following steps is necessary.

1. Complete the relocation program from Emergency Zone in El Divino Niño area
2. Set up Emergency Zones in La Capilla area.
3. Proceed relocation program from Emergency Zones in La Capilla area following the process in El Divino Niño area.
4. Set up Critical Zones and Emergency Zones in El Arroyo area (Villa Esperanza area) where is surrounded by steep slopes formed by mining activities.
5. Proceed relocation program from Emergency Zone in El Arroyo area (Villa Esperanza area) in accordance with the process in El Divino Niño area.
6. Set up Critical Zones and Emergency Zones in other areas where steep slopes in abandoned quarries are exist, and proceed with the program of relocation from Emergency Zones.
7. After completion the relocation program from Emergency Zones, proceed relocation program from Critical Zones in El Divino Niño area, and continue the relocation program from Emergency Zones.

Precipitation monitoring and record of landslides which commenced in the pilot project of this study should be continued in order to collect and accumulate the basic information for analysis of the relation between rainfall and occurrence of landslide and to study landslide disaster prevention measures. After the precipitation data accumulated and analyzed, automatic record type rain gauge is recommendable in Altos de Cazuca area in order to improve the resolution of precipitation monitoring.

### 7.4 Recommendations for DPAE (Flood)

The early warning criteria tentatively proposed by the Study Team are only estimations given the conditions derivate from scarcity of registers Such rainfall criteria and waterlevel should be updated to precise their reliability through the use of registered information by the community even after the Study; therefore those tentative criteria are not definitive values.

After the Study, DPAE will conduct the following activities, (a) Continuous monitoring, (b) Studies for early warning criteria using the monitored data, (c) Establishment of more reliable early warning plan, (d) Dissemination of the plan to the communities, based on the recommendation of the Study Team.

### 7.5 Recommendations for Soacha (Flood)

#### (1) Monitoring of Rainfall and Waterlevel

The activities carried out in this Study, such as monitoring of rainfall, waterlevel and riverbed elevation, information transfer/evacuation drill, etc. should be continued by the Soacha Municipality's initiative. Soacha Municipality and community will take necessary actions and/or measures if necessary things rise in the activities.

Equipment installed in Firefighter station, Llano Grande station, Ladrillera Santa Fe station, Prison station, Fusunga station and San Jorge station should be maintained by each station with the support of Soacha Municipality.

#### (2) Training on Information Transfer and Evacuation

The Soacha Municipality should organize to conduct continuous training of information transfer and evacuation.

#### (3) Dredging of Soacha river and Tibanica river

Management and maintenance of Soacha river and Tibanica river including dredging should be done by CAR, EAAB and Soacha Municipality.

### 7.6 Recommendations for Soacha (Community Disaster Prevention Activities)

#### (1) Role of Soacha Municipality

In the course of a series of community workshop held in the Study, Soacha Municipality recognized that the importance of its role as facilitator between CLOPAD and communities. It means Soacha Municipality should put a emphasize on making of supportive, inclusive and safe working environment for disaster prevention, rather than setting top down rules or limiting information sharing to a minimum. Soacha Municipality should confirm its role and maintain and develop the disaster prevention activities.

#### (2) Expanding to other communities

Through the repeated community workshops in the Study, an interchange between communities in the study area and disaster prevention related organizations proceeded a lot. Also the communities who participated in the monitoring and disaster prevention activities, especially the community leaders became interested in the Soacha river itself and hydrological data, as well as gained some confidence to hold a workshop by themselves. Soacha Municipality should expand the community disaster prevention activities to cooperate with the community leaders involved in the pilot project.

## 7.7 Recommendations for Soacha (Temporary Works)

The Study Team sincerely expresses fully respects for the Soacha Municipality's efforts on the relocation from landslide emergency zone.

Even after the temporary works are completed, the Study Team does not guarantee the safety of the remaining critical zone in El Divino Niño area. Therefore the Study Team recommended that relocation program should be continued by the Soacha Municipality.

The temporary works is implemented in the Emergency Zone after relocation program by the Municipality. In this situation, following recommendations are given.

### (1) Manual for the Relocation Program

Until now the Municipality does not have any experiences of the relocation from the hazardous area, and the relocation in El Divino Niño area is defined as the first experience for the Municipality. The processes and methods for the municipal relocation program; for example 1) understanding of the risk in the hazardous area to the community through the seminars, 2) examination of the legal process and 3) solutions for the new settlement area, etc., are legally implemented. The results of the relocation works which the Municipality has examined and decided are very useful for other dangerous areas of the Municipality. In order to apply easily to other relocation program, the relocation manual which includes the experience and results of the relocation activities until now is required.

### (2) Countermeasures including Temporary Works

In the period of this Study, several countermeasures have been executed by the Municipality according to the disasters. The countermeasures for the disasters require a suitable and adequate execution in short time. In order to correspond promptly to the disasters, it is recommended that the unified management system which organizes executed measures by the Municipality until now is prepared.

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**PART 3 MONITORING AND EARLY WARNING PLANNING IN SOACHA**

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## List of Abbreviations

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| ASE | Exclusive Service Areas (Áreas de Servicio Exclusivo) |
| AFRODES | Association of Displaced Afro-Colombians(Asociacion de Afrocolombianos Desplazados) |
| CAM | Municipal Committee of mutual Attendance for Prevention and Attention of Disasters (Comité Municipal de Atención Mutua para Prevención y Atención de Desastres) |
| CAR | Regional Autonomous Corporation (Corporación Autónoma Regional) |
| CBDM | Community Based Disaster Management (Manejo de Desastres Basado en la Comunidad) |
| CCTV | Closed-circuit Television( Cicuito Cerrado de Televisión) |
| CHF | Canadian Hunger Foundation (Fundación Canadiense para el Hambre) |
| CLE | Emergency Local Committee (Comité Local de Emergencia) |
| CLOPAD | Local Committee for the Prevention and Attention of Disasters (Comité Local para la Prevención y Atención de Desastres) |
| CODENSA | |
| CODHES | Advisory for Human Rights and Displacement (Consultoría para los derechos humanos y el desplazamiento) |
| CREPAD | Regional Committee for the Prevention and Attention of Disasters (Comité Regional para la Prevención y Atención de Desastres) |
| DABS | Administrative Department of Social Welfare (Departamento Administrativo de Bienestar Social) |
| DANE | National Administrative Department of Statistics (Departamento Administrativo Nacional de Estadísticas) |
| DAPD | Administrative Department for District Planning (Departamento Administrativo de Planeación Distrital) |
| DCP | Data Collection Platform(Plataforma Colectora de Datos) |
| DNPAD | National Office for the Attention of Disasters (Dirección Nacional para la Atención de Desastres) |
| DPAE | Direction for the Prevention and Attention of Emergency (Dirección para la Prevención y Atención de Emergencias) |
| DTM | Digital Terrain Model (Modelo Digital del Terreno) |
| EAAB-ESP | Company of Water Supply and Sewage Service of Bogotá (Empresa de Acueducto y Alcantarillado de Bogotá) |
| EDAN | Ecumenical Disability Advocates Network( Red de Defensores de la Discapacidad Ecuménica) |
| EFP(PEF) | Emergency Family Plan (Plan de Emergencia Familiar) |
| ETB | Company of Telecommunications of Bogotá (Empresa de Telecomunicaciones de Bogotá) |

| | |
|---|---|
| FOPAE | Fund for Prevention and Attention of Emergencies (Fondo para la Prevención y Atención de Emergencias) |
| FTP | File Transfer Protocol (Protocolo de Transferencia de Archivos) |
| GDP/PIB | Gross Domestic Product (Producto Interno Bruto) |
| GDS | Grid Development System (Sistema de Desarrollo de Grilla) |
| GIS/SIG | Geographic Information System (Sistema de Información Geográfica) |
| GMS | Geostational Meteorological Satellite(Satélite Meteorológico Geo- estacional) |
| GNP | National Gross Product (Producto Nacional Bruto) |
| GOC | Government of Colombia (Gobierno de Colombia) |
| GOES | Geostatinaly Operatinal Environment Satellite (Satélite Geoestacionario de Operación Ambiental) |
| GOJ | Government of Japan (Gobierno de Japón) |
| GPS | Global Positioning System (Sistema de Posicionamiento Global) |
| GSM | Global Scale Model (Modelo a Escala Global) |
| GST | Greenwich Standard Time (Hora Estándar Greenwich) |
| HECRAS | Hydrologic Engineering Center River Analysis System(Centro de Ingeniería Hidrológica Sistema de Análisis de Ríos) |
| ICA | Colombian Institute of Agriculture (Instituto Colombiano Agropecuario) |
| ICBF | Colombian Institute for Family Welfare (Instituto Colombiano de Bienestar Familiar) |
| ICS/SCI | Incident Command System(Sistema Comando de Incidentes) |
| ICT | Institute of Territorial Credit (Instituto de Crédito Territorial) |
| IDB | Inter-american Development Bank (Banco Inter-americano de Desarrollo) |
| IDEAM | Institute of Hydrology, Meteorology and Environmental Studies (Instituto de Hidrológica, Meteorología y Estudios Ambientales) |
| IDF | Intensity Duration Frequency (Frecuencia Duración de la Intensidad) |
| IDU | Institute of Urban Development (Instituto de Desarrollo Urbano) |
| IGAC | Geography Institute ¨Agustin Codazzi¨ (Instituto Geográfico Agustín Codazzi) |
| INGEOMINAS | Institute of Investigation and Geo-scientific, Mining-Environmental and Nuclear Information (Instituto de Investigación e Información Geocientífica, Minero Ambiental y Nuclear) |
| INM | National Institute of Meteorology (Instituto Nacional de Meteorología) |
| IOM/OIM | International Organization for Migration(Organisation Internationale pour les Migrations) |
| ITCZ | Inter-tropical Confluence Zone (Zona de Convergencia Intertropical) |
| JAC | Assembly of Community Actions (Junta de Acción Comunal) |
| JAL | Local Administrative Assembly (Junta Administradora Local) |
| JICA | Japan International Cooperation Agency (Agencia de Cooperación Internacional del Japón) |
| JMA | Japan Meteorological Agency(Agencia Meteorológica del Japón) |
| MAT | Multi-annual Average (Promedio Multi -Anual) |
| MAT | Multi-annual Average Temperatura (Temperatura Promedio Multi-anual) |
| MATPEL | Dangerous Material (Materiales Peligrosos) |
| MAVDT | Ministry of Environment, House and Land Development (Ministerio de Ambiente, Vivienda y Desarrollo Territorial) |
| MEWS | Monitoring and Early Warning System (Sistema de Monitoreo y Alerta Temprana |

| | |
|---|---|
| MHz | megahertz |
| MM5 | Mesoscale Model 5 (Modelo a Meso Escala 5) |
| MSM | Meso Scale Model (Modelo a Meso Escala) |
| NASA | National Aeronautics and Space Administration(Administración del Espacio y Aeronáutica Nacional) |
| NGOs | Non-Governmental Organization(Organización No-Gobernamental) |
| NOAA | National Oceanic and Atmospheric Administration (Administración Atmósferica y Oceanica Nacional) |
| NWP | Numerical Weather Prediction(Predicción Numérica del Clima) |
| OCHA | United Nations Office for the Coordination of Humanitarian Affairs(Oficina para la Coordinación de Asuntos Humanitarios) |
| OFDA | Foreign Disaster Attendance (Oficina de Relaciones Exteriores de los EE.UU. de Asistencia para Desastres) |
| ONG | Non Government Organization (Organización No Gobernamental) |
| OPAD | Office for the Prevention and Attention of Emergency and Disasters of Cundinamarca (Oficina para la Prevención de Desastres y Emergencias de Cundinamarca) |
| P.M.U. | Unified Control Post (Puesto de Control Unificado) |
| PAHO/OPS | Pan-American Health Organization/Worldwide Health Organization(Organización Panamericana de la Salud/Organización Mundial de la Salud) |
| POT | Territorial Ordering Plan (Plan de Ordenamiento Territorial) |
| PRIMAT | First Response to Incidents with Dangerous Materials (Primera Respuesta en Incidentes con Materiales Peligrosos) |
| RTU | Remote Terminal Unit(Unidad Terminal Remota) |
| SDA | District Secretary of Environment(Secretaria Distrital Ambiental) |
| SEGOBDIS | District Secretariat of Government(Secretaria de Gobierno Distrital) |
| SIRE | Information System for Risk Management and Attention of Emergency (Sistema de Información para el Manejo y Atención de Emergencias) |
| SISBEN | Selection System of Beneficiaries for Social Programs (Sistema de Selección de Beneficiarios para Programas Sociales) |
| SMLM | Monthly minimum legal salary (Salario Minimo Legal Mensual) |
| SRTM | Shuttle Radar Topography Mission(Misión Topográfica Radar Shuttle) |
| SYNOP | Surface synoptic observations (Observaciones Sinópticas de la Superficie) |
| UBN | Unsatisfied Basic Necessities (Necesidades Básicas Insatisfechas) |
| UESP | Executive Unit of Public Services (Unidad Ejecutiva de Servicios Públicos) |
| UHF | Ultra High Frequency (Frecuencia Ultra Alta) |
| UN | United Nations (Naciones Unidas) |
| UNDP/PNUD | United Nations Development Programme(Programa de las Naciones Unidas para el Desarrollo) |
| UNHCR/ACNUR | United Nations High Commissioner for Refugees (Alto Comisionado de las Naciones Unidas para los Refugiados) |
| UNICEF | United Nations Children´s Fund (Fondo de las Naciones Unidas para la Infancia) |
| UNIFEM | United Nations Development Fund for Women(Fondo de Desarrollo de las Naciones Unidas para la Mujer) |
| UNV/VNU | United Nations Volunteers (Voluntarios de las Naciones Unidas) |
| UPS(SAI) | Uninterruptible Power Supply(Sistema de Alimentación Ininterrumpida) |
| UPZ | Unit of Zone Planning (Unidad de Planeamiento Zonal) |

| | |
|---|---|
| URL | Uniform Resource Locator (Localizador Uniforme de Recurso) |
| USA/EUA | United States of America (Estados Unidos de América) |
| USD | United States Dollar (Dolár de Estados Unidos) |
| USGS | United States Geological Survey (Levantamiento Geológico de Estados Unidos) |
| WMO | World Meteorological Organization(Organización Meteorológica Mundial) |
| ZMPA | Environmental Management and Reservation Zone (Zonas de Manejo y Preservación Ambiental) |

**PART1 GENERAL**

# CHAPTER 1 INTRODUCTION

## 1.1 Background and Objectives of the Study

Bogotá City and its surrounding area are called Bogotá Metropolitan Area of the Republic of Colombia. They cover the vast area of 1,949 $km^2$ with a population of 6.99 million in 2000. The area for this Study is located in the southern part of the Metropolitan area. The total area for the Study is about 84 $km^2$, which is 4% of the Metropolitan area.

The Study area includes a lot of landslide-prone areas in terms of topography and geology where the low-lying areas have suffered from flooding of the Tunjuelo River. In addition to such natural conditions, the population of Bogotá city and Soacha Municipality increased very rapidly in the 90's due to migration into those cities by national refugees. Because of a rapid increase of the population, slopes of landslide areas and flood-prone areas in the Tunjuelo river basin, which are supposed to be protected, were developed extensively, resulting in high vulnerability in terms of natural disasters such as landslide and floods. In responding to this situation, the organizations related to disaster prevention in Bogotá and its surrounding area have implemented disaster prevention measures such as monitoring in major landslide areas, flood control projects for the Tunjuelo river, and a flood monitoring system. However, the implementation of structural measures for the entire area including tributaries will require a long time. For a priority in saving lives, monitoring and early warning system has been given priority.

Under these circumstances, the Government of Colombia requested the Government of Japan to implement a study on monitoring and early warning system for landslides and floods.

This Study made use of existing and valuable outputs made by the Colombian side, and also formulate a plan on monitoring and early warning system for landslide and flood for the areas in which disaster prevention measures have not yet been completed. Further, pilot project(s) for the selected areas shall be implemented in the course of the Study for a better preparation against disaster by governmental authorities as well as the communities.

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

- To prepare a Plan for monitoring and early warning system for the Study area in Tunjuelo middle river basin and the Soacha river basin, for landslides and floods.
- To establish, operate and maintain the monitoring and early warning system for the selected areas as pilot projects relying on the initiative of community people as much as possible.
- To transfer the technologies and knowledge to the Colombian personnel involved in the Study.

## 1.2 Study Area

The study area covers part of the Capital District of Bogotá and Soacha Municipality as shown in Figure 1-1. With regard to flood disaster and landslide disaster, the Study covers the six (6) creek/river basins and three (3) specific areas as shown in Figure 1-1. The term "flood disaster" covers "disaster caused by flood, and flash flood containing sediment such as debris flow". The term "landslide disaster" covers "disaster caused by mass movement such as slow landslide, steep slope failure and rock fall".

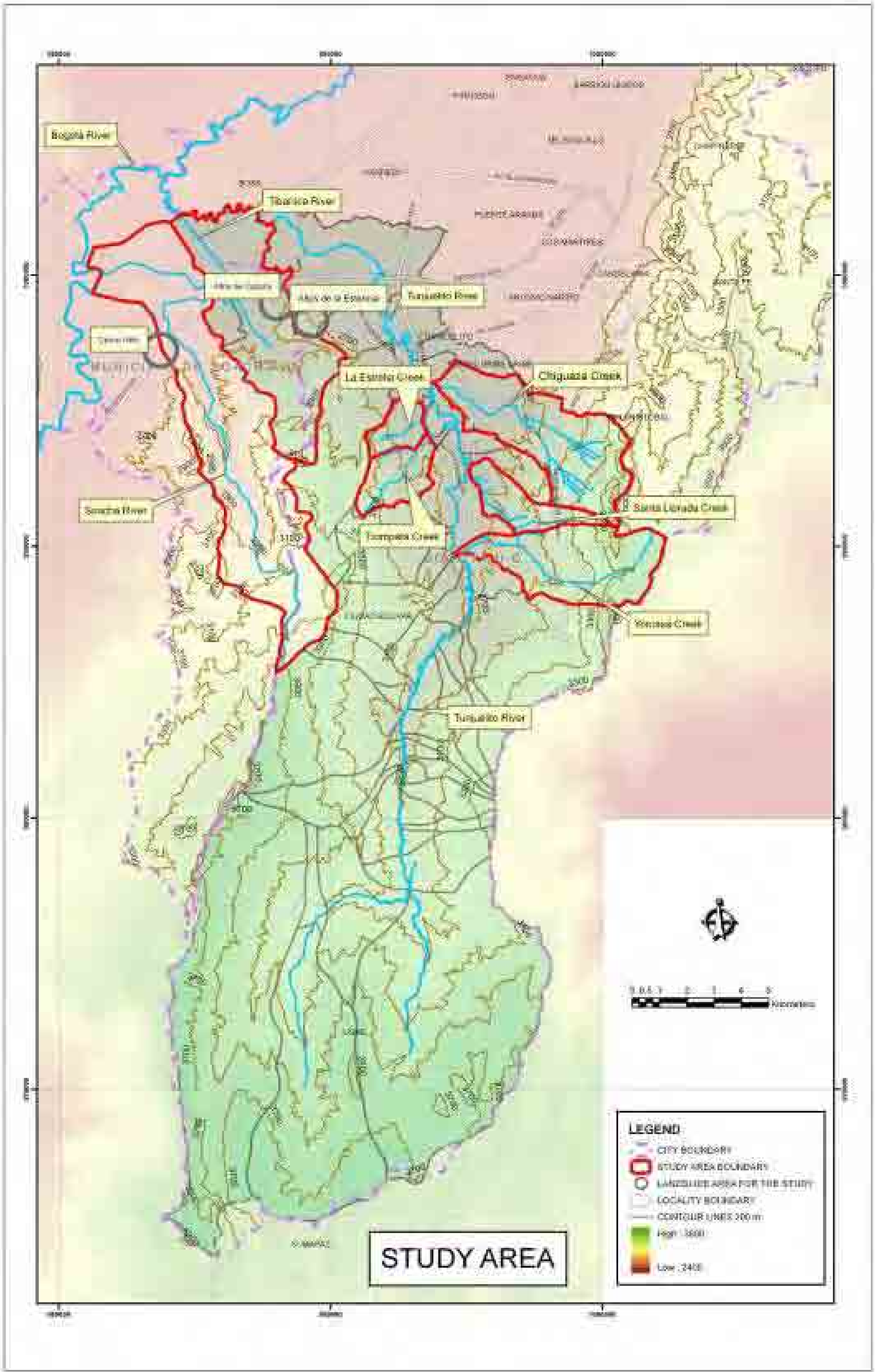



Figure 1-1 Study Area

Table 1-1 Basic Features of Study Area

| City | Monitoring and early Warning System for Floods | | | Monitoring and Early Warning System for Landslides |
|---|---|---|---|---|
| | Creek/River | Catchment Area ($km^2$) | Principal River Length (km) | |
| Bogotá City | Chiguaza Creek | 18.9 | 7.0 | Altos de La Estancia (100 ha) |
| | Santa Librada Creek | 5.5 | 5.0 | |
| | Yomasa Creek | 15.4 | 5.0 | |
| | La Estrella-El Infierno Creek (Trompeta creek) | 8.3 | 1.5 | |
| Soacha Municipality | Soacha River | 44.3 | 13.0 | Altos de Casuca and El Divino Niño area (total 230 ha) |
| | Tibanica River | 19.2 | 6.0 | |
| Total No. | 6 creeks/rivers | | | 3 areas |

## 1.3 Study Schedule

The Study was undertaken in three (3) Phases: Basic Study (Phase I), Formulation of the Plan for Monitoring and Early Warning System (Phase II), and Implementation of Pilot Project(s) (Phase III), for a period of 22 months starting from June 2006 and ending in March 2008.

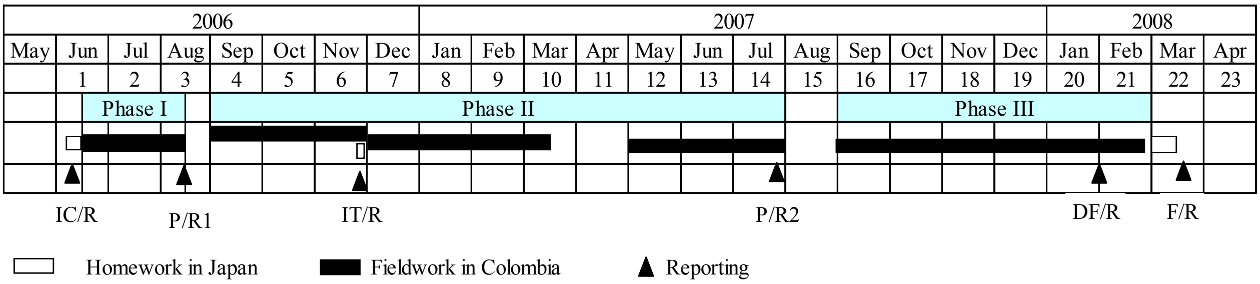



Figure 1-2 Study Schedule

## 1.4 Study Organization

The Study was undertaken in close cooperation between DPAE, Soacha Municipality and the Study Team with the support of the Cundinamarca Government (OPAD) and JICA Colombia.

JICA Headquarter dispatched the Monitoring Team related to the Study in November 2006 and November 2007. The members of the Monitoring Team had a discussion with the DPAE and Soacha Municipality as well as the Study Team and gave technical advises to JICA.

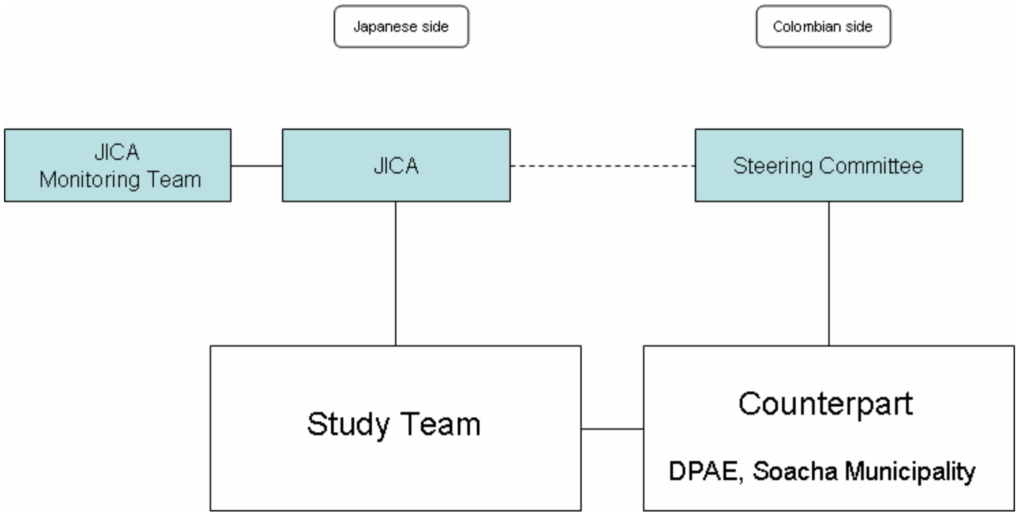



Figure 1-3 Organization for the Study

## 1.5 Composition of the Report

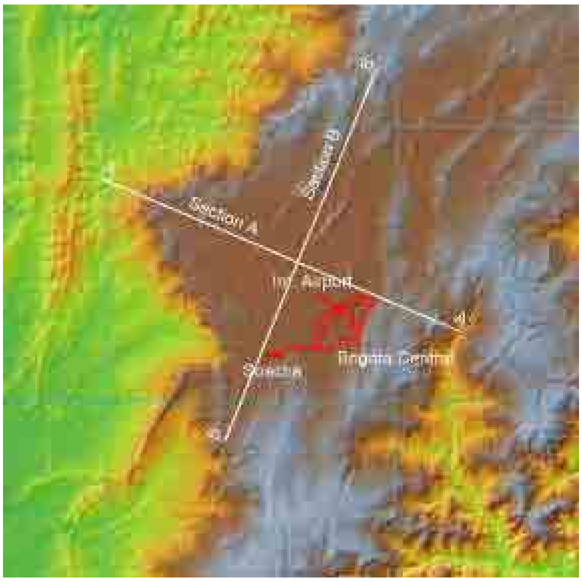
This report presents all results of the technical studies achieved during the study period. The report consists of the following;

Summary Report, Main Report, Supporting Report and Data Book.

# CHAPTER 2 NATURAL CONDITIONS

## 2.1 Topography and Geology

Bogota is located on a flat plateau that is designated by Bogota Plateau or Sabana de Bogota, found approx. at 2,560 m above the sea level, and the height of eastern mountainous area reaches 3,000 m or more, and beside the west side slope of the Cordillera Oriental. Bogota Plateau (Sabana de Bogota) is extending about 40 km from northwest to southeast and 60 km from northeast to southwest as shown in Figure 2-1. The city is located in the area limited by the surrounding hills in the east and by Bogota River in the west.





Section A


Section B

Figure 2-1 Topographical Cross Sections correspond to the lines in the Figure (base data : NASA SRTM-3)

The geology in the area and its environment is composed of sandstone, siltstone and clay stone of Cretaceous to Tertiary in mountainous area. Quaternary sediment of lake origin spreads in Bogota Plateau, while the mountains area in the east and south of Bogota Plateau is mostly composed of Cretaceous or Tertiary origin sediment rock. They are made mostly of sandstone or siltstone. Thickness of the Quaternary sediment in Bogota Plateau is over 500 m as shown in Figure 2-2.

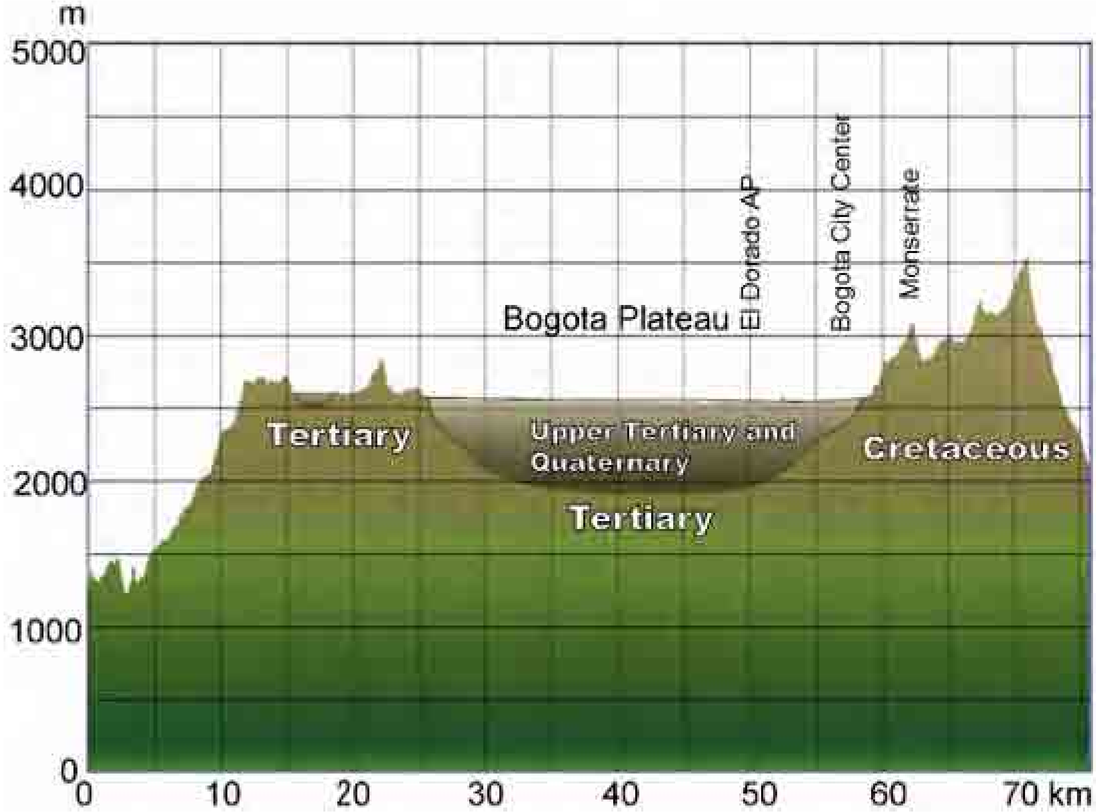



Figure 2-2 Sediment in Sabana de Bogota (Bogota Plateau, Section A)

(Prepared based on IGAC, 1995)

## 2.2 Meteorology and Hydrology

### 2.2.1 Meteorological/Hydrological Stations in and around the Study Area

Quite a few meteorological and hydrological stations are found nowadays, or existed in and around the Study Area, which are/were monitored and operated by DPAE, EAAB, CAR, IDEAM and other organizations. Some of the stations are telemeter stations, but most of the stations are conventional. Figure 2-3 shows the location map of meteorological and hydrological stations managed by DPAE, EAAB, CAR and IDEAM in and around the Study Area, and Table 2-1 shows the list and conditions of the stations.

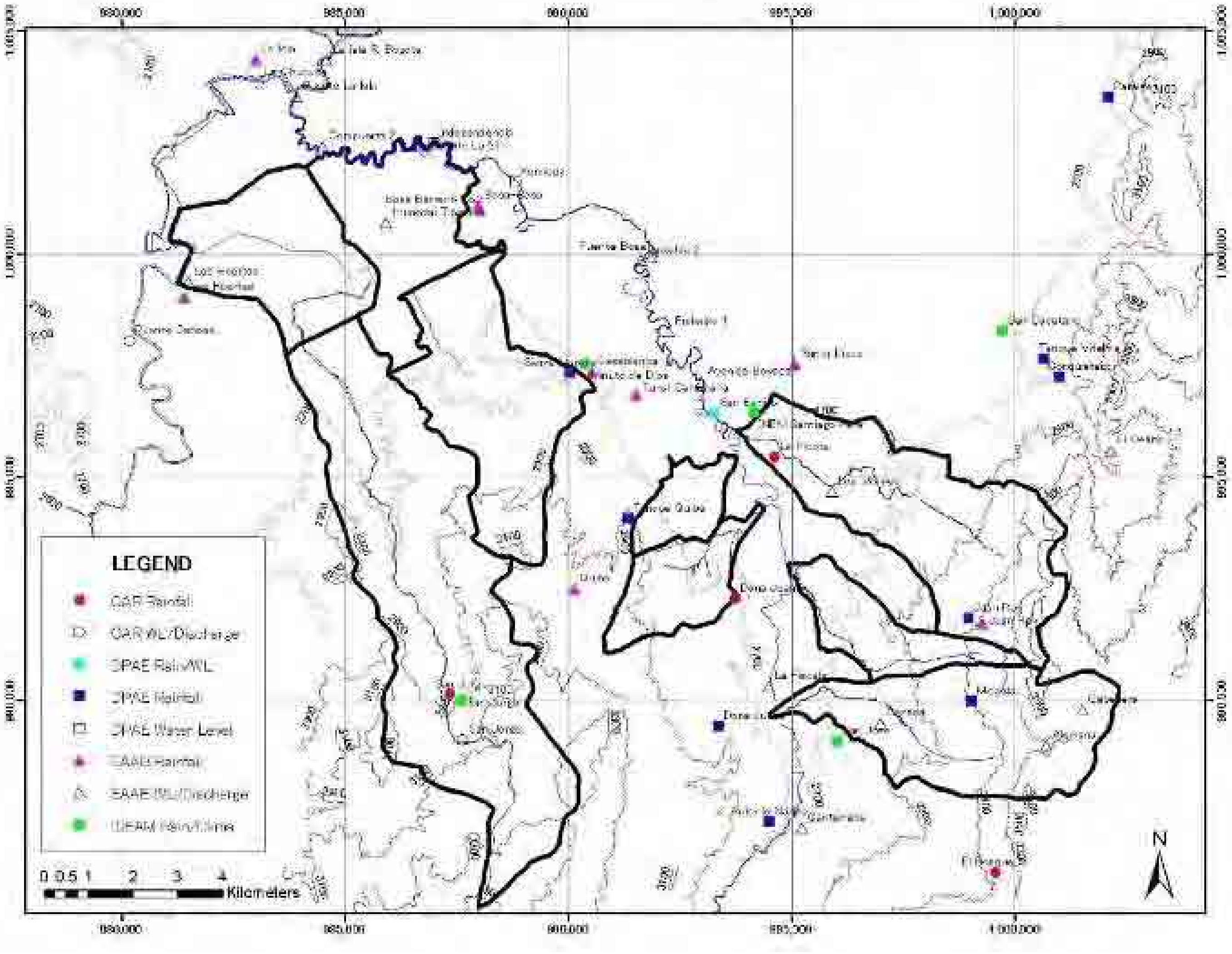



Figure 2-3 Location Map of Meteorological/Hydrological Stations in and around the Study Area

Table 2-1 List of Meteorological/Hydrological Stations in and around the Study Area

| ENTITY | CODE 1 | CODE 2 | TIPO | NAME | SUBCUENCA | DEPTO. | MUNICIPI | COORD | Elevation | INST DATE | SUSP DATE | Status in Oct. 2006 | Telemeter | TYPE | Present Situation/Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DPAE | | | PG,LG | San Benito | Tunjuelito | BOGO | BOGOTA | 043351N740817W | 2590 | 200010 | | | Telemeter (Radio) | DPAE Rain/WL | |
| DPAE | | | PG | Sierra Morena | Tunjuelo | BOGO | BOGOTA | 043430N741014W | 3078 | 200010 | | | Telemeter (Radio) | DPAE Rainfall | |
| DPAE | | | PG | Tanque Quiba (Quiba-Mirador) | Tunjuelo | BOGO | BOGOTA | 043235N740921W | 3078 | 200010 | | | Telemeter (Radio) | DPAE Rainfall | |
| DPAE | | | PG | Conquistador (Escuela de Logistica) | San Cristobal | BOGO | BOGOTA | 043428N740435W | 2780 | 200010 | | | Telemeter (Radio) | DPAE Rainfall | Out of study area |
| DPAE | | | PG | Juan Rey | Q. Chiguaza | BOGO | BOGOTA | 043108N740520W | 3160 | 200010 | | No Function | Telemeter (Radio) | DPAE Rainfall | |
| DPAE | | | PG | Tanque Vitelma | San Cristobal | BOGO | BOGOTA | 043431N740418W | 3078 | 200010 | | | Telemeter (Radio) | DPAE Rainfall | Out of study area |
| DPAE | | | PG | Micaela (Santa Maria Micaela) | Q. Yomasa | BOGO | BOGOTA | 043021N740511W | 2900 | 200010 | | | Telemeter (Radio) | DPAE Rainfall | |
| DPAE | | | PG | Dona Juana | Tunjuelo | BOGO | BOGOTA | 043002N740815W | 3078 | 200010 | | | Telemeter (Radio) | DPAE Rainfall | |
| DPAE | | | PG | Paraiso II | Rosales | BOGO | BOGOTA | 043742N740331W | 2820 | 200010 | | No Function | Telemeter (Radio) | DPAE Rainfall | Out of study area |
| DPAE | | | PG | U. Antonio Narino (Nariano USME) | | BOGO | BOGOTA | 042854N740331W | 2820 | 200010 | | | Telemeter (Radio) | DPAE Rainfall | Out of study area |
| DPAE | | | LG | Kennedy | Tunjuelo | BOGO | BOGOTA | 043650N741053W | 2577 | 200303 | | | Telemeter (Radio) | DPAE Water Level | |
| DPAE | | | LG | Independencia | Tunjuelo | BOGO | BOGOTA | 043719N741154W | 2576 | 200010 | | | Telemeter (Radio) | DPAE Water Level | |
| EAAB | P-042 | 2120057 | PG | Santa Lucia | Tunjuelo | BOGO | BOGOTA | 043410N740701W | 2618 | 195607 | | | | EAAB Rainfall | |
| EAAB | P-051 | 2120154 | PG | Bosa Barreno No.2 | Tunjuelo | BOGO | BOGOTA | 043646N741106W | 2578 | - | | | | EAAB Rainfall | |
| EAAB | PS-91 | 2120154 | PG | Bosa-Bosa | Bosa | BOGO | BOGOTA | 0436N7412W | 2640 | 195705 | 195812 | | | EAAB Rainfall | |
| EAAB | P-081 | 2120204 | PG | Juan Rey | Q. Chiguaza | BOGO | BOGOTA | 0431N7405W | 2985 | 199008 | | | | EAAB Rainfall | |
| EAAB | P-090 | 2120205 | PG | Quiba | Bogota | BOGO | BOGOTA | 0432N7410W | 3000 | 199001 | | | | EAAB Rainfall | |
| EAAB | P-092 | 2120211 | PG | Las Huertas | Bogota | CUND | SOACHA | 0435N7414W | 2572 | 196811 | | | Telemeter (GSM) | EAAB Rainfall | |
| EAAB | P-083 | 2120209 | PG | La Isla | Bogota | BOGO | BOGOTA | 0438N7413W | 2537 | 196510 | | | | EAAB Rainfall | |
| EAAB | P-045 | 2120059 | PM | Tunal Candelaria | Tunjuelo | BOGO | BOGOTA | 0434N7409W | 2599 | 195704 | | | | EAAB Rainfall | |
| EAAB | P-031 | 2120197 | PM | Casablanca | Tunjuelo | BOGO | BOGOTA | 0434N7410W | 2665 | 197605 | | | | EAAB Rainfall | |
| EAAB | L-192 | | L | Puente La Isla | Tunjuelo | BOGO | BOGOTA | - | - | - | | | | EAAB WL/Discharge | |
| EAAB | L-036 | 2120701 | LG | Puente Bosa | Tunjuelo | BOGO | BOGOTA | 0436N7412W | 2550 | 192607 | | | Telemeter (GSM) | EAAB WL/Discharge | |
| EAAB | L-005 | 2120806 | LG | Las Huertas | Bogota | CUND | SOACHA | 0435N7414W | 2572 | 196811 | | | Telemeter (GSM) | EAAB WL/Discharge | One of the main station in EAAB. |
| EAAB | L-004 | 2020802 | LG | La Isla R. Bogota | Bogota | BOGO | BOGOTA | 0438N7413W | 2537 | 196510 | | | Telemeter (GSM) | EAAB WL/Discharge | |
| EAAB | L-026 | 2120705 | LM | El Delirio | San Cristobal | BOGO | BOGOTA | 0433N7404W | 2890 | 192701 | | | | EAAB WL/Discharge | |
| EAAB | L-033 | 2120750 | LM | Cantarrana | Tunjuelo | BOGO | BOGOTA | 0430N7407W | 2643 | 195508 | | | | EAAB WL/Discharge | |
| EAAB | L-058 | 2120858 | LM | La Fiscala | Tunjuelo | BOGO | BOGOTA | 0430N7408W | 2460 | 198811 | | | | EAAB WL/Discharge | |
| EAAB | L-070 | 2120904 | LM | Embalse 1 | Tunjuelito | BOGO | BOGOTA | 0435N7409W | 2586 | 199009 | | | | EAAB WL/Discharge | |
| EAAB | L-071 | 2120905 | LM | Embalse 2 | Tunjuelito | BOGO | BOGOTA | 0435N7409W | 2583 | 199009 | | | | EAAB WL/Discharge | |
| EAAB | L-034 | 2120943 | LM | Humedal Tibanica (Compuesta 1) | Tunjuelo | BOGO | BOGOTA | 0437N7413W | 2600 | 198603 | | No Function | | EAAB WL/Discharge | |
| EAAB | L-035 | 2120944 | LM | Compuerta 2 | Tunjuelo | BOGO | BOGOTA | 0437N7437W | 2600 | 198701 | | No Function | | EAAB WL/Discharge | |
| EAAB | L-039 | 2120945 | LM | Alemana | Q. Yomasa | BOGO | BOGOTA | 0429N7404W | 3300 | 198501 | | No Function | | EAAB WL/Discharge | It was stolen march 2000. |
| EAAB | L-111 | 2120956 | LM | Los Molinos | Q. Chiguaza | BOGO | BOGOTA | 0433N7407W | 2800 | 199001 | | No Function | | EAAB WL/Discharge | |
| EAAB | L-038 | 2120957 | LM | Cabecera | Q. Yomasa | BOGO | BOGOTA | 0430N7404W | 3360 | 198507 | | No Function | | EAAB WL/Discharge | |
| EAAB | L-094 | | LM | Canada | Q. Yomasa | BOGO | BOGOTA | - | - | - | | | | EAAB WL/Discharge | |
| EAAB | L-060 | 2120836 | LM | Avenida Boyaca | Tunjuelito | BOGO | BOGOTA | 0434N7409W | 2630 | 198811 | | | | EAAB WL/Discharge | 1 year ago, some equipment was stolen, since then the station has been operated as "LM". |
| CAR | | 2120630 | CP | Dona Juana | Tunjuelito | BOGO | BOGOTA | 0430N7410W | 2700 | 198903 | | | | CAR Rainfall | |
| CAR | | 2120085 | PG | El Bosque | Tunjuelito | BOGO | BOGOTA | 042820N740458W | 2880 | 196212 | | | | CAR Rainfall | One of the main station in CAR. |
| CAR | | 2120156 | PG | La Picota | Q. Chiguaza | BOGO | BOGOTA | 0434N7408W | 2580 | 198006 | | | | CAR Rainfall | |
| CAR | | 2120172 | PG | San Jorge | Soacha | CUND | SOACHA | 0431N7412W | 2890 | 196004 | | | | CAR Rainfall | |
| CAR | | 2120755 | LM | San Jorge | Soacha | CUND | SOACHA | 0430N7411W | 2952 | 196004 | | | | CAR WL/Discharge | |
| CAR | | 2120771 | LM | Puente La Isla | Tunjuelo | BOGO | BOGOTA | 0437N7412W | 2569 | 196402 | 196712 | No Function | | CAR WL/Discharge | |
| CAR | | 2120772 | LM | La Chucuita | Bogota | BOGO | BOGOTA | 0438N7414W | 2538 | 196402 | 196612 | No Function | | CAR WL/Discharge | |
| CAR | | 2120829 | LM | Puente Canoas | Bogota | CUND | SOACHA | 0431N7415W | 2550 | 195809 | | | | CAR WL/Discharge | It was replaced by Las Huertas (EAAB). |
| IDEAM | | 2120664 | CO | San Jose | Tunjuelito | BOGO | BOGOTA | 0430N7407W | 2700 | 200111 | | | | IDEAM Rain/Clima | |
| IDEAM | | 2120665 | CO | San Cayetano | Tunjuelito | BOGO | BOGOTA | 0435N7405W | 3100 | 200111 | | | | IDEAM Rain/Clima | |
| IDEAM | | 2120666 | CO | INEM Santiago Pere | Tunjuelito | BOGO | BOGOTA | 0434N7408W | 2565 | 200111 | | | | IDEAM Rain/Clima | |
| IDEAM | | 2120572 | CO | San Jorge | Soacha | CUND | SOACHA | 0431N7412W | 2900 | 196004 | | | | IDEAM Rain/Clima | |
| IDEAM | | | CO | Minuto de Dios (Sierra Morena) | Tunjuelo | BOGO | BOGOTA | 043436N741003W | - | - | | | Telemeter (GOES) | IDEAM Rain/Clima | |

### 2.2.2 Characteristic of Rainfall in and around the Study Area

(1) Annual Rainfall

The Annual Rainfall Distribution in the area in 2003 is shown in Figure 2-4. The annual rainfall amount in the Study Area varies by the area from 470 mm to 1,040 mm in 2003. Its spatial distribution has a similar tendency for which the rainfall amount is high in the eastern hilly area in Bogota and southern mountain area in Soacha, and it is low in the lowland area such as along the Rio Tunjuelo and near the confluence of Tunjuelo river and Bogota river.

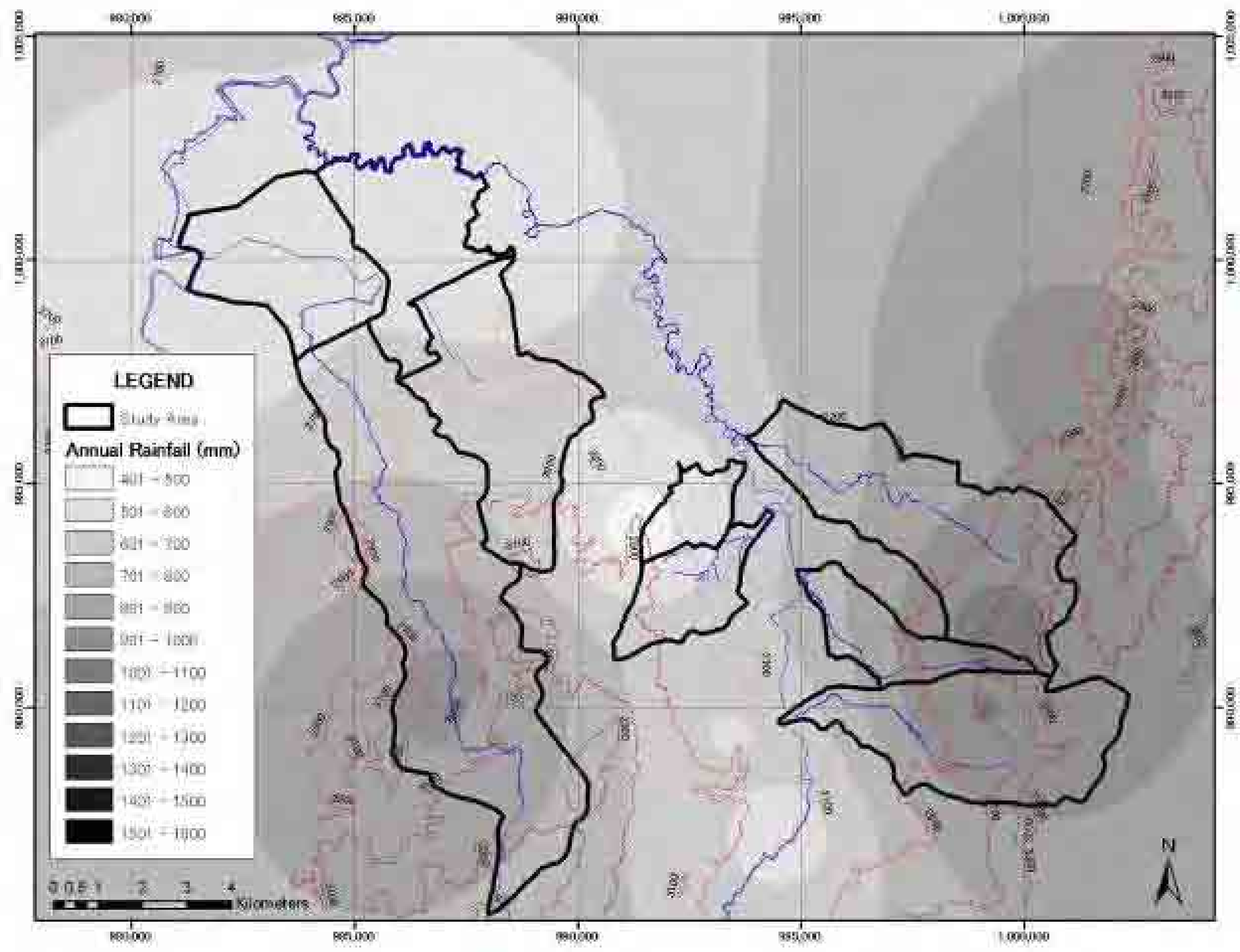



Figure 2-4 Annual Rainfall Distribution (2003)

(2) Monthly Rainfall

The monthly rainfall variation in 2003 in the Study Area is shown in Figure 2-5. There are two (2) rainy seasons from March to May and from September to November in the Study Area. As for the characteristic of the Study Area, the rainfall amount is comparatively high in the eastern hilly area in Bogota and southern mountain area in Soacha through the year, and especially the rainfall amount in July is also high in these areas apart from the two (2) rainy seasons as registered by the Micaela station located in eastern and southern hilly area in the Study Area. This trend is also observed in other years such as 2002, 2004 and 2005.

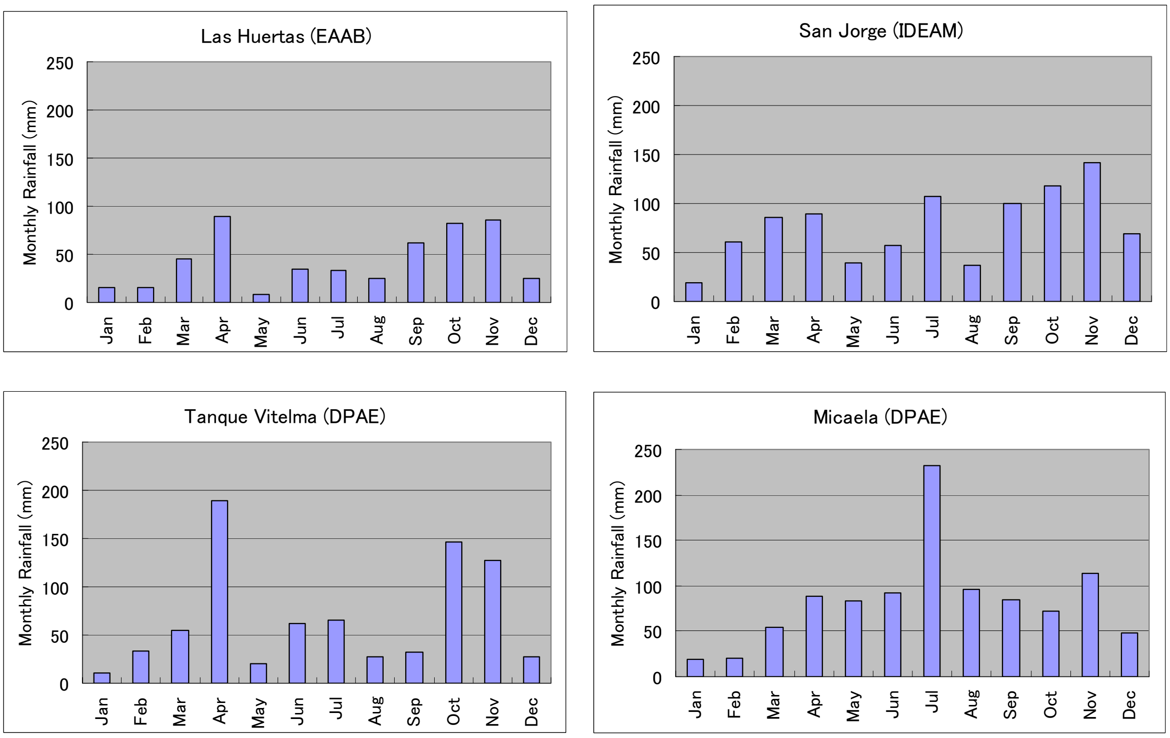



Figure 2-5 Monthly Rainfall Variation in 2003

(4) Daily Rainfall

Table 2-2 shows the probable daily rainfall amount with several return periods in 5 (five) stations. It was analyzed through the Gumbel method using collected data in this Study.

Table 2-2 Probable Daily Rainfall (unit: mm)

| Station | Return Period (year) | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 5 | 10 | 25 | 50 | 100 |
| Las Huertas (EAAB) | 29.2 | 32.0 | 35.6 | 40.1 | 43.5 | 46.8 |
| San Jorge (IDEAM) | 35.4 | 38.7 | 43.0 | 48.3 | 52.3 | 56.2 |
| Bosa Barreno No.2 (EAAB) | 33.6 | 37.2 | 41.8 | 47.7 | 52.0 | 56.3 |
| Juan Rey (EAAB) | 47.7 | 53.0 | 59.6 | 67.9 | 74.1 | 80.2 |
| La Picota (CAR) | 35.9 | 40.3 | 45.9 | 52.9 | 58.1 | 63.3 |

(5) Hourly Rainfall

Figure 2-6 shows the zoning of intensity – duration – frequency by EAAB, 1995, with Study Area. Almost all the Study Area is included in zone of Z4, Z5 and Z7. The rainfall pattern varies by the zone. The rainfall intensities in several return periods in each zone by EAAB, 1995 are shown in Table 2-3.

Figure 2-7 shows the relation between daily rainfall and hourly rainfall in DPAE stations in 2000-2006. The daily rainfall has a maximum value for each month from 2000 to 2006, and the hourly rainfall has also the maximum value for each month from 2000 to 2006. From the figure, we can see that the percentage of hourly rainfall amount to the daily rainfall amount is about 40-60%, which means the heavy rainfall finishes in short time. Figure 2-8 shows a rainfall distribution in 1 day for Micaela station. These 10 examples in each figure are top 10 of high daily rainfall amount from October 2000 to July 2006 in Micaela station. In the Micaela station, the rainfall distribution can include also two (2) patterns. One is a very moderate curve such as 2001/11/12 and 2002/6/22, and the other is comparatively steep curve such as 2003/9/27 and 2005/10/23.

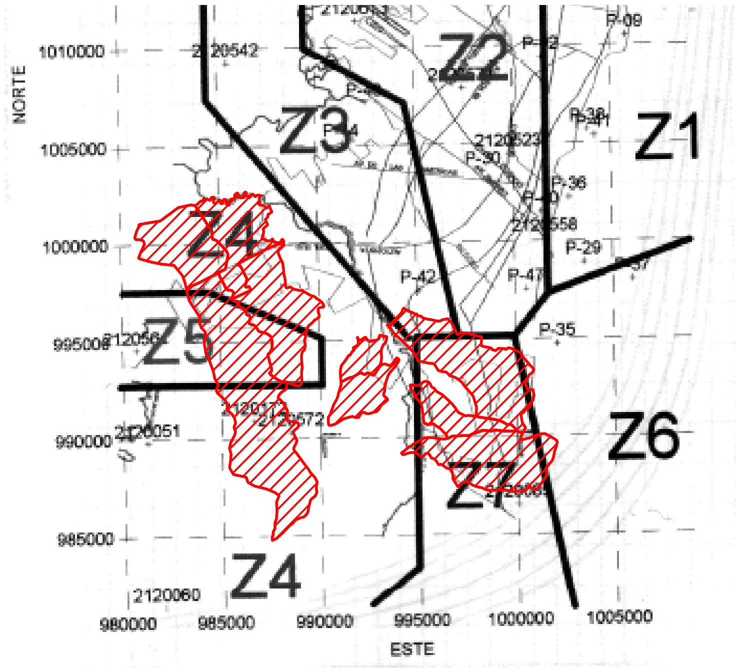



Figure 2-6 Zoning of Rainfall Pattern

*Source: "ESTUDIO PARA EL ANALYSIS Y CARACTERIZACION DE TORMENTAS EN LA SABANA DE BOGOTA", EAAB, November 1995*

Table 2-3 Rainfall Intensity in each Zone(unit:mm/h)

| Zone 4 (Z4) | | | | | | |
|---|---|---|---|---|---|---|
| Duration (min.) | 3 years | 5 years | 10 years | 25 years | 50 years | 100 years |
| 15 | 48.72 | 57.42 | 68.38 | 82.21 | 92.49 | 102.67 |
| 30 | 34.47 | 39.91 | 46.74 | 55.40 | 61.82 | 68.19 |
| 60 | 22.09 | 25.34 | 29.43 | 34.59 | 38.43 | 42.23 |
| 120 | 12.68 | 14.55 | 16.95 | 19.92 | 22.15 | 24.35 |
| 360 | 4.85 | 5.50 | 6.37 | 7.47 | 8.27 | 9.06 |
| Zone 5 (Z5) | | | | | | |
| Duration (min.) | 3 years | 5 years | 10 years | 25 years | 50 years | 100 years |
| 15 | 39.30 | 44.10 | 50.10 | 57.70 | 63.40 | 69.00 |
| 30 | 27.80 | 31.60 | 36.30 | 42.30 | 46.70 | 51.10 |
| 60 | 17.50 | 19.90 | 23.00 | 27.00 | 29.90 | 32.80 |
| 120 | 10.10 | 11.80 | 13.80 | 16.40 | 18.30 | 20.20 |
| 360 | 3.70 | 4.30 | 5.10 | 6.00 | 6.80 | 7.50 |
| Zone 7 (Z7) | | | | | | |
| Duration (min.) | 3 years | 5 years | 10 years | 25 years | 50 years | 100 years |
| 15 | 42.35 | 53.25 | 66.90 | 84.15 | 96.95 | 109.65 |
| 30 | 28.60 | 34.45 | 41.85 | 51.15 | 58.10 | 64.95 |
| 60 | 17.40 | 20.10 | 23.50 | 27.75 | 30.95 | 34.05 |
| 120 | 11.25 | 13.45 | 16.30 | 19.80 | 22.40 | 25.00 |
| 360 | 5.35 | 6.55 | 8.00 | 9.95 | 11.35 | 12.75 |

*Source: "ESTUDIO PARA EL ANALYSIS Y CARACTERIZACION DE TORMENTAS EN LA SABANA DE BOGOTA", EAAB, November 1995*

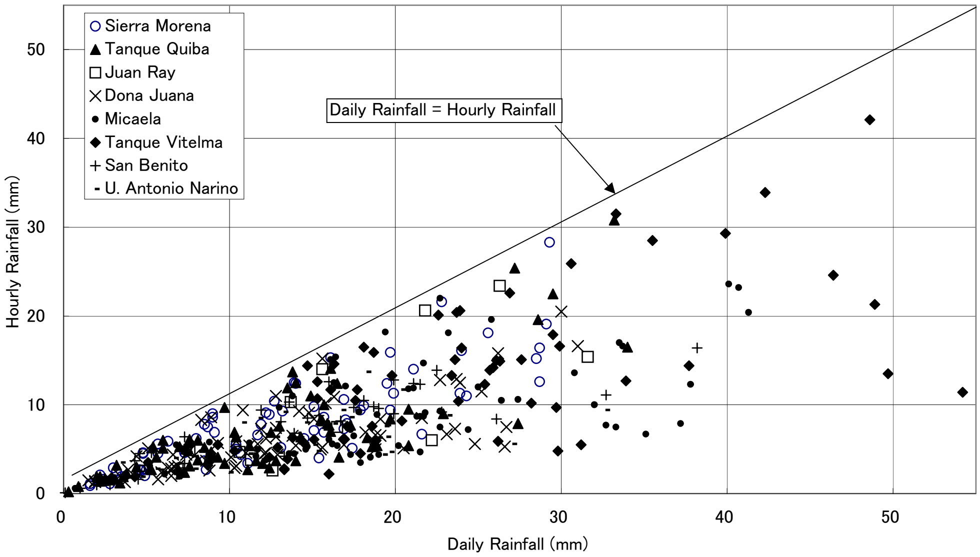



Figure 2-7 Relation between Daily Rainfall and Hourly Rainfall in the DPAE Stations in 2000-2006

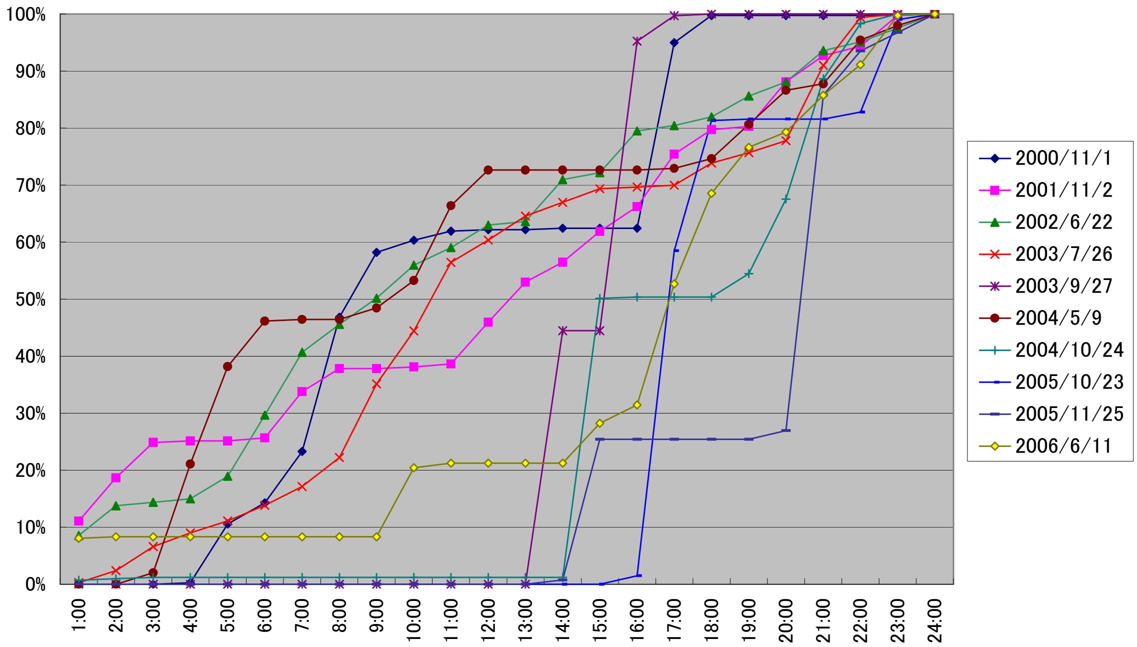



Figure 2-8 Rainfall Distribution in 1:00-24:00 in the Micaela Station

### 2.2.3 Correlation of Rainfall Stations

(1) Correlation of Rainfall Stations in and around the Study Area

In order to examine the correlation of stations and the rainfall pattern in and around the Study area, the correlation coefficient of each station is calculated using the monthly rainfall data from 2000 to 2006 and daily rainfall data in 2003. It can be said that if the correlation coefficient is high between two (2) stations, the rainfall pattern is similar in relevant area. Figure 2-9 shows the result of correlation calculation of daily rainfall in and around the Study Area. The values on the lines between stations designate the square value of correlation coefficient of each station.

The correlation of the stations, particularly of daily rainfall, is summarized as follows:

- The correlation is high in each stations located in lowland area such as along the Rio Tunjuelo and northern area of Soacha
- The correlation is comparatively high in the stations of Juan Rey, Micaela, Dona Juana (DPAE) and U. Antonio Narino, which are located in southeastern part of the Study Area
- The correlation is comparatively high in the stations of Tanque Vitelma, San Benito and La Picota, which are located northeastern part of the Study Area
- The correlation of comparatively low in east - west direction

(2) Correlation of DPAE Rainfall Stations

Figure 2-10 shows the result of correlation calculation of daily rainfall data in 2003 only in the DPAE rainfall stations. However, the data of Juan Rey station of EAAB are used for analysis instead of Juan Rey station of DPAE because the operating period of Juan Rey of DPAE is very short. The numerical characters in the figures designate the square value of correlation coefficient of each station.

The correlation of the DPAE rainfall stations, particularly of daily rainfall, is summarized as follows:

- The correlation is extremely high in the stations located along the Rio Tunjuelo in north - south direction
- The correlation is high or comparatively high in the stations located in western side of the Rio Tunjuelo
- The correlation of comparatively high in east - west direction except Sierra Morena - Tanque Quiba, Tanque Quiba - Juan Rey, and Tanque Quiba - Micaela station

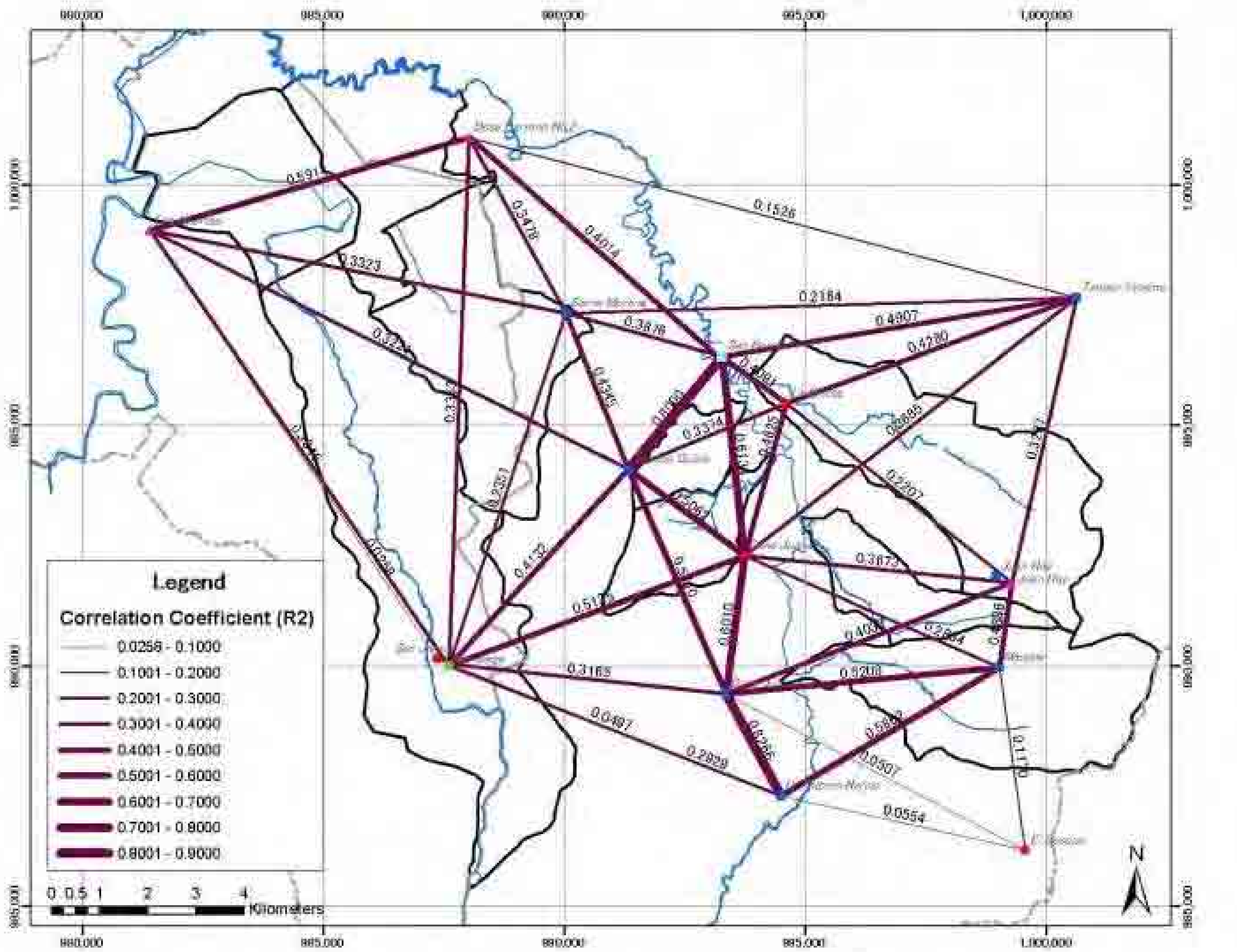



Figure 2-9 Correlation of Daily Rainfall (2003)

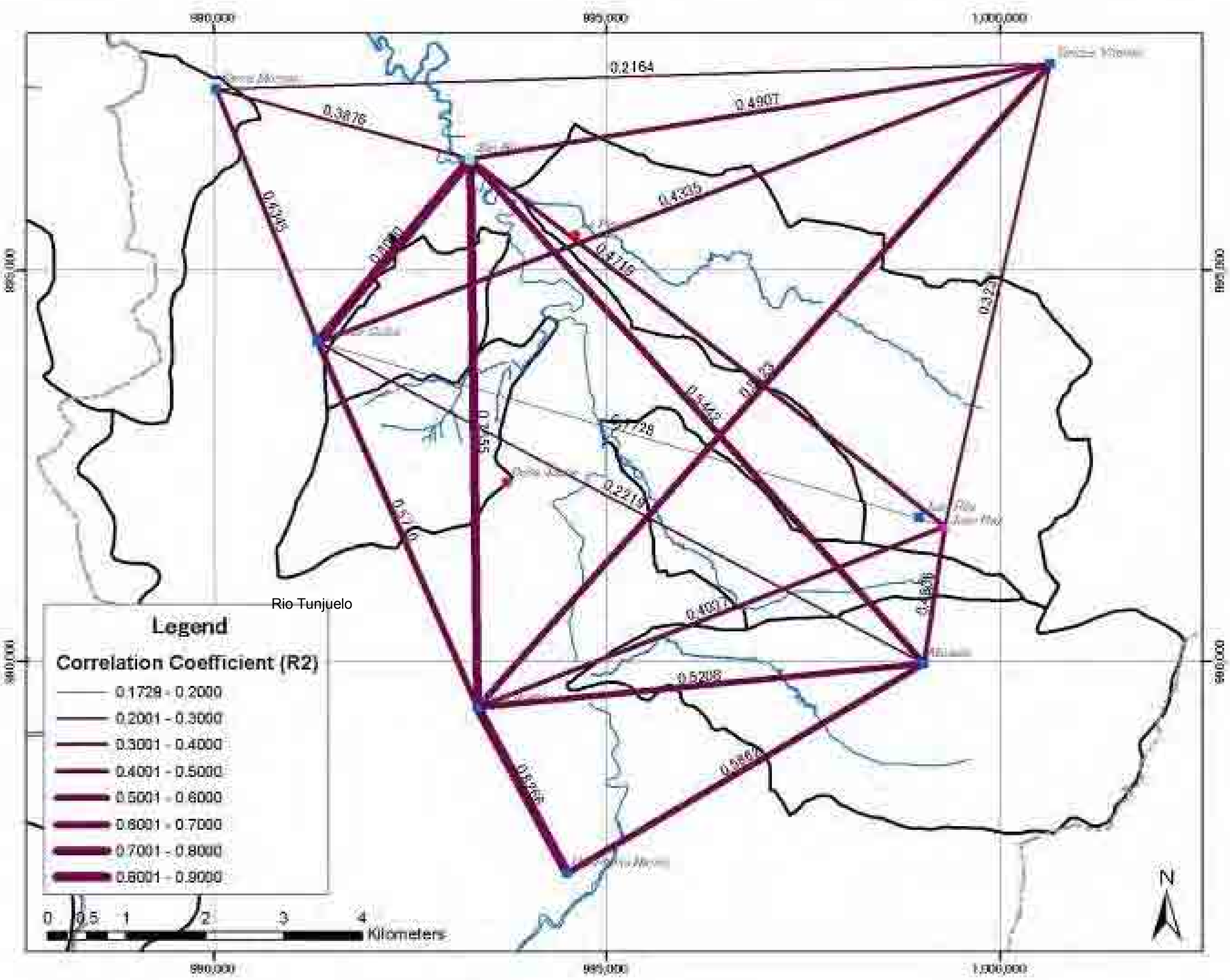



Figure 2-10 Correlation of Daily Rainfall in DPAE Stations (2003)

## PART 2 MONITORING AND EARLY WARNING SYSTEM IN BOGOTA

# CHAPTER 3 BOGOTÁ SOCIO-ECONOMIC CONDITIONS

## 3.1 Administrative System

Bogotá is the capital of the Republic of Colombia as well as the Cundinamarca Department, and also acting as the center of economy and cultural activity of the country. The city has a territorial extension of 177.598 Ha with a population of more than 7 million[1].

Bogotá is divided in four main administrative sectors[2], namely Central Sector (Sector Central), Decentralized Sector (Sector Descentralizado), Localities (Sector Localities) and Special Regimen (Régimen Especial).

According to the city's regulation, five (5) percent of the city's annual budget is allocated to the disaster management investment and activities. FOPAE (Fondo de Prevención y Atención de Emergencias; Fund for Prevention and Emergencies response) is the authorization body for implementing this budget and has been established as a public entity (Establecimiento Público) belonging to the Decentralized Sector.

DPAE (Dirección de Prevención y Atención de Emergencias) is responsible for planning and implementing the disaster management activities within the city area as the legal representative of FOPAE.

DPAE has five Sub-directions namely Sub-direction of Territorial Management (Gestión Territorial), Sectoral Management (Gestión Sectorial), Emergencies (Emergencias), Research and Development (Investigación y Desarrollo), and Institutional Support (Apoyo Institucional) and several units under the sub-directions to implement the activities with more than 100 staffs.

## 3.2 Socio-Economic Condition: Bogotá

### 3.2.1 Population and Urban Expansion

Bogotá is experiencing a continuous population increase from its first census in 1775 with about sixteen thousand to 6.8 million in 2005, and hosts 16.42% of the nation's population. With the continuous population growth, the urban area of the city is also expanding, while the city area had 900 hectares in 1900, today it has 30,000 hectares[3].

Under unstable conditions for their livelihood, the immigrants have settled in the fringe area of the city especially in the south-western part of the city and developed and expanded unplanned settlements with low quality buildings, lack of public infrastructure, transport integration and social services. Consequently, the expansion of unplanned urban areas took place with high population density towards the south.

### 3.2.2 General Economy

The economy in Bogotá is growing constantly with an Internal Gross Income (Producto Interno Bruto, PIB) for 2005 of USD 22,204 millions.

In 1999, Colombia suffered an economic crisis and the country is under unstable economic condition with high rates of unemployment. According to the survey undertaken by DANE in 2003, approximately 3 million residents in Bogotá were working with 14.67% of the unemployed rate, which is significantly high compared with the national figure of 12.3%.

1: Taken from DANE http://www.dane.gov.co/files/investigaciones/poblacion/inf_geo/Pob20062007.xls
2: Source (organigrama general del distrito. http://www.bogota.gov.co/portel/libreria/php/frame_detalle.php?h_id=468
3: Alvarez G. Ana Maria. Urban Practices in Bogotá. 40th ISOCARP Congress 2004. http://www

## 3.3 Socio-Economic Conditions: Study Area

### 3.3.1 Socio-economic conditions

This Study concerns six Localities of Rafael Uribe, San Cristobal, Usme, Ciudad Bolivar, Bosa and Tunjuelito. Their economic activities are related to commerce, restaurants, and hotels followed by the domestic services. Also, the manufactory industry that concentrates no qualified labor reports revenues of around four hundred eighty thousand pesos.

Due to low income, the families are unable to cover their basic needs. The lack of permanent and stable jobs increase the poverty rates forcing people to a poor consumption of food, clothing and recreation.

The Strata (Estrato) represents the index of urban residential area and is classified into six, from Strata 1 (lowest) to Strata 6 (highest). Approximately 30% of the households in the Study Area are classified as Strata 1 earning less than the minimum wage (approx. $175 USD monthly) and 70% have an average monthly income between $175 and $525 USD (Strata 2).

EAAB (Empresa de Acueducto y Alcantarillado de Bogotá) provides a relatively high percentage (more than 90%) of coverage of water and sewerage. The Study Area covers the waste management services by three private companies through concessions with the city government; however, some areas encounter problems in providing services due to physical limitations in site.

In addition, some Localities related to the Study such as Rafael Uribe, San Cristobal, Bosa, and Tunjuelito are suffering from an insufficient capacity as local towns to provide the community needs for education, public services and infrastructure due to the rapid growth of population.

### 3.3.2 Disaster Hazard

In the city of Bogotá, landslide hazard areas can be found in Ciudad Bolívar, San Cristobal, Rafael Uribe, Santa Fe, Usme, Chapinero, Usaquén y Suba. A total of 825 blocks are found in high hazard in these six Localities, as opposed to 2,720 blocks in low risk.

The Localities of Usme, Tunjuelito, Rafael Uribe, Bosa and Ciudad Bolívar have hazard areas of flood disasters. Nearly the area of 111 ha in the high flood hazard area.

## 3.4 Land Use and Urban Planning

In Year 2000, Bogotá has set the Metropolitan Territorial Plans namely POT (Plan de Ordenamiento Territorial) which conceptually integrates the best diverse and land uses in expanding cities.

According to the POT, the land in the city has been classified into Urban Land, Rural Land, Protection Land and Expansion Land as shown in the following table.

Table 3-1 Bogotá, Rural Urban, Protected and Expansion Lands (in hectares, 2002)

| Rural Land | | | Urban Land | | | Expansion Land | | | BOGOTA |
|---|---|---|---|---|---|---|---|---|---|
| Rural | Protected | Total | Urban | Protected | Total | Expansion | Protected | Total | Total |
| 48,029 | 73,445 | 121,474 | 34,219 | 4219 | 38,438 | 2,557.70 | 1106 | 3,664 | 163,575 |

*(Source:http://www.segobdis.gov.co/)*

A locality is further divided to smaller planning units of UPZ (Unidades de Planeación Zonal: Units of Zonal Planning), and the UPZ is composed of a number of Barrios.

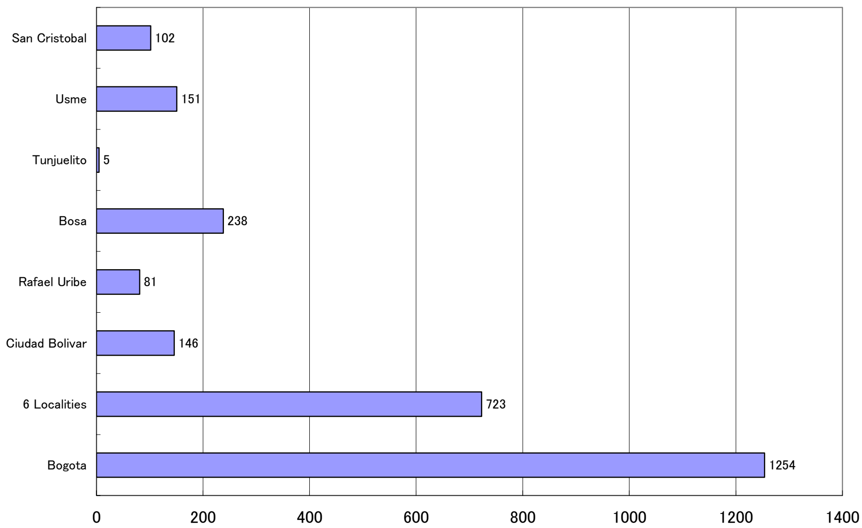



Figure 3-1 Number of Legalized Barrios in Six Localities[4]

Figure 3-1 shows the number and area of Legal Barrios in six Localities. A total area of 3,745 has represents 57.6 % of legalized barrios extension of Bogotá (6499 has.).

## 3.5 Citizen participation

More than 800 community organizations (JAC and community councils) have been established in the Localities related to the Study. Only in three localities of Usme, Rafael Uribe and Bosa have a total of 137 Community Centers. These community centers are usually constructed through collective work of the community, which suggests an important community activity.

During the Study period, rainfall and water level gauges are installed in Molinos II, Moralba Suroriental and San Jacinto to allow the community based flood monitoring, and JAC is the organization in charge of monitoring these gauges.

4: Departamento Administrativo de Planeación. Recorriendo Usme. Diagnóstico Físico y Socioeconómico de las localidades de Bogotá D.C. Alcaldía Mayor de Bogotá. D.C. 2004. Calculations for the year 2002

# CHAPTER 4 BOGOTA RAINFALL AND DISASTERS

## 4.1 General Characteristic of Disasters and Selection of Disaster Events for Analyses

### 4.1.1 Landslide

Figure 4-1 shows the frequency of landslide events in five (5) Localities including target basins in Bogota. Landslides frequently occur in latter month of first rainy season from March to May. The frequency shown in the figure includes all events categorized in "Fenómeno de Remoción en Masa (Landslide)" in disaster records of DPAE from January 2002 to July 2006, which concern various phenomena such as slope failure, rock fall, earth flow, etc., and it is presumed that their causes vary from rainfall to accidental impacts. Many landslide events may occur by accidental impacts regardless of rainfall. In order to confine the cause of landslides through natural condition from mainly rainfall as much as possible, the analysis is targeting at only the date when a number of landslides were recorded in the same basin on the same date since it is difficult to specify the causes of landslides from the database.

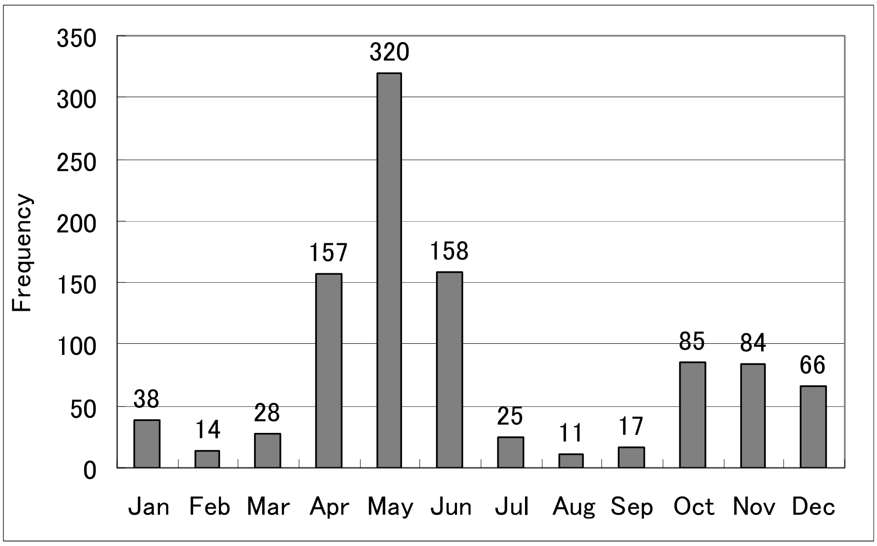



Figure 4-1 Frequency of Landslide Events (2002 Jan. - 2006 Jul.) in Tunjuelito, Rafael Uribe, San Cristobal, Ciudad Bolivar and USME Localities

### 4.1.2 Inundation

In the Study Area in Bogota, the inundation phenomena are categorized in following three (3) types: 1) High water and overflow of creeks, 2) overflow of drainage system, and 3) backwater through sewerage. In the Study area, the sewerage is connected directly to the creeks, therefore an inundation due to the backwater through the sewer pipes may occur even though the water level of the creek does not exceed the bank height. At the same time, an inundation occurs due to lack of drainage because the storm sewerage system is not laid down or does not have enough capacity in some barrios.

Figure 4-2 shows the frequency of inundation events in five (5) Localities including target basins in Bogota. Inundations frequently occur in two (2) rainy seasons especially in the second rainy season from October to December. The frequency shown in the figure includes all the events categorized in "Inundación (Inundation)" in disaster records of DPAE from August 2001 to June 2006, which concerns not only high water and overflow of the creek but also overflow of drainage system and backwater through the sewerage as described above. For the analysis of relation between rainfall and inundation, the abstracted inundation events in target basins are used, which may be caused by high water and overflow of the creeks out of the records.

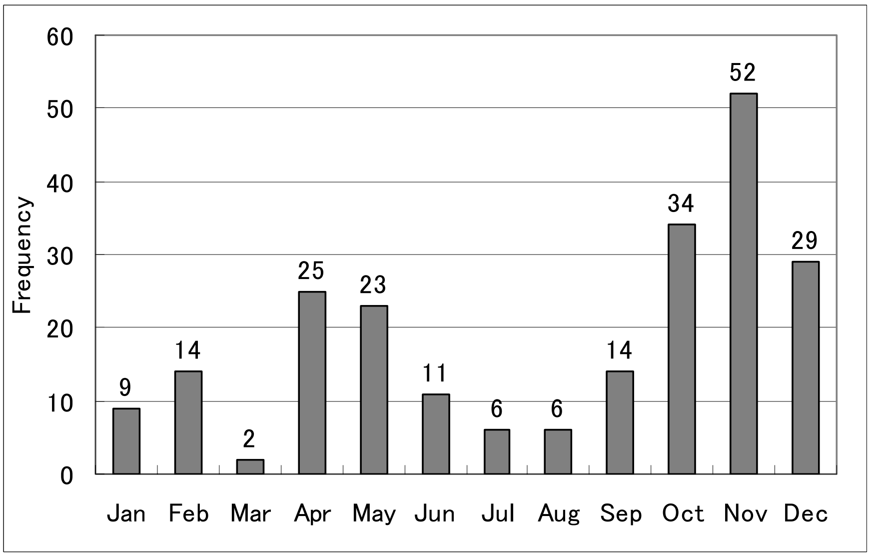



Figure 4-2 Frequency of Inundation Events (2001 Aug. - 2006 Jun.) in Tunjuelito, Rafael Uribe, San Cristobal, Ciudad Bolivar and USME Localities

## 4.2 Analysis for Relation between Rainfall and Selected Disaster Events

The relation between rainfall and disaster is analyzed using collected daily rainfall data, and selected disaster records.

### 4.2.1 Analyses for Landslide

Table 4-1 summarized the daily rainfall amount in the day when a number of landslides occurred in each basin on the same date.

Table 4-1 Daily Rainfall of the Day of Landslides Occurrence

| Basin/Station | No. of Days when multiple Landslides Occurred from 2002 to 2006 | Daily Rainfall (mm) | | | | |
|---|---|---|---|---|---|---|
| | | < 5 | < 10 | < 15 | < 20 | < 25 |
| Chiguaza Basin (Juan Rey (EAAB)) | 18<br>100% | 8<br>44% | 14<br>78% | 17<br>94% | 17<br>94% | 18<br>100% |
| Yomasa Basin (Micaela (DPAE)) | 2<br>100% | 0<br>0% | 0<br>0% | 1<br>50% | 2<br>100% | 2<br>100% |
| Santa Librada | 0 | - | - | - | - | - |
| La Estrella Basin (Tanque Quiba (DPAE)) | 8<br>100% | 5<br>63% | 6<br>75% | 6<br>75% | 8<br>100% | 8<br>100% |
| Trompeta Basin (Tanque Quiba (DPAE)) | 3<br>100% | 3<br>100% | 3<br>100% | 3<br>100% | 3<br>100% | 3<br>100% |
| Total | 31<br>100% | 16<br>52% | 23<br>74% | 27<br>87% | 30<br>97% | 31<br>100% |

More than 50% of landslides occurred at less than 5 mm of daily rainfall. It is difficult to understand the characteristics of rainfall in landslides occurrence using only daily rainfall of the day of the landslides occurrence. Figure 4-3 shows the various types of rainfall amount of Juan Rey (EAAB) station in landslides occurrence in Chiguaza basin and the average values in Juan Rey (EAAB) station for comparison. The upper values with box in each category are the rainfall amount in landslides occurrence. Accumulative rainfall is a total rainfall amount up until the calculated day (the day of landslides occurrence), which was calculated adding the entire daily rainfall amount after the day when the daily rainfall was zero (0) previously.

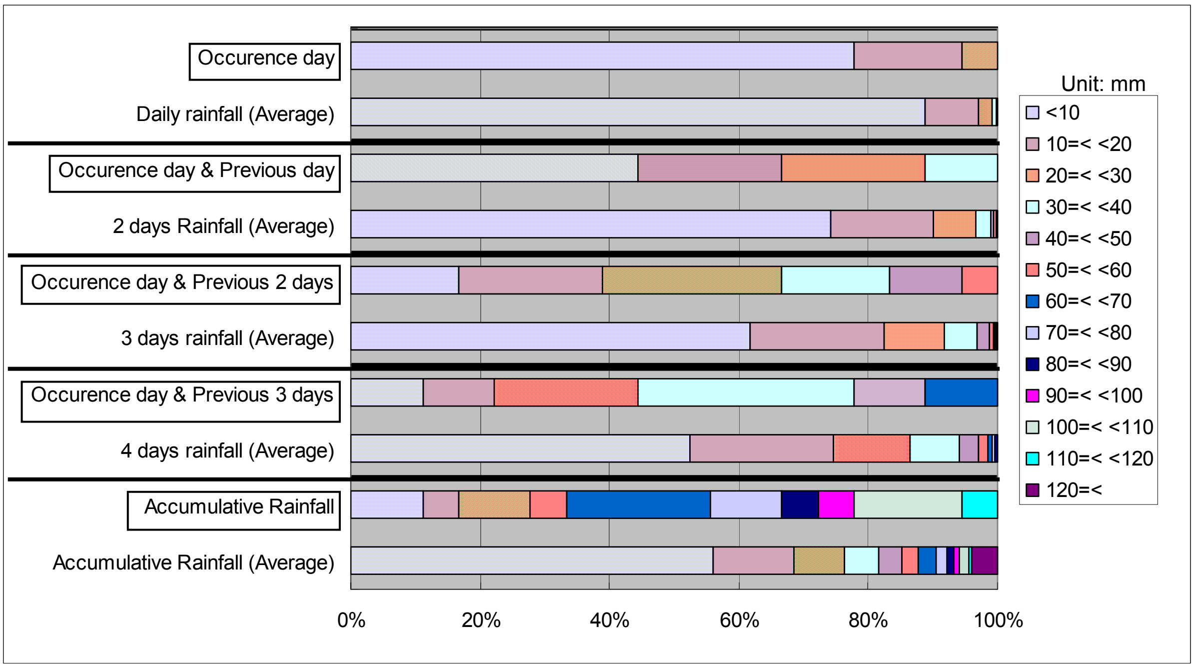



Figure 4-3 Various Rainfall Amount in Landslides Occurrence and Average Values in Juan Rey Station (EAAB)

From the above figure, the differences of the tendency can be clearly found in case of accumulative rainfall, and can be recognized in 3 days and 4 days rainfall. DPAE already sets and uses the 3 days rainfall for the criteria in the current monitoring system. Therefore, analyses are undertaken using accumulative rainfall and 3 days rainfall (rainfall of occurrence day and previous 2 days).

The relation between landslide events and three (3) days or accumulative rainfall is summarized in Table 4-2. In the table, the percentage of “Landslide” rows constitutes the rate of the number of days with the designated rainfall amount when landslides occurred, and the percentage of “Average” rows is the rate of the number of days with the designated rainfall amount in the period of 2001-2006.

Table 4-2 Summary of Relation between Rainfall and Landslide Events

| Basin | Rainfall | | Rainfall (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | <10 | <20 | <30 | <40 | <50 | <60 | <70 | <80 | <90 | <100 | <110 | <120 | 120=< |
| Chiguaza (Juan Rey) | 3 days Rainfall | Landslide | 17% | 39% | 67% | 83% | 94% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 62% | 83% | 92% | 97% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Landslide | 11% | 17% | 28% | 28% | 28% | 33% | 56% | 67% | 72% | 78% | 94% | 100% | 100% |
| | | Average | 56% | 68% | 76% | 82% | 85% | 88% | 91% | 92% | 93% | 94% | 96% | 96% | 100% |
| Yomasa (Micaela) | 3 days Rainfall | Landslide | 0% | 0% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 63% | 83% | 93% | 97% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Landslide | 0% | 0% | 0% | 0% | 50% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 54% | 66% | 75% | 80% | 84% | 88% | 89% | 91% | 92% | 93% | 94% | 95% | 100% |
| La Estrella (Tanque Quiba) | 3 days Rainfall | Landslide | 13% | 25% | 75% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 86% | 95% | 98% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Landslide | 13% | 13% | 25% | 50% | 75% | 75% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 84% | 91% | 95% | 97% | 98% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 100% |
| Trompeta (Tanque Quiba) | 3 days Rainfall | Landslide | 0% | 0% | 67% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 86% | 95% | 98% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Landslide | 0% | 0% | 33% | 33% | 67% | 67% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 84% | 91% | 95% | 97% | 98% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 100% |

### 4.2.2 Analyses for Inundation

(A) Analysis for Relation between Annual Top 10 of Daily Rainfall and Inundation Events

For a better understanding of the rainfall characteristic in inundation, the relation between annual top 10 of daily rainfall and inundation events is analyzed. The analysis is done by the following procedure:

1. To select the annual top 10 of rainfall in each year in selected stations from 2000 to 2006
2. To check whether inundations occurred or not in the day when annual top 10 of rainfall was recorded

The results of analysis are shown in Table 4-3. In Table "No. of Days when Inundation Occurred from 2001 to 2006" literally shows all the numbers of the days when inundations occurred in each basin from 2001 to 2006, and the values of each row show the number of inundation events in each basin, which occurred when the top 10 of daily rainfall was recorded in each station.

Table 4-3 Summary of Relation between Annual Top 10 of Daily Rainfall and Inundation Events

| Station / Basin | *No. of Days when Inundation Occurred from 2001 to 2006* | La Picota (CAR) | Juan Rey (EAAB) | Micaela (DPAE) | Tanque Quiba (DPAE) |
|---|---|---|---|---|---|
| Chiguaza | *38* | 8 | 6 | - | - |
| Yomasa | *9* | - | - | 3 | - |
| Santa Librada | *11* | - | 6 | 5 | - |
| La Estrella | *15* | - | - | - | 9 |
| Trompeta | *7* | - | - | - | 5 |

From the above results, it can be said that the relation between occurrence of past inundations and heavy rainfall are comparatively high in Santa Librada, La Estrella and Trompeta basins, whereas its relation is comparatively low in Chiguaza and Yomasa basins. However, it can be hardly said that heavy rainfall is directly related to inundation.

The following reasons or possibilities can be considered as the above explanation:

1) Since catchment areas of Santa Librada, La Estrella and Trompeta basins are less than 6 $km^2$,

the nearby rainfall stations can represent the rainfall in all the basins. On the other hand, nearby stations in Chiguaza and Yomasa basins cannot represent the rainfall in the basins because their basins have comparatively large catchment areas of about 19 $km^2$ and 15 $km^2$, respectively.

2) The spatial rainfall pattern in the Study Area may be extremely local.

(B) Relation between Inundation Events and Rainfall

The daily rainfall amounts in past inundations from 2001 to 2006 in each target basins are summarized in Table 4-4.

Table 4-4 Summary of Relation between Daily Rainfall and Inundation Events

| Basin/Station | *No. of Days when Inundation Occurred from 2001 to 2006* | Daily Rainfall (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | < 5 | <10 | <15 | <20 | <25 | <30 | <35 | <40 | 40=< |
| Chiguaza<br>La Picota (CAR) or<br>Juan Rey (EAAB) | *38*<br>*100%* | 14<br>37% | 20<br>53% | 26<br>68% | 31<br>82% | 34<br>89% | 35<br>92% | 35<br>92% | 37<br>97% | 38<br>100% |
| Yomasa<br>Micaela (DPAE) | *9*<br>*100%* | 3<br>33% | 3<br>33% | 4<br>44% | 5<br>56% | 8<br>89% | 8<br>89% | 9<br>100% | 9<br>100% | 9<br>100% |
| Santa Librada<br>Juan Rey (EAAB) or<br>Micaela (DPAE) | *11*<br>*100%* | 0<br>0% | 0<br>0% | 3<br>27% | 3<br>27% | 5<br>45% | 7<br>64% | 8<br>73% | 10<br>91% | 11<br>100% |
| La Estrella<br>Tanque Quiba (DPAE) | *15*<br>*100%* | 4<br>27% | 5<br>33% | 7<br>47% | 10<br>67% | 12<br>80% | 13<br>87% | 15<br>100% | 15<br>100% | 15<br>100% |
| Trompeta<br>Tanque Quiba (DPAE) | *7*<br>*100%* | 1<br>14% | 2<br>29% | 2<br>29% | 4<br>57% | 5<br>71% | 5<br>71% | 7<br>100% | 7<br>100% | 7<br>100% |

Figure 4-4 shows the daily rainfall in all the days when inundation occurred in Chiguaza basin from 2001 to 2006.

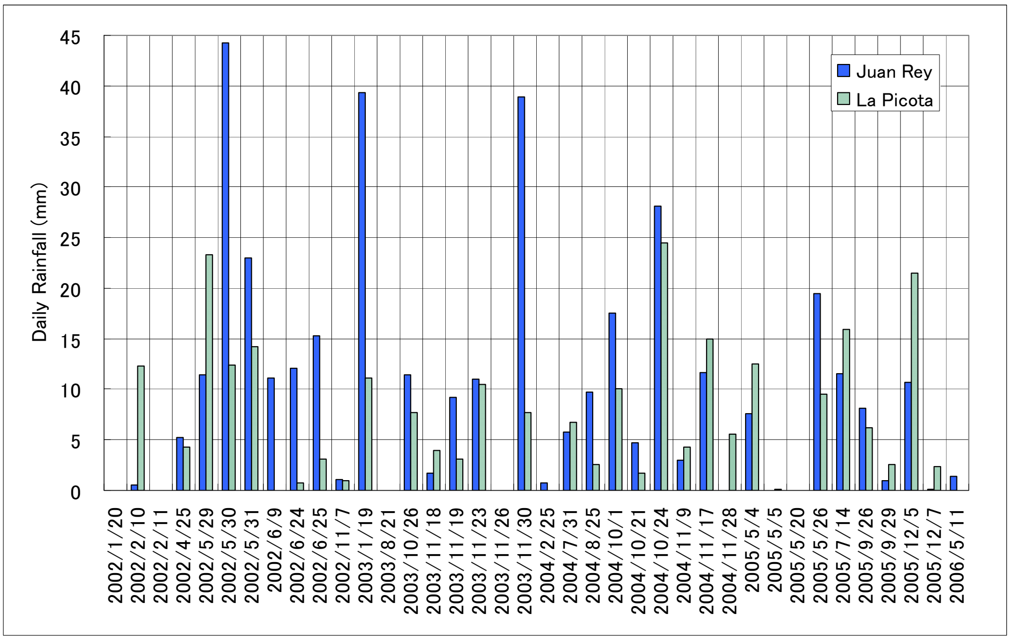



Figure 4-4 Relation between Inundation Events in Chiguaza Basin and Daily Rainfall in Juan Rey (EAAB) and La Picota (CAR) Stations

In the above figure, inundations occasionally occurred when the rainfall amount is very small or in case of no rainfall. The following reasons may be considered:

- The accuracy of rainfall data and inundation records is low
- Long time lag between the occurrence time in the records and the actual occurrence time.
- Long distance of rainfall station and actual rainfall area (local rainfall).
- Influence of other factors such as human activities or some surrounding environmental problems

In addition to the above possibilities, the antecedent rainfall may influence the occurrence of inundation. From the result of analysis of antecedent rainfall when inundation occurred, however, the influence of antecedent rainfall to the inundation is not clear.

# CHAPTER 5 LANDSLIDE

## 5.1 Outline of Landslide

There is only one place for the landslide study area in Bogota and it is designated commonly by Altos de La Estancia, and is located southwest of Bogota, north of the Bolivar City. In Chapter 5, the landslide in the Sector Altos de La Estancia is referred to as “the Landslide”. The Landslide includes two major masses, namely La Carbonera in the south and El Espino in the north, displaces hundred of thousand of cubic meters, and forces hundreds of families to resettlement in an approximate area of 100 ha. The type of the Landslide is related to a mass movement accompanied by some small different types of movement. DPAE divided the Landslide area in 3 zones, namely high alert, middle alert and low alert [or Phase I area, Phase II area and Phase III area] with the purpose of relocation program as shown in Figure 5-1. The figure shows that there were no residential houses in Phase I area, but still there were a lot of houses in Phase II area in Year 2007.

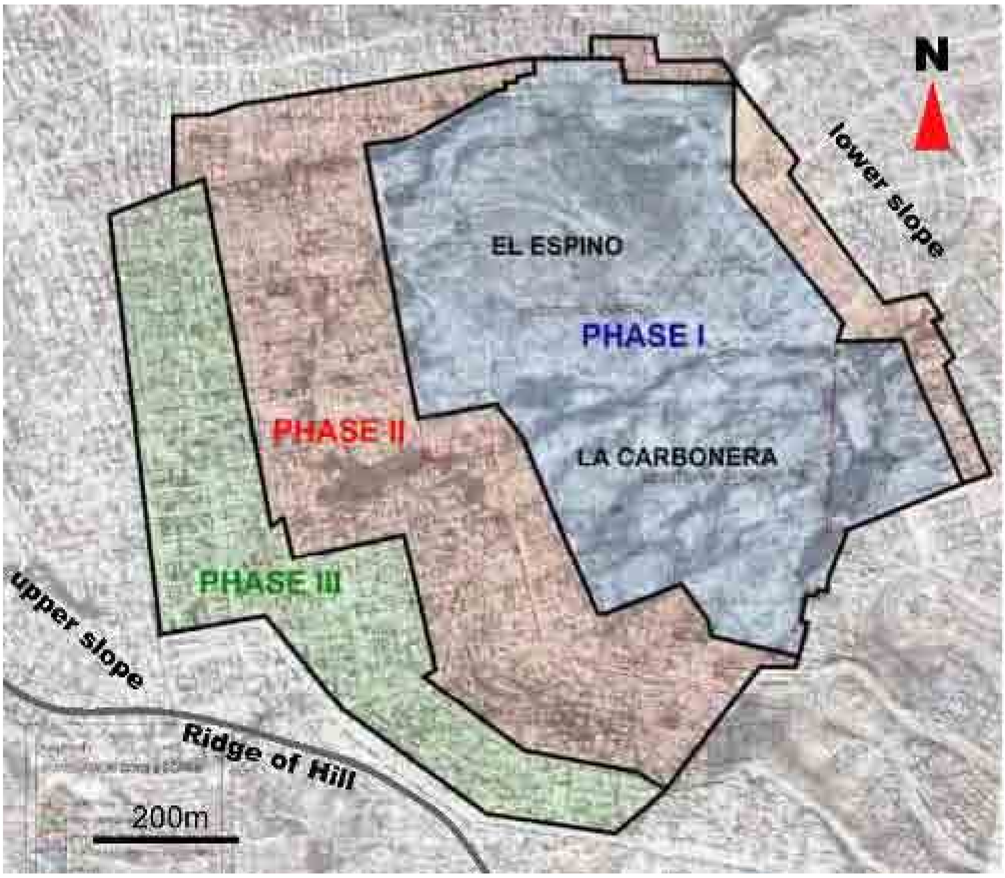



Figure 5-1 Phases in Altos de la Estancia

(Combination of aero photo and topographic map)

Topography

The slope direction in the area is to north east and the moving direction of the Landslide in the aggregate is from south west to north east. The tops of slopes around the landslide are found at 2810 – 2830 m above sea level, and they are about 300 m higher than the level of the Bogota Plateau. The average angle of the slope is about 15 - 20 degrees and the slope angle is less than 30 degrees. Steep slopes (over 30 degrees) in the area shape the outlines of the active landslide masses.

Geology

The reference studies show the presence of two lithostratigraphic units in the area, Sandstone's Member of Guadalupe Formation (Ksglt) and Guaduas Formation (KTg). These members of sandstone which belong to the age of Cretaceous and Tertiary are dipping almost toward east. Therefore the geological structure is a "daylight structure" with 20-degree inclination of strata in the slope of the Landslide.

## 5.2 Existing Studies

### 5.2.1 History of Landslide

The feature of the Landslide has been studied in details in 1977. In spite of the occurrence of landslides, however, the quarries in the area had been exploited until the 90's, and this situation could have resulted in a serious pass. According to Figure 5-2 which shows the development of the cracks, we can observe cracks on the upper to lower slopes in 1952. The cracks in 1952 might not be formed by the landslide activities, but existed before the Landslide occurred. These cracks might be seen easily in the slopes since there were few human activities on the slope in the 50's and before that period. After 1977, the cracks shown in Figure 5-2 tended to invade upward from lower parts of slopes. The crack's upward invasions means the Landslide grew upward.

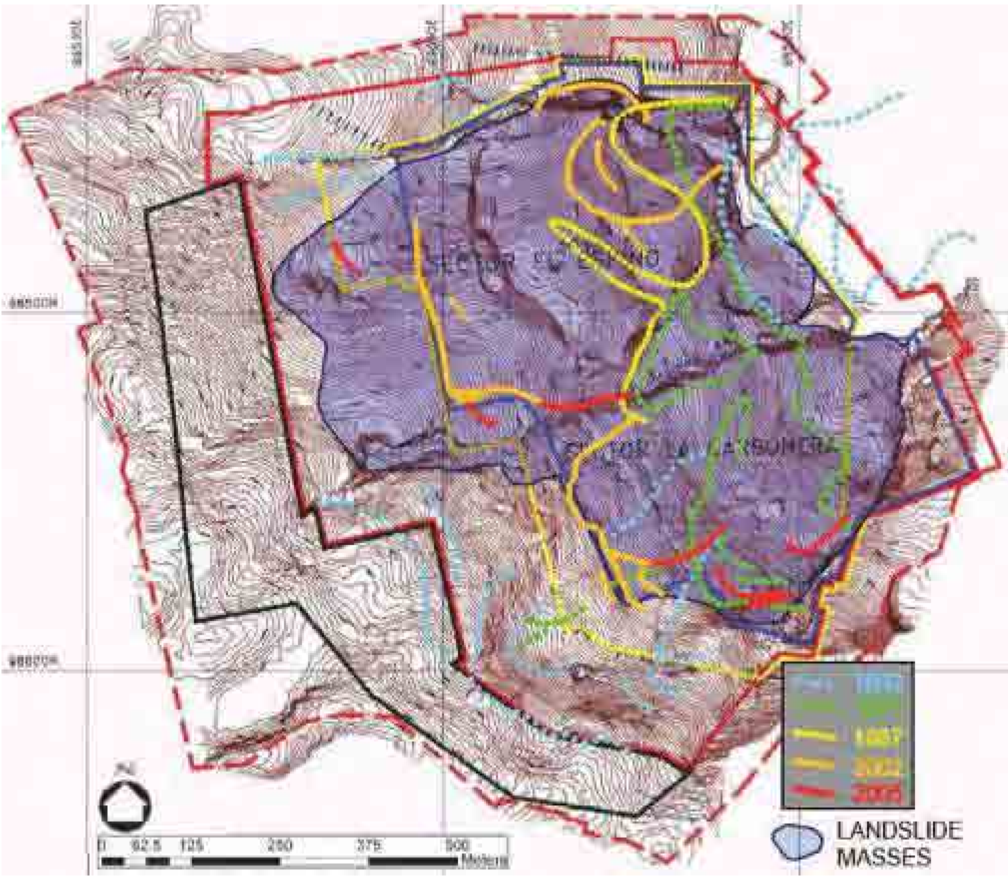



Figure 5-2 Development of Cracks in the Landslide

*Vectores de desplazamiento, (Modified from Monitoreo y seguimiento de los deslizamientos activos que afectan el sector Altos de la Estancia, localidad de Ciudad Bolívar, Bogotá D.C.".INGENIERIA Y GEORIESGOS, 2004 by Yokoo this study)*

### 5.2.2 Existing Studies

The Landslide has been studied for a long period of time and many reports are available regarding this subject. The most complete and comprehensive study is the report written in 2004 by World Bank, which compiled the result of the studies made in the past. Monitoring works on the Landslide have been executed and reported since 1999. The latest monitoring study in 2005 concluded that the maximum displacement was up to 90 mm during the period of monitoring. In La Carbonera, two inclinometers show sliding surfaces at the depth of 9 to 18 m and a total magnitude of the movement in three months was 50 mm (17 mm/month). Figure 5-3 shows the directions of topographic control points differential. Most of the directions cross the contour lines at right angles. The directions are shown lightly toward north east.

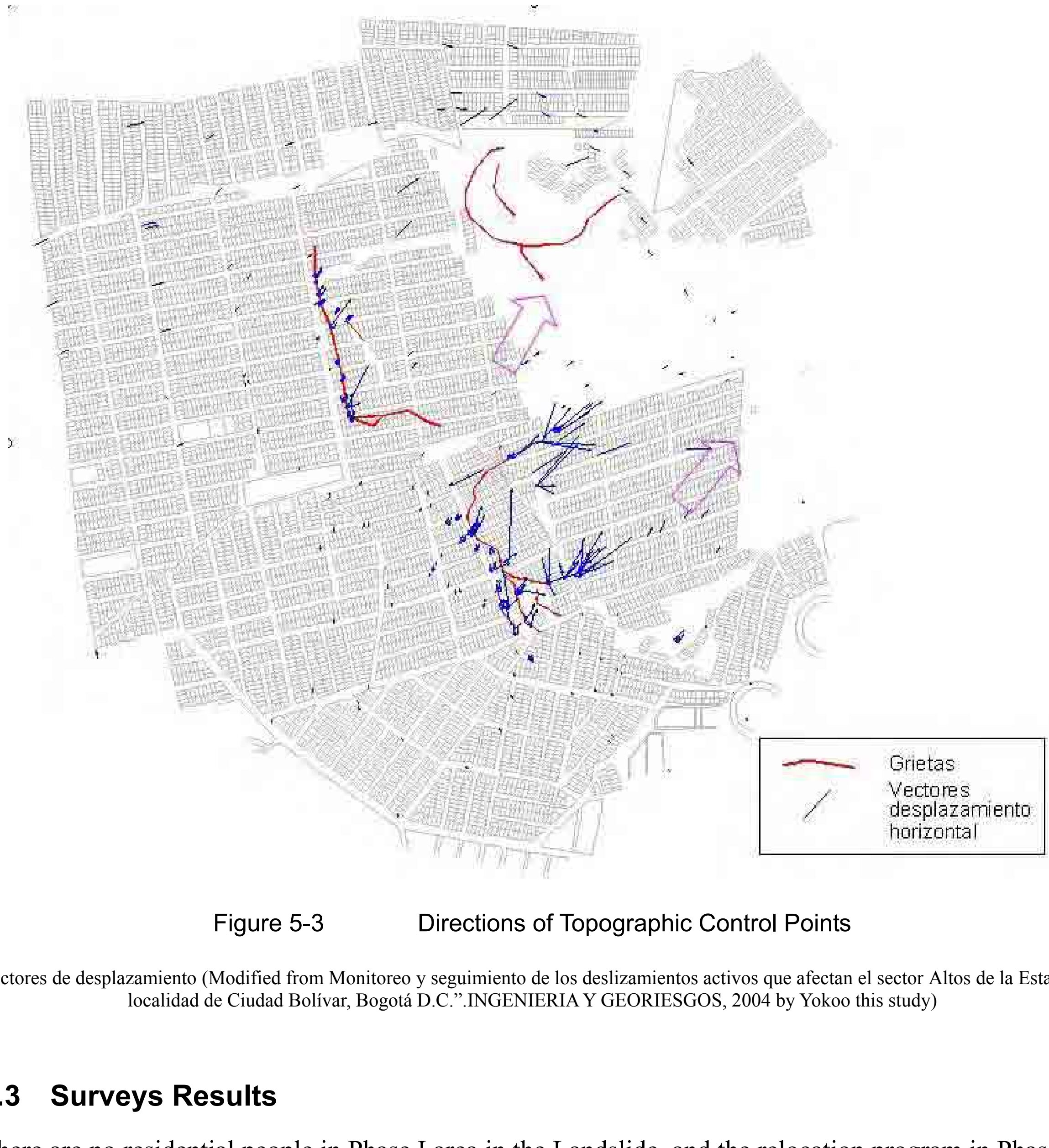



Figure 5-3 Directions of Topographic Control Points

Vectores de desplazamiento (Modified from Monitoreo y seguimiento de los deslizamientos activos que afectan el sector Altos de la Estancia, localidad de Ciudad Bolívar, Bogotá D.C.".INGENIERIA Y GEORIESGOS, 2004 by Yokoo this study)

## 5.3 Surveys Results

There are no residential people in Phase I area in the Landslide, and the relocation program in Phase II area is on progress. Therefore no serious danger would be encountered that threatens the lives of people in the Landslide. However, a small community is found living near the Landslide, in Phase III area and outside of Phase I and Phase II areas. The Landslide could affect the surrounding community through its expansion. Hereinafter, the places outside Phase I and II areas are designated by "the residential area". The residential area includes Phase III area.

A Site Survey was carried out at three sectors where the parts of the Landslide may approach the residential areas, as shown in Figure 5-4. Any abnormalities such as cracks or deformations on the ground or structures are not found at three sectors in the residential areas, except for Espino 1. At Espino 1, some cracks were found in a house outside the landslide near the uplift which was made through compression at toe of landslide recently. The cracks were found on the basement floor and ground floor by some family members in 2006.

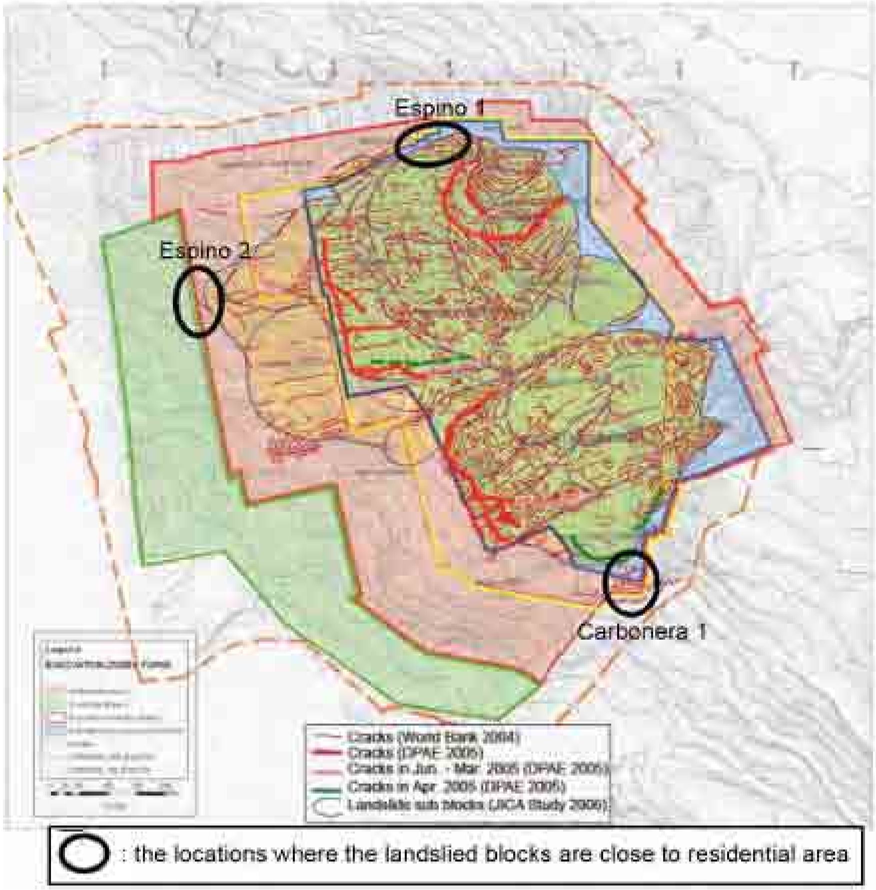



Figure 5-4 Location for Site Survey

The uplift at Espino 1 probably rose through compression at the toe of the landslide, as shown in Figure 5-5. The house which got cracks is close to the uplift, and the force of the landslide which lifts the ground about 15 m, could damage the house. The uplift which began in 2004 and was lifted rapidly seems calm at the moment.

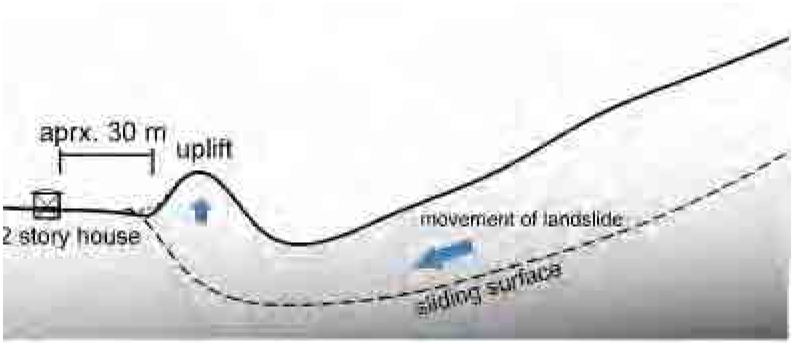



Figure 5-5 Supposed Mechanism of the Uplift

An interview survey was carried out on the residents who live near the boundary between Phase II and III. Almost all residents complained about the existence of deformation on their houses and inundation in the vicinity during heavy rain. However, a clear evidence of influences of the landslide on the residence area was not found in the interview survey.

The results achieved through these surveys are summarized as follows.

a. Any abnormality could not be found in the residential areas (outside Phase I and II areas) deemed safety areas and it would be out of the relocation program.

b. There is no danger of threatening residents' lives in the Landslide because the relocation program is progressing and nobody lives in hazardous area in the Landslide. An early warning system for the residents is not required.

c. The Landslide has expanded upwards and its expansion would continue. There is no guarantee that the residential area will be safe in future; thus it is necessary to monitor the safety of the residential area.

d. There is an abnormality in a house near the uplift in Espino 1. If the abnormality in that house depends for the Landslide activity, the area of the Landslide should be reconsidered.

e. The drainage system in Phase III is inadequate. For the stability of the Landslide, it is necessary to maintain the drainage system in Phase III to prevent the water flowing into the Landslide.

## 5.4 Hazard Map

DPAE proceeded with the area division in three areas, namely Phase I area, Phase II area and Phase III area, based on available information and especially on data from the study of INGEOMINAS (2003) in order to relocate the population of all areas (Figure 5-1). A map has been issued to the public as Hazard Map. Almost all of the inhabitants in Phase I area actually have been relocated, and their relocation in Phase II area is progressing. The Phase III area, deemed a stable area and being outside relocation plan, corresponds to the high slope part.

## 5.5 Monitoring Plan

### 5.5.1 Outline of Monitoring Works

The early warning systems using the automatic monitoring devices are not required in the Landslide in terms of saving human loss in the area, because of an existing resettlement program and the movement speed of landslide. The instrumentation and monitoring should be applied as follows, for the conditions of this Landslide.

a. Safety of the residential area; this confirms the Landslide activity is not approaching the residential areas. This monitoring should be continued as far as the people are living there, along the rim of the Landslide.

b. Monitoring on specific cracks and deformation on structures and the ground; this concerns the monitoring works on cracks or deformations on the ground or structures when they are found. This monitoring should be applied whenever cracks or deformation are found on the ground and structure.

c. Safety of construction works; this concerns the monitoring works to prevent accidents under construction. Accidents could occur on both workers and residents surroundings. This monitoring should be applied on each construction works during their progress.

d. Verification of effectiveness of stabilization works; it is necessary to confirm the effect of stabilization woks at completion of the construction works.

### 5.5.2 Monitoring for Safety of the Residential Area

The residential areas deemed safe with authoritative assurance based upon the past study should be monitored to check any change of the conditions of the areas as far as the people are living there. The stability of the slope should be confirmed, especially during the stabilization works. In order to prognosticate any imminent landslide danger in the residential surroundings as early as possible and to take the appropriate administrative measures, the most important step to undertake would be an observation survey carried out by engineers periodically. This would allow finding abnormality on the ground or houses in the residential areas that are close to the Landslide and observing the condition of the Landslide. Then, collecting information from the residential people who are sensitive to the change of surroundings would be required.

The problem of theft and delinquency should be considered in the area when the instruments for monitoring are provided. For a large scale landslide, the survey points monitoring should be as simple and easy to handle as possible. The survey points should be installed along the boundary between the Landslide and residential areas. If the movement is found on a point, one should assume that the Landslide approaches the residential area, and engineers should carry out an observation survey around the point, and the frequency of the monitoring should be raised.

Tiltmeter and GPS can be used for the monitoring of the ground movement. By monitoring the ground movement using these instruments along the Landslide and the residential areas as shown in Figure 5-6, we can estimate whether the Landslide is approaching. Tiltmeter and GPS should be installed in secure places such as private sections and premises.

The extensometer is useful at the toe of landslide to monitor the expansion of landslides. Generally, the extensometer requires wire to monitor the distance, therefore it is not recommendable for this area. The laser distance meter should be used for the area since no wire is required between the residential houses and the Landslide.

Figure 5-6 illustrates an example of instrumentation along the Landslide and Residential Areas.

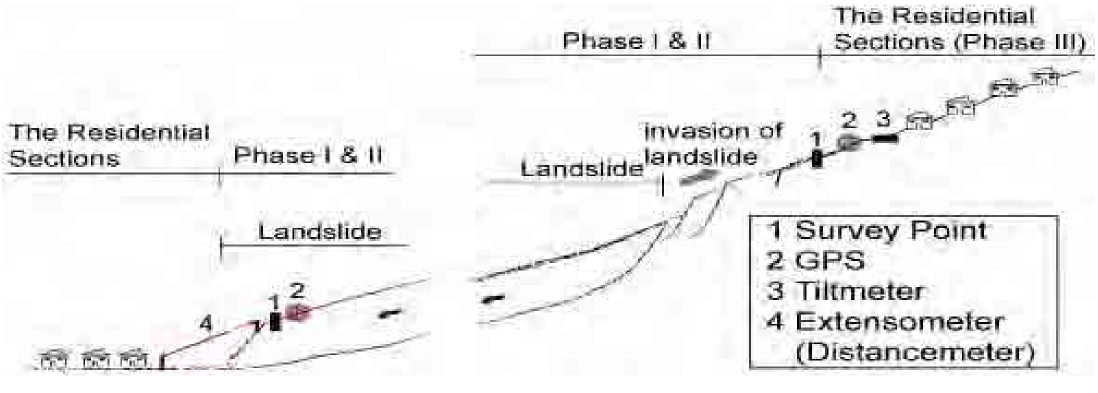



Figure 5-6 Example of Instrumentation along the Landslide and the Residential Areas

At the area where the Landslide approaches, an intensive monitoring should be carried out. Figure 5-7 shows four places where the landslide blocks close to the residential area by growth of the Landslide. The place “A” may be closer to the imminent landslide danger since the landslide has grown upward. At the places “B” and “C”, the locations should be watched since cracks can be seen outside the landslide mass. The place “D” could be in danger in the future since the location is found at the toe of the landslide and it is oriented in the direction of the landslide movement. A priority should be given to the locations A, B, C and D for monitoring over other areas, even there is no clear evidence of a critical situation at the moment.

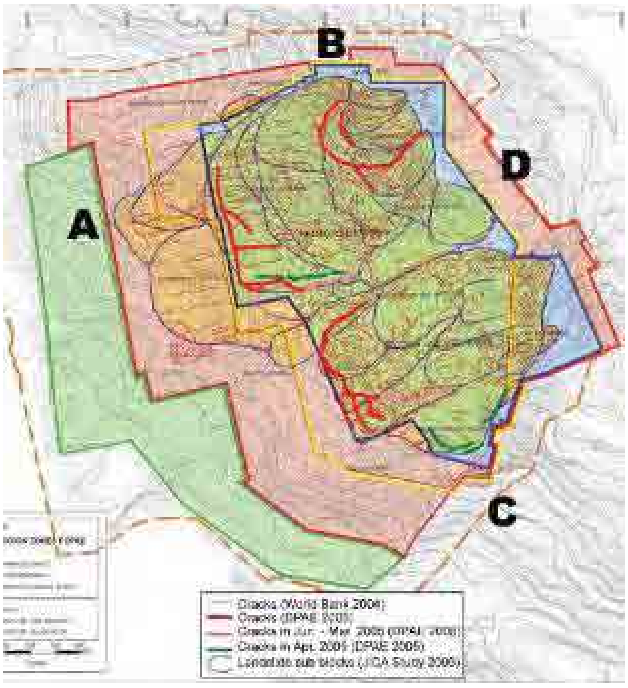



Figure 5-7 Four Places Where the Landslide Blocks Close to the Residential Area

### 5.5.3 Monitoring for Specific Cracks and Deformation on Structures and the Ground

When new cracks or deformation on the ground or structures are found, they should be monitored simply and easily. In case of crack on the ground, monitoring should be using a simple crack gauge. If there is a big difference in level between both sides, an extensometer will be useful. A verification should be made to know whether the crack is still opening or ceasing through monitoring.

The followings are explanation of Simple ground crack gauge and extensometers.

Simple Ground Crack Gauge; One of the simplest methods to determine landslide movement is a simple ground crack gauge. For the installation of the crack gauge, drive the stakes across a tension crack along the direction of slide movement. Then attach a horizontal board to the stakes, and saw through the board. Any movement across the tension crack can be determined by measuring the space between the sawed portions of the board.

Extensometer; the extensometer is used to measure the relative movement by comparing the extension of two points. The extensometers are generally installed across the main scarp, at transverse cracks and transverse ridges near the toe or front portion of the slide and parallel to the suspected slide direction. The measurements should be accurate to within 0.2 mm and the magnitude of the movement and daily rainfall data should be recorded to establish the relationship between the measurable movement and the precipitation rate.

Regarding simple crack gauge and tiltmeter on structures; when a new deformation is found in a house, the latter should be monitored. The crack in a house can be monitored simply by marker pen and ruler or by simple gauge. For the monitoring on a deformed house, a tiltmeter is also useful.

The establishment of an alert system in the study area has been proposed in 2005 by DPAE as shown in Table 5-1. However, for the basic concept of the automatic monitoring on a landslide, the detection of differential movement can activate the alert (for instance, the increase of velocity of movement or inclination of the ground, or new movement may occur in the stable place).

Table 5-1 Proposed Index of Alert

| Item | Unit | Factor of Weighting | Category of Alert | | | |
|---|---|---|---|---|---|---|
| | | | Low | Medium | High | Critical |
| Altimetry | mm/day | 0.25 | < 1.6 | 1.6 – 3.3 | 3.3 – 5.0 | > 5.0 |
| Inclinometer | mm/month | 0.15 | < 2.0 | 2.0 – 5.0 | 5.0 – 10 | > 10 |
| Structural control | - | 0.3 | 0.25<br>CGR (< 1.5) | 0.5<br>CGR (1.5 – 2.0) | 0.75<br>CGR (2.0 – 2.4) | 1.0<br>CGR (> 2.4) |
| Location of house with movement | - | 0.3 | 0.25<br>(> 50m) | 0.5<br>(50 – 30m) | 0.75<br>(30 – 10m) | 1.0<br>(10 - 0m) |
| Index of alert | | **1.0** | **< 1** | **1 – 2.3** | **2.3 – 4.1** | **> 4.1** |

(Source: Monitoreo y seguimiento a los deslizamientos activos que afectan el sector Altos de La Estancia de la localidad de Ciudad Bogota, 2005)

### 5.5.4 Monitoring for Verification of the Effectiveness of Stabilization Works

The instruments used for the stabilization works in the verification of effectiveness of the works should be selected. DPAE is planning the stabilization works in the Landslide; however, the details are not confirmed yet. The stabilization works are classified in two main categories, namely works for reducing the driving forces and those for increasing the resistance force. In the case of a large scale landslide such as the Landslide, a priority is given to the method for reducing the driving forces, since the cost effectiveness for a large scale landslide is normally a better choice than for the method in increasing the resistance force.

- Common Monitoring

  The monitoring of the ground movement should be necessary to confirm the effectiveness of the stabilization works, a factor that is important to stop or mitigate the landslide activities. Monitoring should be continued before and after the execution of the stabilization works. It is also necessary to continue in this manner in the future following the completion of the construction works in order to monitor any resumption of the landslide.

- Monitoring for Water Control Works

  To confirm the effectiveness of the water control works, the ground water monitoring is necessary through the use of water standpipes and piezometers. Rain gauge monitoring in or around the Landslide should be applied.

- Monitoring for Works for Increasing the Resistance Force, Piling and Anchoring

  The individual or contiguous piles are common for the increase of the resistance force. Monitoring of deformation of piles should be applied if the pile works are employed in the stabilization works. The ground inclinometer close to the pile and behind it can measure the movement of the pile. A strain gauge pasted on a steel pile or on reinforcement bars of a bored pile can monitor the movement of the pile. The depth of ground inclinometer should be deeper than the pile. If the monitoring shows a great movement of the pile, the latter might be at risk against the Landslide force. Anchors are also commonly used for the increase of the resistance force. The anchors can control by monitoring the tension force by means of a load cell at the anchor head.

### 5.5.5 Safety of Construction Works

Most of the construction works of stabilization follow digging and watering, therefore they could trigger a resumption of the landslide. The frequency of monitoring should be raised during the construction period.

A small landslide occurring near the construction site may endanger the workers on the construction site. To protect them and the site, the construction site should be always monitored by the engineers or workers. If a crack is found, it should be verified using a simple crack gauge or an extensometer. In case the crack is opening, the construction works should be stopped and the area should be checked carefully.

## 5.6 Pilot Project

The purpose of the monitoring is to verify the residential areas as for its safety. This concerns only the object areas of the monitoring of the residential zone (Phase III area and the areas outside the landslide area). Any landslide monitoring is not proposed in Phase I and II areas, since there are no houses to be protected in the areas of Phases I and II. The locations of monitoring are as follows:

1. Boundaries between Phase II and III areas
2. The areas above the heads of the main landslide in Phase II area
3. The house in which cracks and distortions were found.

### 5.6.1 Monitoring Equipment

The following five kinds of monitoring works concern the items mentioned hereinafter.

(1) Survey Points

(2) Crack Gauges

(3) Level Survey

(4) Tiltmeter

(5) Laser Distance Meter

The extent of the monitoring is shown in Table 5-2.

Table 5-2 Extent of Monitoring

| Location | Monitoring | Item | Quantity |
|---|---|---|---|
| Boundary between the Landslide and the Residential Area | Location Survey | Survey Points | 15 |
| | | Fix Points (Bench Marks) | 5 |
| Phase II area | Crack Gauge | Crack Gauges | 3 |
| | | Pegs (4 pegs for 1 set) | 3 sets |
| Uplift and Deformed House | Level Survey | Survey Points | 3 |
| | Tiltmeter | Sensor | 1 |
| | | Logger | 1 |
| | Distance Meter | Laser Distance Meter | 1 |
| | | Target Plate | 2 |

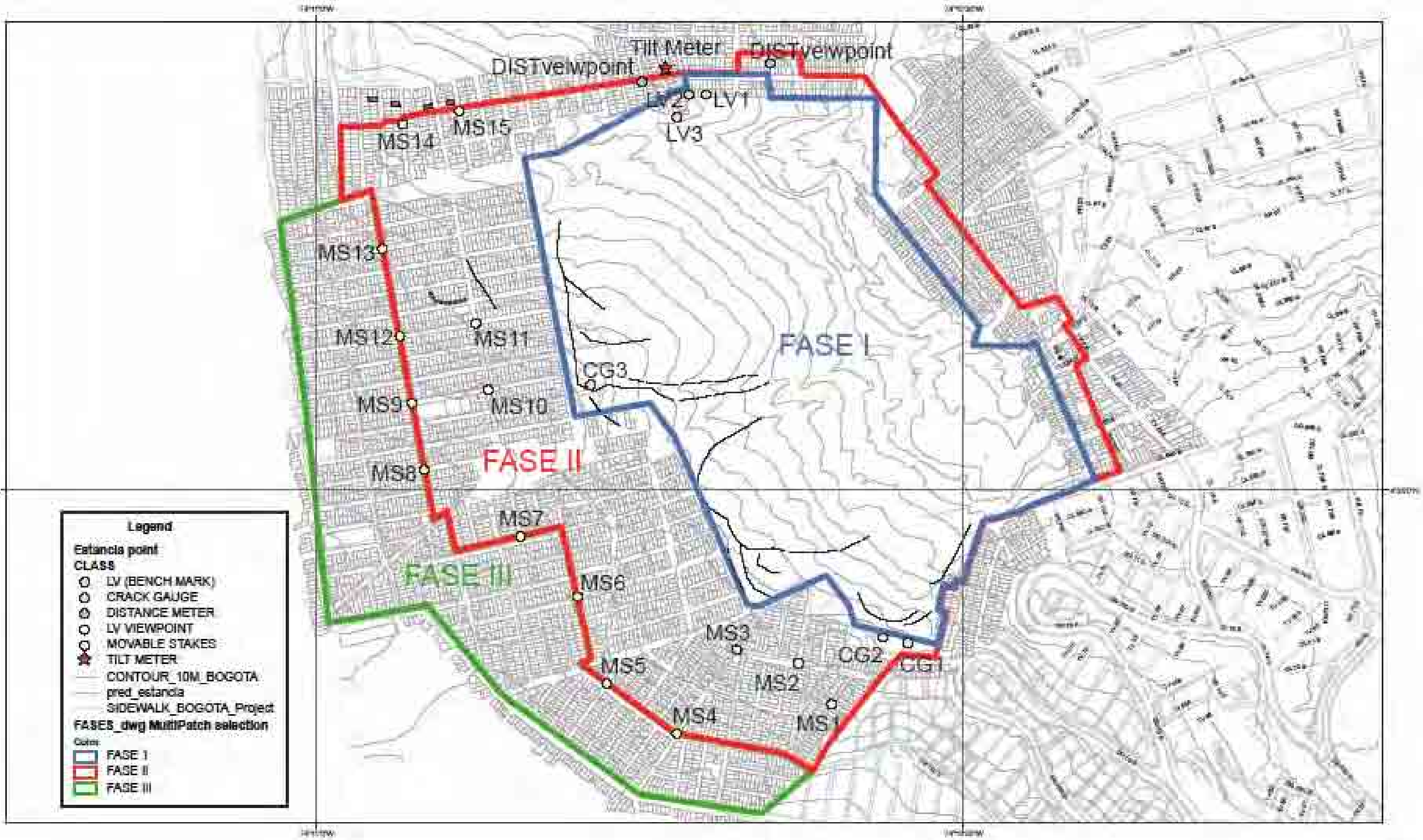



Figure 5-8 Location of Survey Points and Other Monitoring Equipments

### 5.6.2 Installation Points of Monitoring Equipment

(1) Boundary between the residential area and the Landslide by Survey Points

The survey points were installed along the boundary between the residential area and the Landslide in order to confirm whether the safe areas are still safe. A total of 15 survey points were installed, and 5 fix points were installed as bench marks. Actually the survey points made of concrete with brass points were installed to avoid their removal.

(2) Phase II area by Crack Gauges

The movement of the cracks monitored by the crack gauges can be summarized in graphs which show relations between time and movement. The graphs can show the movement of the head of landslide block, then the velocity of the landslide movement may be estimated. Sign boards are installed at the crack gauges to explain the meaning of monitoring to the residential people.

Crack gauges installed on the site are bigger and stronger than those found in Japan since they might be destroyed. However some of them were destroyed by people after their installation on the site, and they were substituted with stakes.

(3) Monitoring for the House by tiltmeter, laser distance meter, and level survey

The following equipments were installed in and around the house located at 30 m away from uplift to monitor the slow progress of tilting of the house and slow movement of uplift.

a. Tiltmeters on the basement floor of the house

b. Laser distance meter to monitor the distance between the house and the uplift

c. Level survey points to monitor uplifting of the uplift

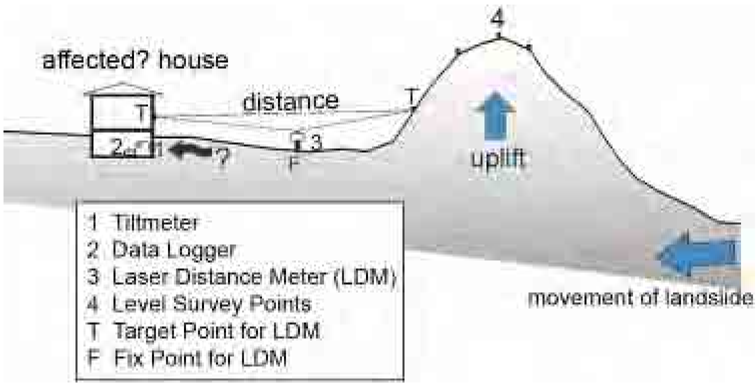



Figure 5-9 Monitoring Equipments for the House

Tiltmeter

If the tiltmeter installed in the house shows that the house is tilting, this means that the landslide may affect the house. The influence of the landslide should be analyzed comparing with the result using the distance meter. If we find the landslide is imminent, the house should be relocated.

To monitor the tilting of the house, one automatic tiltmeter is installed with data logger on the wall of the basement in the house.

Distance Meter

In case the distance between the house and the uplift is short, the landslide may get closer to the house, and the extension of Phase II area should be discussed. One portable laser distance meter is employed for the monitoring.

Level Survey

The level survey is undertaken to monitor the rising of the uplift. The results are analyzed with another monitoring such as the distance meter and the tiltmeter.

Table 5-3 Monitoring for the House by tiltmeter, laser distance meter and level survey

| Equipment | Quantity | Purpose and specification |
|---|---|---|
| Tiltmeter | 1 | Automatic monitoring, to monitor the deformation of the house (location: base floor of the house) |
| Data Logger | 1 | To be connected to tiltmeter for the storage of data<br>Standard Range: ±10° or more precisely,<br>Sensitivity: ±10 arc seconds or more precisely, and<br>A single channel type data logger was employed to collect the tiltmeter data. Specifications of the tiltmeters are as follows;<br>Available to change any measurement interval (selectable every 1 sec, 1 min, 1 hr, 1 day),<br>Data memory: more than 1,000 data |
| Distance Meter | 1 | Two (2) numbers of target plates for the laser distance meter were installed on the uplift ground<br>Maximum distance to measure: 100 m or farther,<br>Measuring accuracy: ±1.5 mm (up to 30 m in distance),<br>Tilt sensor accuracy to laser beam: ±0.15°, to the housing: ±0.3° |
| Level Survey | 3 points | To monitor the rising of the uplift |

### 5.6.3 Results

Any significant movement has not been seen on all the monitoring during the pilot project.

# CHAPTER 6 FLOOD

## 6.1 Creeks in Study Area

All target creek catchments of Bogota are located in the Tunjuelo river basin. The Tunjuelo River, which is a tributary of the Bogota River, is located in the southern part of the Metropolitan District of Bogota. The target creeks are Chiguaza creek, Santa Librada creek, Yomasa creek and La Estrella Trompeta creek. (Figure 6-1).

| City | Monitoring and early Warning System for Floods | | |
|---|---|---|---|
| | Creek/River | Catchment Area ($km^2$) | Principal River Length (km) |
| Bogotá City | Chiguaza Creek | 18.9 | 7.0 |
| | Santa Librada Creek | 5.5 | 5.0 |
| | Yomasa Creek | 15.4 | 5.0 |
| | La Estrella-Trompeta creek | 8.3 | 1.5 |

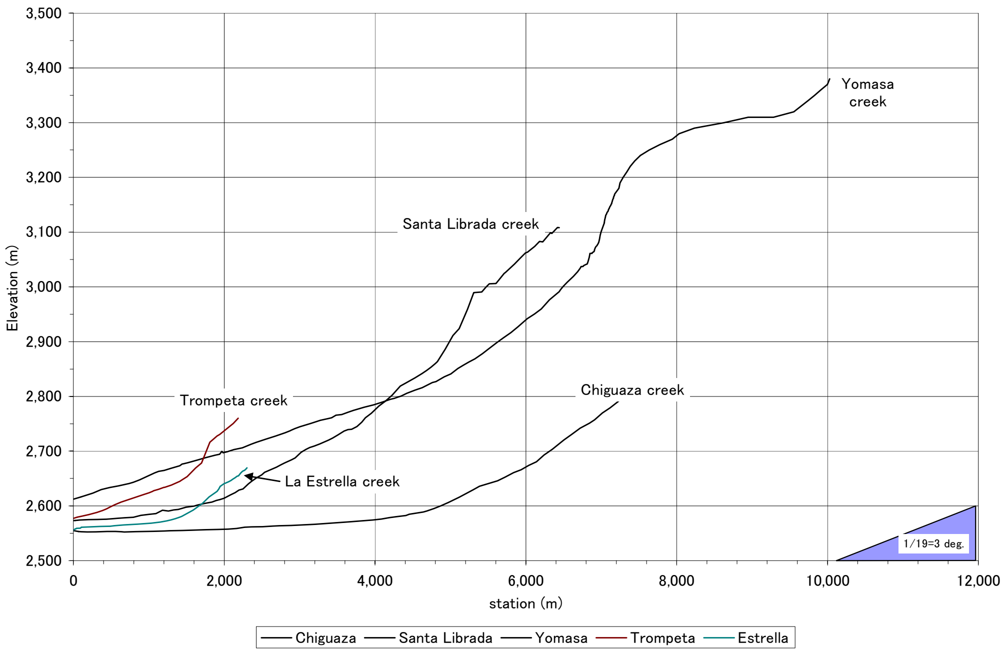



Figure 6-1 Longitudinal Profiles of Target Creeks in Bogota

The rainfall intensity, duration, and frequency are defined by EAAB for Bogota area. Table 6-1 is the Zone 7 in Bogota.

Table 6-1 Rainfall Intensity, Duration and Frequency (Zone 7)

| Return Period | 5 min | 10 min | 15 min | 30 min | 60 min | 120min | 180 min | 240 min |
|---|---|---|---|---|---|---|---|---|
| 3yr | 89.8 | 56.9 | 43.6 | 27.6 | 17.5 | 11.1 | 8.5 | 7.0 |
| 5yr | 109.9 | 69.4 | 53.0 | 33.5 | 21.1 | 13.3 | 10.2 | 8.4 |
| 10yr | 169.7 | 90.4 | 66.2 | 40.4 | 25.3 | 16.1 | 12.3 | 10.2 |
| 25yr | 154.4 | 102.0 | 79.0 | 50.2 | 31.6 | 19.8 | 15.0 | 12.4 |
| 50yr | - | 146.2 | 96.1 | 55.2 | 34.2 | 21.9 | 17.0 | 14.2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 100yr | - | 164.0 | 107.7 | 61.7 | 38.3 | 24.5 | 19.0 | 15.9 |

## 6.2 Past Floods

### 6.2.1 General

The Study Team undertook an interview survey for flood in the Study Area. According to the results obtained, the following flood phenomenon can be observed in the study area:

- Prolonged inundation by high water in the Tunjuelo River
- Overflow of main creek (with or without debris)
- Overflow of local drainage system and backwater through sewerage

The prolonged inundation by high water in the Tunjuelo River may be mitigated by the completion of the Cantarrana Dam (EAAB).

The overflow of local drainage or backwater through sewerage is a local phenomenon and the damage is limited. They are mainly caused by garbage deposit and a small capacity of ditch. This inundation is not concerned by the Study.

The remaining flood problem concerns the overflow from main creek in the Study Area. This type of flood frequently occurred in the middle and upper part of the Chiguaza creek. In other creeks, the study results of the interview survey did not show any significant damage.

### 6.2.2 Flood on May 19, 1994

Chiguaza creek basin: it was said at an interview in Quindio (Barrio) that this is a kind of flash flood that happened in the past in the neighborhood. This phenomenon concerns that observed in Qda. Zuque. According to the interview, the flash flood was 30 m width and lasted 3 hours.

The most significant phenomenon in the 1994 event was the diversion from the bridge on *old highway to "Villavicencio"*. The resultant flash flood went to barrios Altamira, running on the streets among the blocks. The area downstream of barrio Altamira suffered from the flash flood damage only in the creek and the limited riverine.

The Local Newspaper "El Tiempo" article dated on May 23, 1994 wrote that 4 people died, 15 people missing and 830 people were affected.

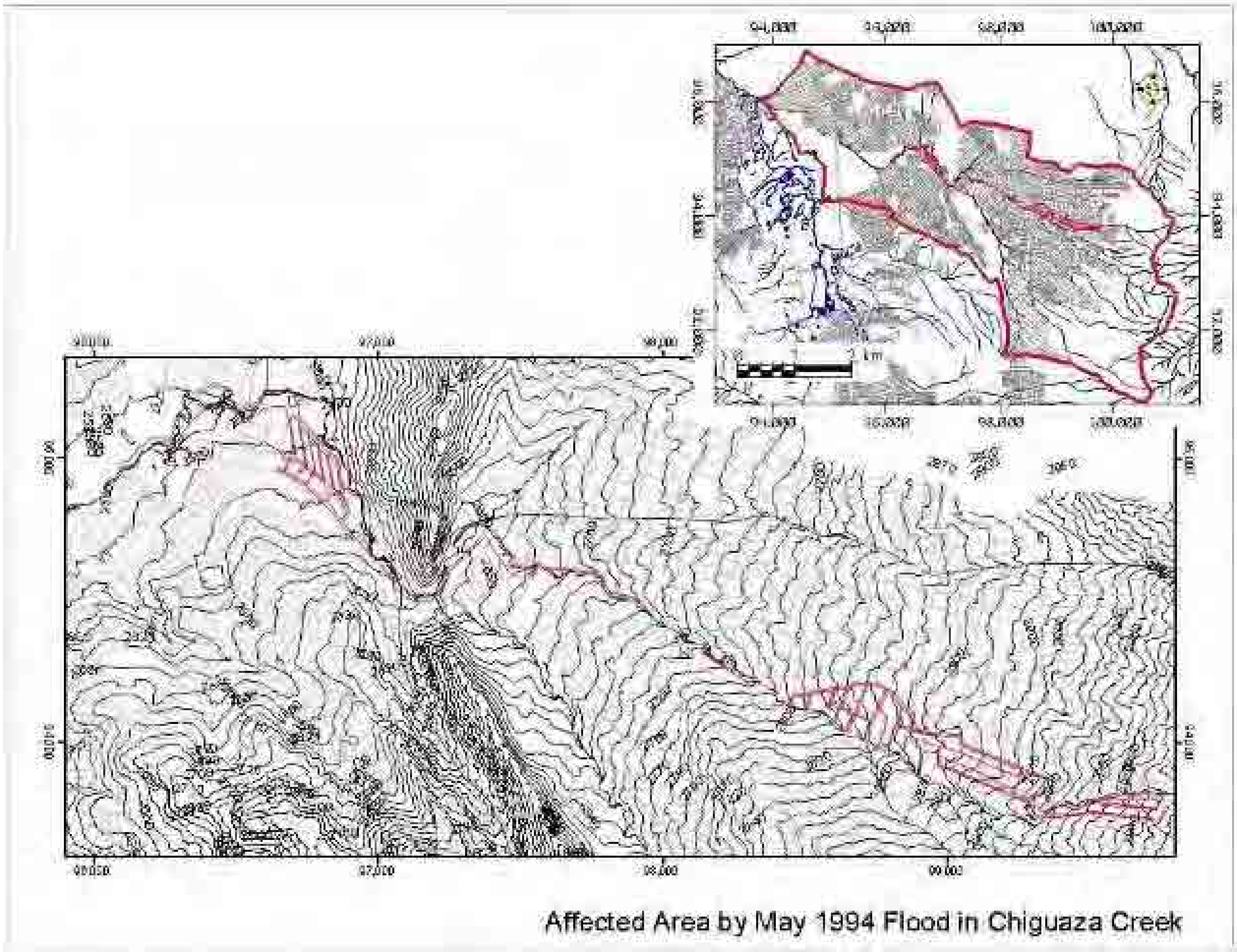



Figure 6-2 Affected by the Flood on May 19, 1994 in Chiguaza creek

### 6.2.3 Flood on May 31, 2002

The inundation in the Chiguaza creek in May 2002 can be considered as one of the main flood disasters in recent years. The area near the Tunjuelo river confluence was seriously affected by flood water. It has been reported that the high water of the Tunjuelo River itself was the main cause of the inundation.

The maximum intensity was 22.4 mm for 15 minutes at 12 Noon on May 30, 2002.

Figure 6-3 shows the flood elevations along the Chiguaza and Tunjuelo River together with the longitudinal profile of the Chiguaza creek and the Tunjuelo River, according to the interview survey by the Study Team. The flood elevations were assumed as the ground elevation of the 2 m contour line plus interviewed inundation depth. The inundation depths are larger than 2 m in some points above the ground elevation of the right bank.

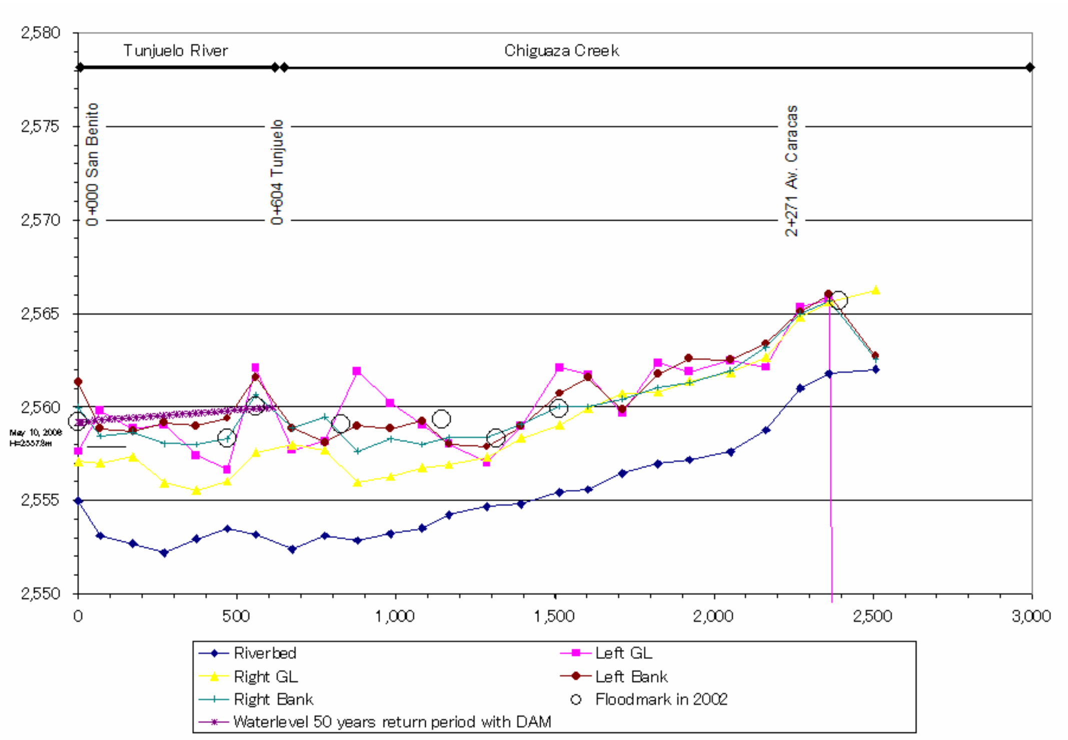



Figure 6-3 Flood Elevation in May 2002 Flood in Chiguaza and Tunjuelo river

Effect of the Cantaranna Dam

After the May 2002 flood, the Tunjuelo river's flood is controlled by the Cantarrana Dam. According to the EAAB information, the Cantaranna Dam could cut 88 $m^3/s$ for 100 years return period. The discharge of 88 $m^3/s$ corresponds to the water level of 1.7 m reduction. The flood mark in May 2002 was 2,559.2 m at San Benito. If at present the same flood occurs in the Tunjuelo river, the water level at San Benito is 2,557.5 m, which is lower than the existing right bank elevation.

## 6.3 Existing Monitoring System

### 6.3.1 Monitoring System of DPAE

In the Tunjuelo River basin, DPAE has already established a flood monitoring system as well as an early warning system using a combination of telemeter system and manual monitoring system. Figure 6-4 shows the DPAE web site of the Tunjuelo River Monitoring System, on which the Study Area boundary and scale were added by the Study Team as reference.

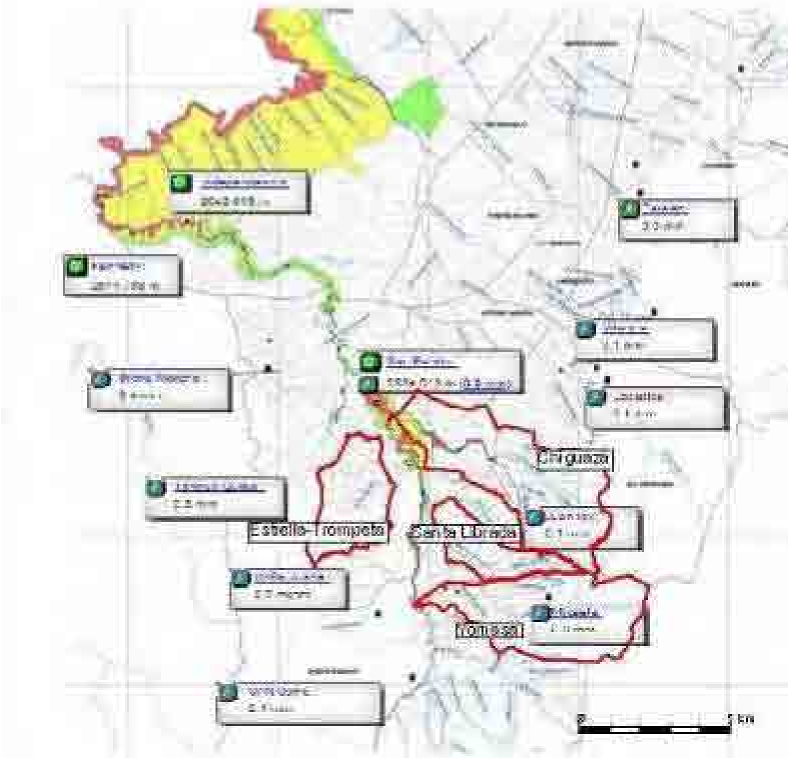



Figure 6-4 Existing Monitoring System by DPAE

### 6.3.2 Monitoring Stations of Other Organizations

There are rainfall and water level stations in and around the Study Area of DPAE, IDEAM, CAR and EAAB. The purpose of each organization regarding the hydrological monitoring is different. IDEAM stations are provided for climate monitoring on the national level viewpoint. CAR stations are provided for environmental monitoring, and EAAB stations concern the water supply potential and drainage planning. Regarding the flood early warning purpose, only DPAE has hydrological stations targeting the Tunjuelo river basin.

The data of the monitoring stations other than DPAE were used for hydrological evaluation in the Study. Only the DPAE stations were considered in the monitoring and early warning planning in the Study Area.

The present system by DPAE presented previously is established for the Tunjuelo River main course as the target area. For the flood-prone area in the Study Area, more monitoring points should be established considering the local flood phenomenon within the Study Area.

## 6.4 Flood Analysis and Mapping

### 6.4.1 Hydrological Modeling

EAAB has defined a group of IDF(Intensity-Duration-Frequency) curve in and around the Study Area. In Bogota, the Chiguaza, Santa Librada and Yomasa creek catchment belong to Zone 7, while La Estrella and Tromepeta catchments belong to Zone 4. The 60 minutes rainfall for 100 years return period of Zone 4 and Zone 7 are only 42.0 mm and 38.3 mm, respectively.

Since in the Study Area in Bogota, the size of creek catchment is small and the creek bed slope is very steep (without storage function). Also some previous studies by EAAB have used a rational method, which is the most appropriate method for the four (4) creek catchments.

### 6.4.2 Channel Flow Capacity

Figure 6-5 shows the profile of creek capacity (left and right banks) comparing with probable discharge distribution. Through this figure, we can see the critical points along the creek. Fortunately the Chiguaza creek has a high flow capacity, because the section of Los Puentes downstream has at least 10 years return period capacity assuming the peak discharge at Los Puentes is considered in the downstream reach as a safety side. The creek presents crossing structures such as bridge and culvert. Figure 6-5 also indicates the capacity of main crossing structure assuming without sedimentation. These structures have a sufficient capacity; however, the clogging due to sedimentation and garbage occurs easily. In this sense, the critical points are selected as shown in Table 6-2.

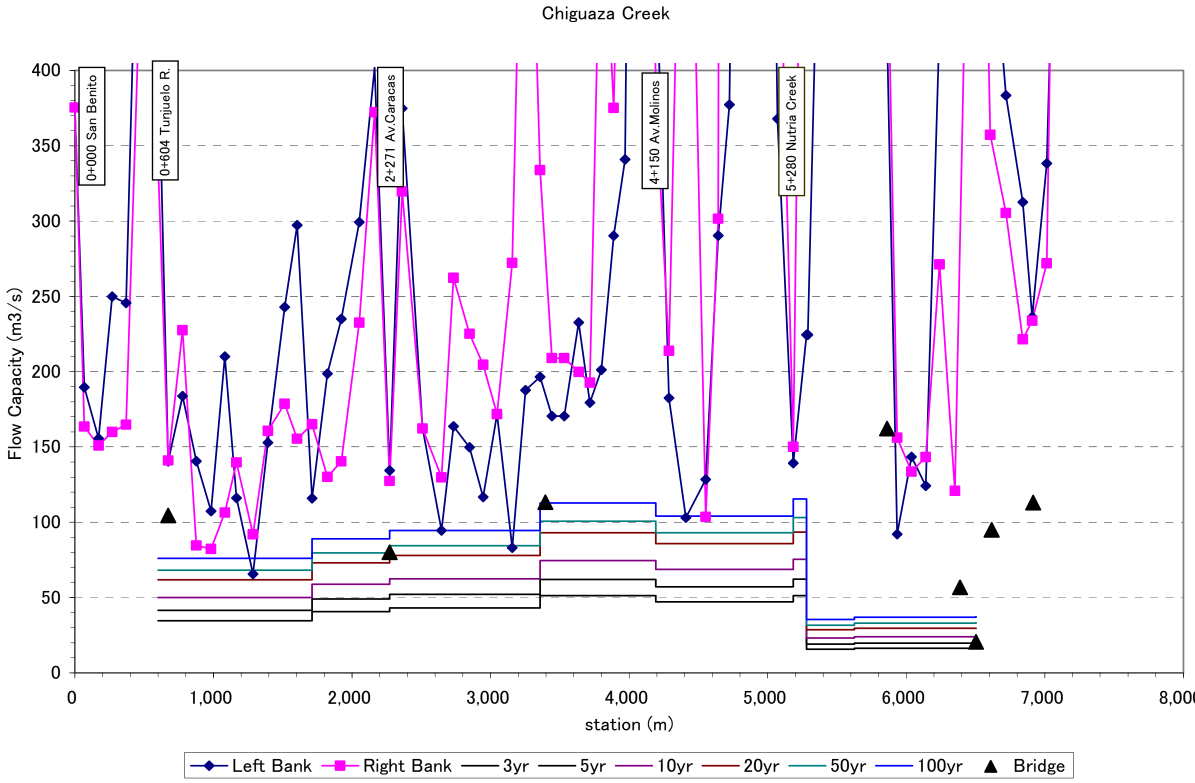



Figure 6-5 Channel Capacity and Probable Discharge of Chiguaza Creek

Table 6-2 Critical Point in Chiguaza Creek

| Area Name | Station | Anticipated phenomenon | Remarks |
|---|---|---|---|
| Caracas Avenue | 2+271 | When sedimentation proceeds at upstream side, overflow could happen toward the surrounding. | The removal of sediment of the Bridge upstream should be done. |
| Molinos II (Residential Complex) | 4+723 | Fan apex topography. The overflow due to the obstacle could spread toward left bank. | |
| Los Puentes (Nutria confluence upstream) | 5+450 | In terms of the creek alignment, the flow from the Chiguaza upstream could hit the right bank side. | |
| CRA3 Este | 6+388 | When sedimentation proceeds at upstream side, the overflow could happen toward left bank side. | Maintenance of bridge upstream side |
| (CRA 3B Este) | 6+504 | Small pipe culvert, overflow could happen | Maintenance of bridge |

| | | | |
|---|---|---|---|
| | | over bridge. | upstream side |
| La Gloria (CRA 6A Este) | 6+916 | When sedimentation proceeds at upstream side, the overflow could happen toward left bank side. | Maintenance of bridge upstream side |
| Avenue Villaviciencia | 0+109 (Zuque) | When sedimentation proceeds at upstream side, the overflow could happen toward left bank side. | Maintenance of bridge upstream side |

### 6.4.3 Flood Map

For Chiguaza creek, the flood area for 25 year return period was mapped (refer to Data Book 1). The flood area is limited at the lowest downstream as it can be seen in Figure 6-5.

At present the lowest downstream reach of the Chiguaza (Ave. Caracas downstream) is improved by EAAB. The channel capacity is estimated at 127 $m^3/s$, therefore the safety will increase further.

## 6.5 Monitoring and Early Warning Plan

### 6.5.1 General

The Monitoring and early warning plan for Bogota includes two (2) components; they are (1) Monitoring and Data Gathering System Plan and (2) Warning Criteria. The warning criteria include hydrological consideration, susceptibility mapping.

Figure 6-6 presents the outline of the proposed monitoring and early warning plan for Bogota. The contents of each component and phase are explained in Section 6.5.2.

| Component of Monitoring and Early Warning System | | Basic Principle of the Study | Planning Phase: Short(2007-2008) — Data Accumulating and People's Training Phase | Planning Phase: Mid(2008-2012) — Timely and Accurate Warning using advanced technology Phase | Planning Phase: Long(2013-2020) — Timely and Accurate Warning using advanced technology Phase |
|---|---|---|---|---|---|
| Monitoring and Data Gathering System | (1) Monitoring Plan | (3) Detailed Monitoring Plan for Chiguaza | Chiguaza: Juan Rey(R/A/T), Moralba(R/A), La Gloria(W/M), Molinos(W/M+A), El Hoyo(W/M)<br>Yomasa: Alemana (R/M), Monte Blanco (W/M) | Upgrade/Replace → Juan Rey(R/A/T), Moralba(R/A/T), La Gloria(W/M), Molinos(W/M+A/T), El Hoyo(W/M) (→ Long)<br>→ Alemana (R/T), Monte Blanco (W/T) | Improvement of Early Warning System in Tunjuelo River based on the accumulated knowledge in the tributaries. |
| | (2) Data Gathering System Planning | | Monitoring and Recording by People and informing by People to DPAE via Phone as People's Training | | |
| Warning Criteria | (1) Hydrological Consideration | | Checking of Flood concentration time by monitoring data | Rainfall Loss and antecedent rainfall based on discharge measurement | |
| | (2) Mapping of Susceptibility | | Flood safety level is increasing due to channel improvement in Chiguaza creek<br>Comparatively high potential of debris flow in Yomasa creek | Based on the analysis of future flood events, maps and warning criteria are modified. | |
| | (3) Warning Criteria | | Tentative Rainfall and waterlevel criteria based on channel flow capacity in Chiguaza | | |

Figure 6-6 Outline of Monitoring and Early Warning Plan for Bogota

### 6.5.2 Basic Conditions and Planning Principle

The target area of the plan is the study area in Bogota including the Chiguaza, Santa Librada, Yomasa, and La Estrella Trompeta creek catchments.

The above-mentioned plan was prepared for short, middle, and long term. The target year of the plan is set up in 2020, assuming that the implementation of the plan starts in 2007 and fourteen (14) years would be required for completion. The reason for starting the said plan in 2007 is that the pilot project(s) in this Study will be undertaken as a part of the proposed plan.

Table 6-3 Definition of Short, Middle and Long Term Plan

| Plan | Year | Definition |
|---|---|---|
| Short | 2007-2008 | It is urgently required and should be implemented as pilot projects for the basis of middle and long plan. |
| Middle | 2008-2012 | This is an extension for a short term plan in order to secure the target creeks. |
| Long | 2013-2020 | This is a fully advanced system based on the experience of short and middle plans. |

In order to achieve the above objectives, the Study Team proposed the following basic principles for the planning.

- The purpose of the proposed plan is to prevent, in the near future, the same flood damage to the people in the area affected previously, or mitigate any damage through the plan.
- Thus, as a tool for the above-mentioned objective, monitoring of hydro-meteorological conditions by equipment and preparation of early warning system based on the monitored data are required.
- Therefore, the people who must evacuate in an event of flood should understand the meaning of the early warning system and take the necessary actions. In this case, unless the people understand the importance of the system and make use of the system effectively, any expensive equipment for the monitoring and early warning would be meaningless.
- In the above context, the Study Team has studied and discussed what to do at first in Bogota in order to achieve the study purposes, while believing that installation of monitoring equipment in the study area is just a tool.

### 6.5.3 Monitoring and Data Gathering System

(1) The target area for Overall Monitoring Plan with Priority

Among the four (4) creeks objects of the Study Area, the flood disaster which caused victims happened in the Chiguaza basin in May 1994. According to newspaper articles relating the May 1994 flood, four (4) people died in the flood. This is deemed the most serious floods in the Study Area on record. In other creeks concerned by the Study Area, such serious floods could not be confirmed by the Study Team. This is one of the main reasons why the Chiguaza creek catchment was selected as the pilot project area.

As the first step, this flood phenomenon shall be set on the basis of the early warning system planning.

The May 1994 flood in the Chiguaza basin can be characterized by the movement of deposited materials on the river bed in the Zuque creek which is located at the highest upstream of the Chiguaza, overflow of sediment to the street along the right side of Chiguaza due to the small capacity of culvert crossing the Carrera Oriente. Also in the middle reach, an overflow of water took place in the street along the left side of the Chiguaza.

In the case of Chiguaza, the flood phenomena can be classified into three (3) according to the river bed slope.

For the area of Los Puentes upstream, first of all, the rainfall measurement, especially for short duration amount of rainfall, should be made. In the upstream area , currently the Juan Rey station (DPAE and EAAB); however, it is far from the Zuque creek where the May 1994 flood happened. In order to monitor the rainfall near the Zuque creek, another rainfall station is necessary. In this context, the area called Quindio was selected as a candidate area.

As mentioned in 6.5.2 (3), the people who suffered from past floods should participate in the hydro-meteorological measurement so that they can understand the importance and meaning of the monitoring equipment. Thus, along the Chiguaza Creek, some candidate locations for manual water level monitoring were considered.

Also, to ensure a more accurate early warning system in the Chiguaza, not only rainfall data but also water level measurement is necessary to accumulate the continuous data set of rainfall and water level. Since there is no automatic water level station in the Chiguaza at this moment, some candidate locations for automatic water level monitoring were considered as long as the location is not affected by the backwater of the Tunjuelo River.

Additionally, the security issue which ensures a stable maintenance and protection against robbery was considered

Table 6-4 List of Stations to be Monitored for DPAE (Short Team)

| Creek | Data | Monitoring Station | Existing or New | Purposes |
|---|---|---|---|---|
| Chiguaza | Rainfall | Juan Rey (DPAE telemeter) | Existing | The currently suspended station should be re-started as soon as possible. |
| | | Moralba in the upper part (self-recording type with small display monitor) | New | To supplement the data of Juan Rey station, self-recording type stations shall be installed in the upper part of the Chiguaza (for example Zuque creek). In order to let people observe the data timely, the equipment should have a small display. |
| Chiguaza | Water level | El Hoyo (DPAE station at bridge before the confluence of the Chiguaza to the Tunjuelo river) | Existing | To analyze the response for the discharge from the Chiguaza creek in the event of storm in the Chiguaza catchment. |
| | | Mullions at bridge of the Chiguaza downstream | New | To analyze the response for the discharge from the Chiguaza creek in the event of storm in the Chiguaza catchment.<br>To prepare water level and discharge relation curve, the rainfall and runoff relation will be studied as well as to issue a warning to the downstream based on the monitored water level. |
| | | La Gloria (affected area along the Chiguaza upstream) | New | To let the people understand the importance and real meaning of the hydrological data, at first they should be trained to observe the hydrological data such as reading of staff gauge by themselves. |

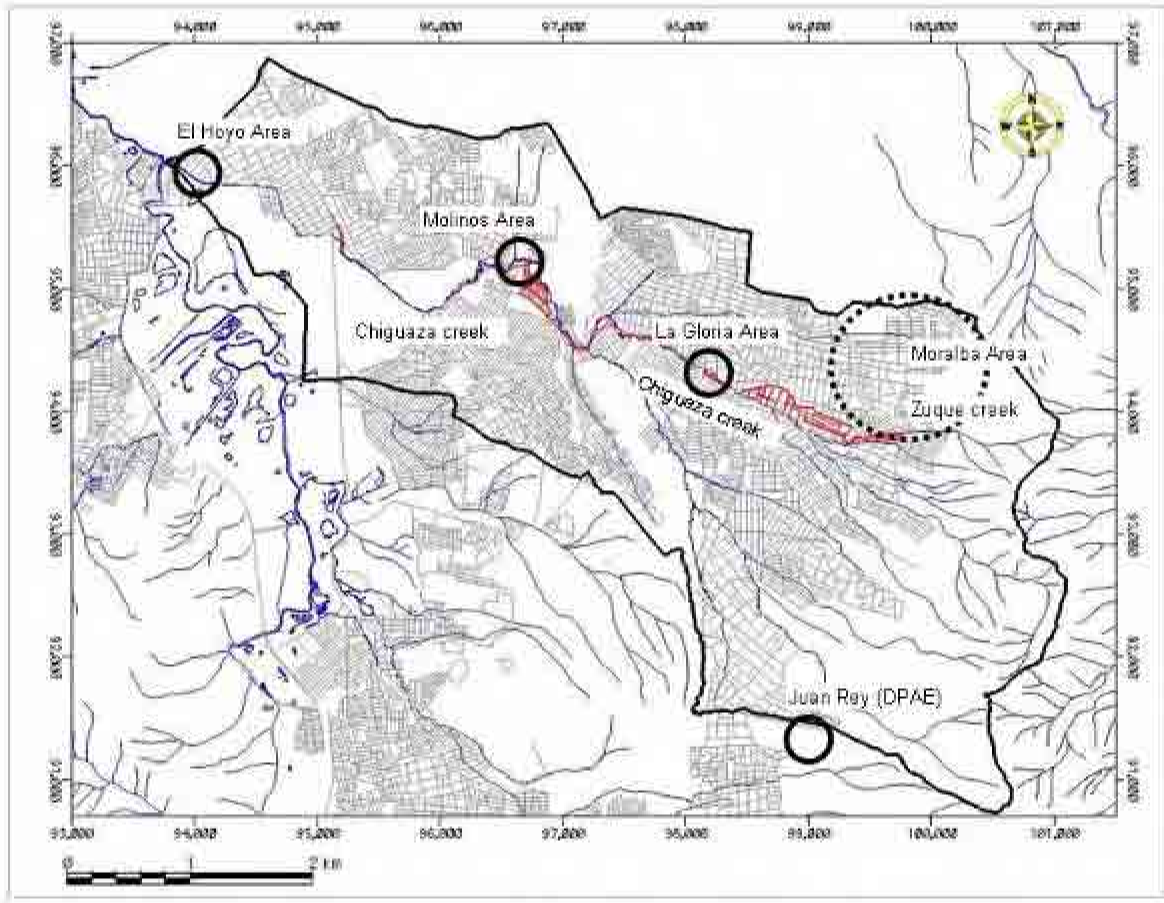



Figure 6-7 Location of Monitoring and Target Area

(2) Data Gathering System Planning

The proposed data gathering system can be separated into two (2) phases, namely, "data accumulating and people's training phase" and "timely and accurate warning using advanced technology phase".

1) Data accumulating and people's training phase (Short Term Data Gathering System)

Based on the above data, the short-term monitoring system is as follows,

Table 6-5 Monitoring Point, Equipment and Monitoring Frequency

| Point | Item | Equipment | Monitoring Frequency |
|---|---|---|---|
| Moralba(school) | 10 minutes rainfall | Tipping bucket type rainfall gauge, data logger with display、solar panel, battery, cabinet | Hourly monitoring by Security guard of school |
| Molinos(foot bridge) | Water level (middle reach) | Staff gauge, ultrasonic type Water level gauge、data logger with display、solar panel, battery, cabinet | Three times a day monitoring by community and security guard of school |
| La Gloria | Water level (upstream reach) | Staff gauge, simple Water level detector | Three times a day monitoring by community and more frequent monitoring standby during high water |

| | | | |
|---|---|---|---|
| El Hoyo | Water level (downstream reach) | Staff gauge | Three times a day monitoring by civil defense |

Among the above-mentioned stations, in Moralba and Molinos, automatic-recording type stations were proposed. The daily monitoring by community or school guard should be continued.

2) Timely and accurate warning using advanced technology phase (Mid and Long term Data Gathering System)

In the mid-term, the installed automatic recording rainfall gauge at Moralba and the automatic recording type water level gauge at Molinos should be telemeterized only when such upgrading is necessary. Also in Molinos, the discharge measurement should be done in order to calculate the water level and discharge relation. By the discharge calculation, the runoff volume can be estimated to study the effective rainfall for more reliable early warning system. The discharge measurement should be done by the community in charge of the water level measurement.

Regarding the data gathering system for rainfall, since DPAE has already the telemeter system, the above proposed new stations is assuring a compatible system for the existing ones.

In the Yomasa creek, in the upper part of the catchment (Alemana upstream) there is potential of flash flood because sediment depositions and recent slope failure are recognized. Therefore, rainfall measurement in upper part and water level measurement in the downstream shall be started using simple equipment as it has been done for the Chiguaza creek.

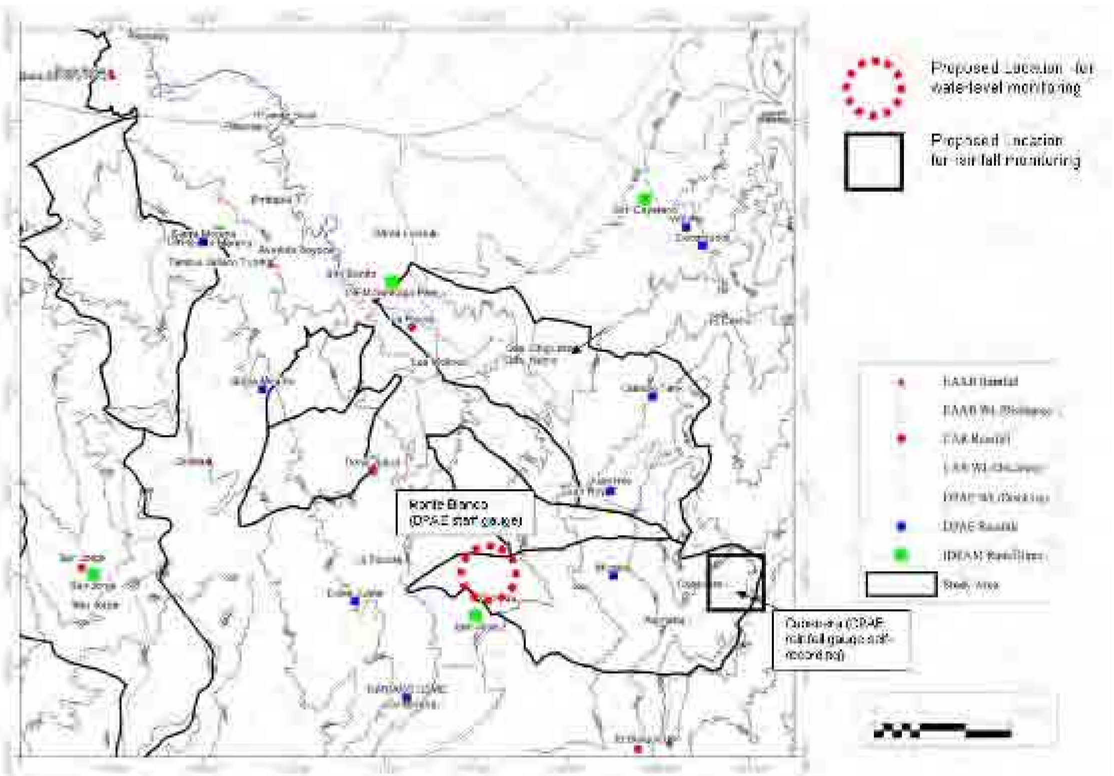



Figure 6-8 Proposed Additional Location to be monitored for DPAE (Mid Team)

### 6.5.4 Warning criteria

(1) Water level Criteria

In the Chiguaza, the most critical section is taken at 0+982. At the right bank, when the water level elevation is 2,558.3 m, the overflow will happen. At that time the discharge at this section can be evaluated at 80 $m^3/s$ according to the water level and discharge relation curve.

At Molinos station the discharge 80 $m^3/s$ is corresponding to the water level 3.2 m on the staff gauge. It means the water level 3.2 m in Molinos constitutes a critical condition at downstream such as Station 0+982. Therefore the warning level is set tentatively at 2.2 m on the Molinos staff gauge.

(2) Rainfall Criteria

a. General Alert

Chapter 4 of this main report shows that in Chiguaza, 53 % of the “flood” incidents occurred when rainfall (La Picota or Juan Rey) exceeds 10 mm (daily). In other creeks, the daily rainfall corresponding to the above criteria is larger than 10 mm. Tentatively, the following criteria shall be set for the Study Area.

| | |
|---|---|
| General Alert | Daily Rainfall 10 mm for the four (4) creeks |

b. Chiguaza Middle Stream

According to runoff analysis in the Chiguaza, the flow capacity of the critical point in Molinos reach corresponds to ten (10) years return period. At Los Puentes, the 10 years return period is 43 mm/h for 27 minutes, which means the rainfall amounts to 19.4 mm for 30 minutes. Tentatively, the following criterion is set for the Chiguaza middle stream.

| | |
|---|---|
| Alert | 10 minutes rainfall 6 mm |
| Warning | 30 minutes rainfall 20 mm |

## 6.6 Implementation Program

The implementation program between 2007 and 2020 is shown in Table 6-6. The cost is also estimated in US$. Year 2007 represents the year of pilot project in the JICA Study.

# Table 6-6 Implementation Schedule for DPAE

unit: US$

| Actions | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Short Term | | Middle Term | | | | Long Term | | | | | | | | |
| Monitoring and Early Waning System Establishment | | | | | | | | | | | | | | | |
| Monitoring and Data Gathering System | | | | | | | | | | | | | | | |
| Installation of Monitoring Equipment for Pilot Project | | | | | | | | | | | | | | | |
| 1 Rain Gauge at Moralba School(Chiguaza creek) | 10,000 | | | | 2,500 (telemeter) | | | | | 10,000 (replace) | | | | | |
| 2 Waterlevel Gauge at Mollinos(Chiguaza creek) | 13,000 | | | | 2,500 (telemeter) | | | | | 13,000 (replace) | | | | | |
| 3 Water Level Gauge at La Gloria(Chiguaza creek) | 5,000 | | | | | | | | | | | | | | |
| Installation of Monitoring Equipment for Future Stage | | | | | | | | | | | | | | | |
| 1 Yomasa upstream Rainfall Station (Yomasa creek) | | | 10,000 | | | 2,500 (telemeter) | | | | | 10,000 (replace) | | | | |
| 2 Yomasa downstream Water Level Gauge (Yomasa creek) | | | 5,000 | | | 2,500 (telemeter) | | | | | 5,000 (replace) | | | | |
| 3 Radar System for IDEAM | | | | | | - by IDEAM | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| Warning Criteria | | | | | | | | | | | | | | | |
| Hydrological Consideration | | | | | | | | | | | | | | | |
| Analysis of Flood Concentration Time (Pilot Project) | 6,000 | | | | | | | | | | | | | | |
| Development of Entire Catchment Model | | | | | | 6,000 | 6,000 | | | | | | 6,000 | 6,000 | (upgrade) |
| Mapping of Susceptibility | | | | | | | | | | | | | | | |
| Susceptibility of Flood and Flash Flood | 6,000 | | | | | | | | | | | | | | |
| Updating of Maps depending on the flood occurrence | | | | | | 6,000 | 6,000 | | | | | | 6,000 | 6,000 | (upgrade) |
| Set Appropriate Warning Criteria | | | | | | | | | | | | | | | |
| Setting of Tentative Warning Criteria | | | | | | | | | | | | | | | |
| Hydrological Analysis using Data during the Pilot Project Period | 10,000 | | | | | | | | | | | | | | |
| Modification of Warning Criteria | | | | 2,500 | | | 2,500 | | | 2,500 | | | 2,500 | | |
| | | | | | | | | | | | | | | | |
| Community Based Disaster Management (CBDM) Activities by DPAE | | | | | | | | | | | | | | | |
| Training on Hydro-meteorological Observation | - | | | | | | | | | | | | | | |
| Information Transfer Simulation and Drill | | - | | | | | | | | | | | | | |
| Evacuation Drill | | - | | | | | | | | | | | | | |
| Community Based Hydro-meteorological Observation | | | | | | | | | | | | | | | |
| Total | 50,000 | 0 | 15,000 | 2,500 | 5,000 | 17,000 | 14,500 | 0 | 0 | 25,500 | 15,000 | 0 | 14,500 | 12,000 | 171,000 |

## 6.7 Pilot Project

### 6.7.1 Outline of Pilot Project

(1) Installation / operation of monitoring equipment

1) Rainfall Station in Moralba

The rainfall station was installed inside the Moralba school in Ciudad Bolivar, in Bogota City. In order to measure the short duration rainfall, a tipping bucket type sensor was selected. The sensor was placed on the roof of the school class building and the data logger, solar panel were installed in the security house in front of the school entrance. Also in order to allow seeing the real time rainfall amount, a display was installed in the logger, which shows the current date and time, the latest 10 minutes, 1 hour and 24 hours rainfall in millimeter.

In addition, the Study Team will install by January 2008 a sound alarm device in the data logger which will beep sound for the security guard when the accumulated 30 minutes rainfall exceeds a threshold.

Since the rainfall data must be monitored by people, the Study Team proposed the school and DPAE that the security guard hired by Moralba school would monitor the display and record the hourly data on data sheet. The school and DPAE agreed with this proposal and the security guard started the monitoring at the beginning of October 2007. DPAE prepared the data sheet for the security guard and was collecting them periodically. In the case of heavy rainfall, by the sound alarm device of the data logger, the security guard can notice the current rainfall is exceeding the threshold and should inform the situation to DPAE and other downstream communities.

The data logger can store the 10 minutes rainfall continually. Data download from the data logger to a notebook computer is possible using Microsoft Excel macro program.

The maintenance of the station was undertaken periodically by the Study Team.

2) Water level Station in La Gloria

The water level station was installed in La Gloria in Ciudad Bolivar, in Bogota City. The station is composed of a water level staff gauge and a simple water level detector device. The Study Team proposed to DPAE that the communities should monitor the water level staff gauge and record the data every day and DPAE agreed with this proposal.

In order to measure the instant water level rising, a simple water level detector device was introduced in La Gloria since the flood concentration time is quite short in the site. The main unit of the alarm device was installed in a house of an observer located in the right bank of the Chiguaza creek. The observer usually monitors the water level of the staff gauge three (3) times a day; however, when the alarm rings, the observer can notice the water level rising and measure the instant water level.

The maintenance of the station was undertaken periodically by the Study Team.

3) Water level Station in Molinos

The water level station was installed in Molinos in Ciudad Bolivar, in Bogota City. The station is composed of water level staff gauge and non-touch stage sensor (ultrasonic water level sensor). The ultrasonic sensor was placed under the foot bridge. The data logger and solar panel were installed in Colombia Viva school located on the right side of the Chiguaza creek. The Study Team proposed DPAE that the communities should monitor the water level staff gauge and record the data every day and DPAE agreed with this proposal.

The data logger can store the water level continually. Data download from the data logger to a notebook computer is possible using the Microsoft Excel macro program.

The maintenance of the station was undertaken periodically by the Study Team.

### 6.7.2 Lesson Learned from the Pilot Project

(1) Flood Concentration Time

The frequency of the monitoring is basically three (3) times a day; however, the community has been recording the high water level as much as possible. In October 2007, La Gloria recorded three (3) high water events at October 13 and October 14 and October 18.

The flood concentration time at La Gloria can be assumed about 22 minutes (until sub-catchment 2-11) according to Kirpich formula.

In the case of October 14, at 2PM the water level was 2.2 m at La Gloria while the Moralba rainfall started at 1:38-1:48PM. The time of water level was recorded by people, so there might be some range of time. For October 13 and October 18, there are 42 minutes and 22 minutes, respectively. Such data should be accumulated more frequently; however, the assumed flood concentration time can be evaluated within the actual range or safety side according to the data obtained in the pilot project.

The monitoring at La Gloria does not contribute directly to the early warning issue for the downstream area; however, as we can see previously, the data of La Gloria are very valuable for the calibration of hydrological parameter.

# CHAPTER 7 RECOMMENDATIONS FOR BOGOTA

## 7.1 Common

One of the significant features in the Study area for flood is the small creek catchment and short flood concentration time. For this type of area, the early warning system needs the timely and accurate information from local level, and also the gathered information should be transferred to others timely and accurately. Also in the landslide area, to know any local phenomenon which may indicate the change of landslide conditions is very important for monitoring system. Considering these necessity in local level, it is regarded that community participant in the monitoring and early warning system is inevitable because they are the first respondents in the case of flood and significant change of landslide area.

For the sustainable monitoring and early warning system, the integration of institutional resources and community participants should be emphasized as it was discussed in a series of technical transfer seminar in the Study. DPAE has already recognized the necessity of technical training for community who can participate in hydrological monitoring and information transfer as the first respondent in order to establish the monitoring and early warning system based on the cooperation with communities. Since DPAE has already started to work with communities in Bogota, DPAE should continue further to develop the collaboration activities with communities in flood ad landslide prone areas.

## 7.2 Landslide

### 7.2.1 Stabilization Works in Altos de Estancia

The most effectiveness measure to be taken for Altos de Estancia is a relocation from the danger area, and DPAE developed a relocation program for families toward immitigable high risk area, and most of inhabitants of Phase I area and Phase II area have been relocated. Therefore, an emergency measure is not required for the Landslide. DPAE is planning the stabilization works in the Landslide; however, the details are not confirmed yet. The stabilization works are classified into two major categories, namely works for reduction of driving forces and works for increase in resistance force. In a large scale landslide such as the Landslide in Altos de Estancia, a method for reduction of driving forces should be adopted as a priority, since cost effectiveness for a large scale landslide is normally better than a method for increase in resistance force.

A noticeable situation occurred in Altos de Estancia: the surface water coming from an inadequate drainage system in Phase III area flows all over the front part of the Landslide and this creates many channels and pools in the Landslide itself. It is easily understood that the water inflow affects greatly the stability of the Landslide. What is most important and effective for the stabilization of the Landslide is to reduce the groundwater level, and prevent the water penetration into the ground, especially from sewer and rainwater.

### 7.2.2 Monitoring in Altos de Estancia

The DPAE engineers and the communities must check the ground conditions through regular patrol. A visual observation of the Landslide and its adjacent areas must be undertaken periodically as for the conditions of the ground, and, if necessary, the site must be measured to determine whether or not any deformation of the ground occurs. As soon as possible, a periodic inspection of the landslide prevention facilities, if any, must be made to detect abnormalities. If cracks or other ground abnormalities on the face of a slope or abnormalities of landslide prevention facilities are found, the changing conditions of such abnormalities should be monitored, followed by a survey so as to allow preparing the emergency mitigation or stabilization works. This observation survey will allow examining the extent, direction of movement, and mechanism of landslides in details when any sign of landslide motion such as slide scarps or cracks are found or when there will be a possibility of occurrence of landslides.

The instrumentation and monitoring could be applicable to following conditions in this Landslide.

a) Safety of the residential area; this will confirm whether the Landslide activity is not approaching the residential areas. This monitoring should be continued as far as the people are living there along the rim of the Landslide.

b) Monitoring on specific cracks and deformation on structures and the ground; this concerns the monitoring works on cracks or deformations on the ground or structures when they are found. This monitoring should be applied every time when cracks or deformation are found on the ground and structure.

c) Safety of construction works; this concerns the monitoring works to prevent accidents under construction that may occur on both workers and residents surroundings. This monitoring should be applied on every construction works as long as the works continue.

d) Verification of effectiveness of stabilization works; it is necessary to confirm the effect of stabilization woks at completion of the construction works.

## 7.3 Flood

1) The early warning criteria are tentatively proposed by the Study Team for only estimations, since the conditions come from scarcity of registers. Such rainfall criteria and water level should be updated to specify their reliability through the use of registered information by the community even after the Study; therefore, those tentative criteria are not definitive values.

2) After the Study, DPAE should conduct the following activities,

(a) Continuous monitoring

The integration of the community monitoring and the telemeter monitoring systems in Bogota are related to the policy of DPAE. One of the important strategies for risk management of floods for DPAE is to give a high priority in proceeding with the community monitoring in the catchment of Chiguaza. The recommendation for monitoring in the catchment made by the Study Team will constitute the starting point for the system. With more information such as monitored data or information from executed by other district entities, DPAE will review and revise the location of the monitoring.

Based on the above-mentioned principles, DPAE should start the following activity recommended by the Study Team.

- Continuation of community people's water level monitoring of staff gauge at Molinos and La Gloria
- Starting and continuation of community people's water level monitoring of El Hoyo bridge with coordination of the related communities

In Molinos water level station and Moralba rainfall station, automatic recording equipments were installed in the Study. The data logger for the sensor includes the display to indicate the current monitored data. Even if the automatic-recording type observation equipment is installed, a manual observation by the community people should be continued.

(b) Studies for early warning criteria using the monitored data

The early warning criteria proposed in this report are only estimated values based on assumption, and they should be modified as early as possible using the observation results, for which DPAE will integrate this data into the existing city flood alert system, including the constant revision to calibrate and adjust the alert criteria.

Since the early warning criteria can be modified only using observed water level relationship, the relation between the water level in the past flooded area and the upstream should be monitored continuously.

(c) Establishment of more reliable early warning plan,

The proposed flood early warning plan would operate properly under the condition that there will be no significant clogging, one of the cause of past serious flood events. The flooding, such as the one of May 1994 that took place through clogging of the structures in the zone, cannot be mitigated by any early warning system.

The creek conditions in the study area have been constantly changing because of channel improvement works as well as sedimentation and garbage. The hydraulic parameters associated with the flow capacity should be monitored and evaluated periodically in order to take into account the revision of the early warning criteria.

(d) Divulgation of the plan to the communities.

Installed equipment may be stolen in certain circumstances or may be damaged depending on the natural conditions. In order to ensure the sustainability for the monitoring system, DPAE should coordinate with the community to watch the equipment on a daily basis.

## PART 3 MONITORING AND EARLY WARNING PLANNING IN SOACHA

# CHAPTER 8 SOACHA SOCIO-ECONOMIC CONDITIONS

## 8.1 Administrative System

The Soacha Municipality is located 18 km southeast of Bogotá. The Municipality has two defined areas, namely urban area with 19 $km^2$ of territorial extension with 98% of the total population of the Municipality, and rural area with 165 $km^2$ territorial expansion.

The urban areas are divided administratively in 6 communes with 348 neighborhoods[1], and the rural area is divided into two jurisdictions with 15 rural villages, and each one has its Corregidor, or supervisor designated by the mayor of Soacha.

The administrative structure is constituted by a Municipal Mayor elected through popular vote, with three control headquarters (Internal Control, Disciplinarian Control, Legal Advise) and eight secretaries (General, Government, Planning, Treasure, Social Development, Education, Health and Infrastructure).

Disaster Management Administration

CLOPAD (Local Committee for Disaster Attention and Prevention) is responsible for disaster management activities at the municipal level. The members of CLOPAD include the Municipal Departments, Firefighters, Civil Defense, Volunteers, and International agencies.

As the CLOPAD is a relatively new organization, has a low budget for disaster prevention activities and lacks an exclusive staff, it has been inactive, and consequently, the people living in the municipality are lacking information about the hazards of their neighborhood and do not know how to cope with eventual emergencies.

## 8.2 Socio-Economic Condition

### 8.2.1 Population

According to the Experimental Census 2003, Soacha is in the fourteenth municipality with about 360 thousand inhabitants. The majority of the urban population is concentrated in the urban area and family members amounts to 3.9 people per household.

The Municipality experienced a population growth with higher rate. From 1985 to 1993, the population was growing at the rate of 5.9 %/annum, with an increase of 6.3%/annum from 1993 to 2003.

### 8.2.2 Economy in Soacha

Soacha significantly contributes in the regional economy. The GDP in Soacha exceeds 1.3 trillion pesos in 2002 and it shares 11.8% of the GDP of Cundinamarca Department.

Mining is one of the main industries of Soacha with 113 open sky exploitation mines[2]. This activity supports the local economy; however, it becomes a main cause of adverse effect of environment in the area.

Soacha's main economic activity changed in the last decades moving from agriculture to services and industry activities. According to a survey carried out by the municipality in 2004, approximately 102 companies settled in Soacha, and 5,551 employees[3] with higher skills were hired. Accordingly, few

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1: Source: File of Alcaldia de Soacha(Power point presentation)partially printed
2 Ideam.
3 Source (http://www.alcaldiasoacha.gov.co/infoNoticia.asp?IdNot=131)

opportunities were left to the locals with low skills which kept the informal and low qualified tasks.

Commercial activity in Soacha is relatively active compared to other municipalities in Cundinamarca with its economic share of 39%[4]. However, this commercial activity does not offer a wide range of employment opportunities or solutions to unemployment because in most cases these small businesses are attended by immediate family members.

In spite of its economic activity, Soacha remains a municipality with low budget, because of lower employment opportunities and an increasing rate of non-qualified and underemployed population. The Municipality promotes its economic activities by helping the working population to reduce their daily commuting distance and costs to Bogotá in search for low pay jobs as domestics, street vendors, construction workers, security guards, or recycling workers.

### 8.2.3 Socio-Economic Conditions

Since the Soacha Municipality continuously receives a large number of immigrants from all over the country, it can be said that the socio-economic conditions of the municipality are affected by the presence of these immigrants.

It is well known that the communities of displaced people and families are enjoying minimal infrastructure and deficient public services, including access to health. Their settlements are sometimes classified as informal settlements lacking legal status or titles for their land. These undocumented "barrios" are living mainly in "Comunas" 4 and 6[5].

In Soacha, those most exposed to harsh conditions are children, youth, elders and people with physical disabilities. The Social Development of the municipality has a list of local organizations classified by types which are working for the social activities in the municipality. According to the list, 57 organizations out of 217 currently devote their activities to physical disabilities, and another 32 groups are formed by or working with elders.

### 8.2.4 Public Services and Education

The municipality has a relatively high coverage of public services except "Comuna" 4 where it suffers from lack of basic services with low coverage of 25% of electricity, water supply, and sewage system.

A total of 165 schools are located within the municipality to provide education to the citizen. Most of the students are receiving traditional education in academic schools and barely a small percentage of total population can frequent the university.

## 8.3 Urban Planning

### 8.3.1 Urban Expansion

With the permanent arrival of immigrants into the municipality, housing areas must be expanded. The land suitable for life has already been occupied and consequently only available spaces for immigrants under hardship conditions are the surroundings of the mining areas (quarries).

The uncontrolled urban expansion with poor infrastructures can be observed in many places within the municipal territory, and this situation creates unfavorable living conditions (poor infrastructure such as lack of road, water supply and sewerage, facing hazards, etc.).

In the informal development areas (non zoned area), no public works are allowed and investments in infrastructures has been thus delayed. Sloppy roads and rain runoff as well as sewerage overflow can be seen anywhere in and around the informal development areas.

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4 Source: Alcaldía de Soacha website: (http://www.alcaldiasoacha.gov.co/infoNoticia.asp?IdNot=131)

5 Garzón, Clara Stella. *Diagnóstico de Género de la Población de Soacha, con énfasis en las Mujeres Desplazadas*. Fondo de Desarrollo de las Naciones Unidas para la Mujer. UNIFEM. Colombia. 2005. www.acnur.org/biblioteca/pdf/4088.pdf.

Other recent topic related to urban expansion is the expansion of the public transportation system. The increase of individual's mobility will generate greater density patterns in the urban cluster, and spin-off new commercial and service activities.

### 8.3.2 Territorial Ordering Plan (POT)

The POT 2000 Zoning Plan has been established in order to check the uncontrolled urban expansion and normalize the land use by integrating the urban development and social, environmental, and disaster management aspects. However, it has been disrupted by the urban expansion, continuous migration, and industrial growth. Areas that were once designated as open space, such as slopes and hills, old mines, and rural lands have already been heavily populated and became hazardous areas for inhabitants.

To overcome the difficulties of the present situation, the Soacha Municipality is updating the POT 2000, and the first phase (Validation) has been completed recently, while the Second Phase (Assessment) is working on the current conflicting topics, such as transportation, connectivity, population, and urban growth. The current analysis of the POT concerns the hazard prone areas and activities, emphasizing the development of policies to protect environmental resources and its enforcement.

### 8.3.3 "Barrio" Area

Ninety-one out of 314 "barrios" are illegal and most of the illegal "barrios" can be found in "Comuna" 4 where displaced persons are mainly settled down, and "Comuna" 6 with a high percentage of illegal settlements inhabited mainly by Soacha natives [6] and also by displaced people.

For the legalization process in "barrio" areas, three independent processes are required, namely the legalization of the land, the building or house, and the legalization of the "barrio" as urban settlement.

## 8.4 Citizen Participation

The office of community participation of the Soacha Municipality is in charge of supervising social organizations (e.g. JAL, JAC, etc.). All six "Comunas" in the urban area and two Jurisdictions in the rural area have JAL organization. JAC is organized by community level and they are also directly supervised by the municipality. The activities of JAC are various, and JAC of Florida II which is located in the Study Area has shown positive achievements.

The JAC of Florida II was constituted in 1986, and has now a total of 93 members. Nine (9) Board directors (originally 17 directors) are working actively. The Board of Directors; President, vice-president, Secretary and Treasurer, and representatives composing commissions such as, Sports, Safety, and Health commissions are elected through neighborhood meeting held every four years.

## 8.5 Institutional Aspects on Disaster Management

According to the chronological review of the legal situation for disaster management, the disaster management concept has changed from the emergency response approach to a total risk reduction approach including institutional strengthening and land use regulations.

Soacha Municipality establishes its local disaster prevention committee (CLOPAD) in 2005. It is composed of a wide range of existing local institutions related to disaster management, not only the organizations directly involved in the disaster management but also the Planning Department of the municipality.

During the flood and landslide disaster caused by heavy rainfall in May 2006, CLOPAD made various efforts to mitigate the damage. The followings should remain as lessons learned during the emergency.

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[6] Ramírez, Juan Carlos-Muñoz Jorge. *Así son los hogares en Soacha* . DANE. Bogotá, Abril 2004

- It is necessary to consolidate the plans and protocols, and to establish a routine for their upgrading.
- It is necessary to improve at least one road in the high risk area as an infrastructure of emergency operation.
- It is necessary to have an office and warehouse for CLOPAD to ensure the logistic support for emergency operation.
- Stable funds for disaster prevention, response and permanent resettlement are required.
- Training at all levels from government to community is necessary to enhance the capacity to cope with disasters.

The direction of the municipality has lead towards working among agencies. A collaboration among institutions and NGOs has been established since 2004. Currently, Red Cross Cundinamarca, OPS/OMS and the National University, Center for Disaster Prevention (CEPREVE)[7], PAHO/WHO and UNDP are carrying out programs.

With the communities in the Study Area facing frequent disaster events, the awareness on the disasters is relatively high though CLOPAD does not operate actively.

CLOPAD prepared a "Municipal Emergency Plan" and "Family Emergency Plan". These documents cover the resource inventory with contact details, drafts of Protocols in case of emergency, necessary approach for any hazardous event, list of minimum emergency kits recommended by CLOPAD and instructions for Evacuation.

7 Need Assessment. Altos de Cazucá, Municipio de Soacha. OCHA. Junio de 2006.

www.colombiassh.org/imagenes_nuevas/documentos/Need_Assesment_Soacha_14.06.06.pdf

# CHAPTER 9 SOACHA RAINFALL AND DISASTERS

## 9.1 Disaster Events for the Analyses in Soacha

For the analyses of the relation between hydrological conditions and disasters in Soacha, disaster records from the fire station (Bomberos) from May 1996 to April 2006 for inundation and from May 1998 to June 2006 excluding 2004 for landslide are used. The disaster records by the fire station do not include enough information to understand the magnitude of disaster, such as inundation depth, inundated area and damage to people and houses; therefore it can analyze only the relation between hydrological conditions and occurrence of disasters.

## 9.2 Analysis for Relation between Hydrological Conditions and Selected Disaster Events

The relation between hydrological conditions and disasters in Soacha is analyzed using collected daily rainfall data and disaster records.

### 9.2.1 Analyses for Landslide

The same analysis as for landslide in Bogota is undertaken for the selected landslide events. Rainfall amount using the analysis is the maximum value of three (3) stations of Las Huertas (EAAB), Bosa Barreno No.2 (EAAB) and Sierra Morena (DPAE).

Figure 9-1 shows the daily rainfall, 3 days rainfall and accumulative rainfall in the day when a number of landslides occurred on the same date. Each rainfall value is the maximum value of the three stations described above.

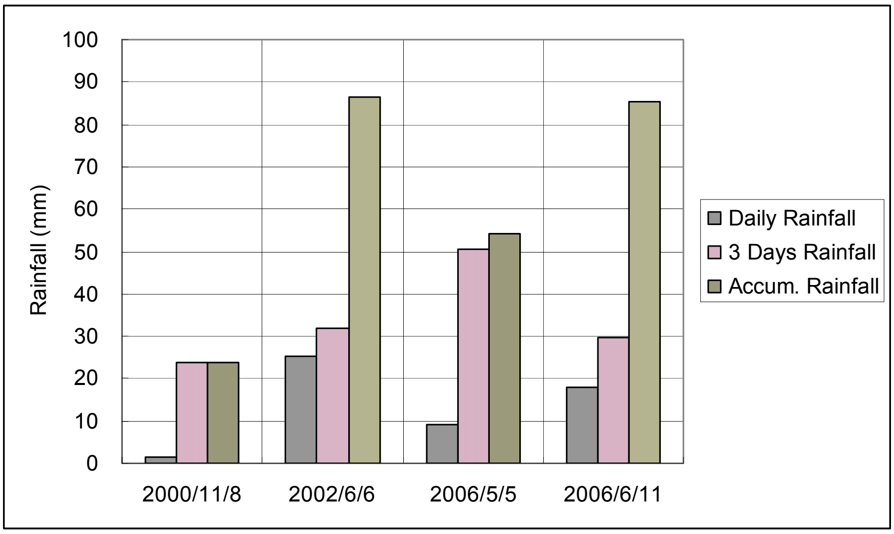



Figure 9-1 Daily, 3 days and Accumulative Rainfall when Landslides Occurred

The relation between landslide events and three (3) days or accumulative rainfall is summarized in Table 9-1.

Table 9-1 Summary of Relation between Rainfall and Landslide Events

| Area | Rainfall | | Rainfall (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | <10 | <20 | <30 | <40 | <50 | <60 | <70 | <80 | <90 |
| Soacha | 3 days | Occurrence of Landslide | 0% | 0% | 50% | 75% | 75% | 100% | 100% | 100% | 100% |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Urban Area | Rainfall | Average in 1996-2006 | 78% | 92% | 97% | 99% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Occurrence of Landslide | 0% | 0% | 25% | 25% | 25% | 50% | 50% | 50% | 100% |
| | | Average in 1996-2006 | 71% | 84% | 91% | 94% | 97% | 98% | 99% | 99% | 100% |

### 9.2.2 Analysis for Inundation

Table 9-2 show the daily rainfall amount of four (4) selected stations in all the days when inundation occurred (101 days, 150 inundation events) from May 1996 to April 2006. More than 50% of inundation events occurred when daily rainfall amount was less than 10 mm.

Table 9-2 Summary of Relation between Daily Rainfall and Inundation Events

| Daily Rainfall (mm) | San Jorge (IDEAM) | Las Huertas (EAAB) | Bosa Barreno No.2 (EAAB) | Sierra Morena (DPAE) | Max of 4 stations |
|---|---|---|---|---|---|
| 0-5 | 65% | 57% | 58% | 49% | 34% |
| 5-10 | 8% | 23% | 19% | 24% | 22% |
| 10-15 | 9% | 11% | 9% | 7% | 15% |
| 15-20 | 8% | 5% | 4% | 9% | 10% |
| 20-25 | 7% | 2% | 7% | 7% | 11% |
| 25-30 | 1% | 1% | 2% | 3% | 5% |
| 30-35 | 0% | 1% | 0% | 0% | 1% |
| 35-40 | 2% | 0% | 1% | 0% | 3% |

Table 9-3 summarizes the relation between past inundation events and maximum value among the four (4) selected stations.

Table 9-3 Summary of Relation between Daily Rainfall and Inundation Events

| Area/Station | No. of Days Inundation Occurred from 1996 to 2006 | Daily Rainfall (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | < 5 | < 10 | < 15 | < 20 | < 25 | < 30 | < 35 | < 40 |
| Soacha Urban Area (Las Huertas (EAAB), Bosa Barreno No.2 (EAAB), Sierra Morena (DPAE) & San Jorge (IDEAM)) | 101<br>100% | 34<br>34% | 56<br>55% | 71<br>70% | 81<br>80% | 92<br>91% | 97<br>96% | 98<br>97% | 101<br>100% |

# CHAPTER 10 LANDSLIDE

## 10.1 Outline of Landslides

The study areas are parts of "COMUNA" 4 named Altos de Cazuca area and El Divino Niño area in "COMUNA" 6. Altos de Cazuca area located near the boundary of the southern urban area of Bogota city is divided into 32 districts named "barrios". El Divino Niño area is one of the "barrios" in "COMUNA" 6.

Landslides, mostly classified into rock fall and surface collapses, in the study areas are found at abandoned quarries in Altos de Cazuca area where houses gathered in the upper and lower area close to steep slopes and landslide hazard areas, also, houses gathered in landslide hazard area formed by a quarry in El Divino Niño area.

Term "Landslide": the perceptible downward sliding or falling of a mass of earth, rock, or mixture of the two. The term "landslide" includes a wide range of ground movement, such as rock falls, deep failure of slopes, and debris flows.

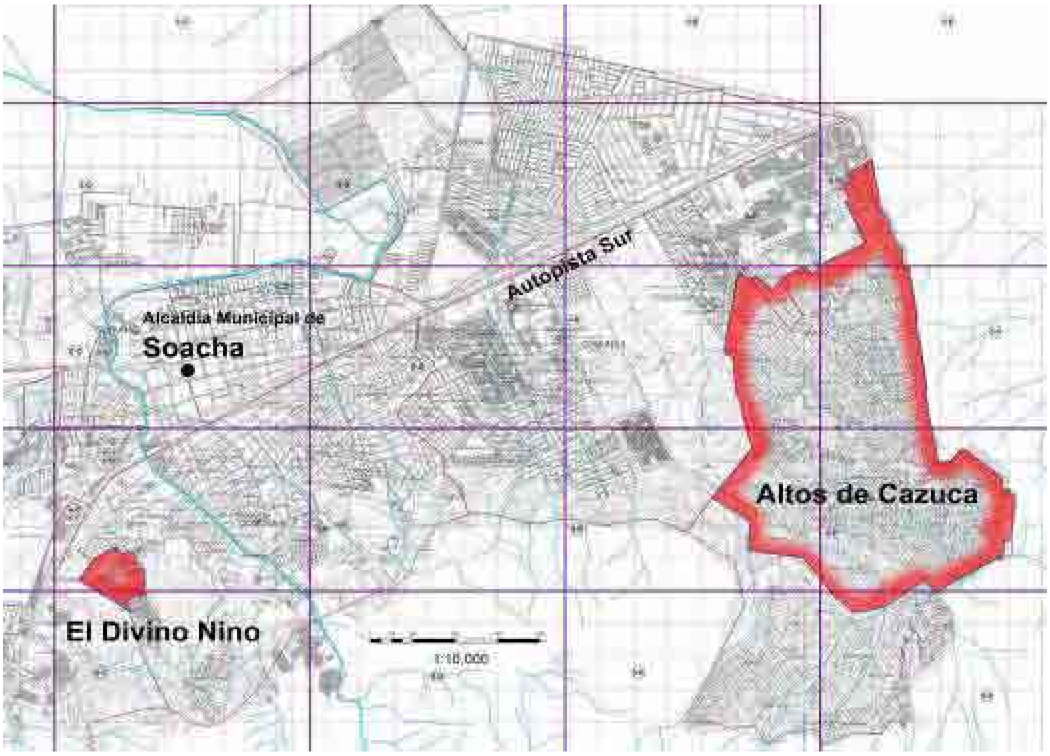



Figure 10-1 Guide Map of the Landslide Study Areas in the Soacha Municipality

The area of Altos de Cazuca is a hill area with 250 m height difference between 2550 m to 2800 m above the sea level. The slopes on the hill are less than 20 degree. Some steep slopes are found at inclines of 45 – 80 degrees with abandoned quarries in the area. The steep slopes in "barrio" La Capilla area and "barrio" Villa Esperanza are the largest of the area.

The area is underlain by Guaduas Formation (KTg) and Guadalupe Group (Ksglt). Both Guaduas Formation (KTg) and Guadalupe Group (Ksglt) covered with Quaternary (Qta) in areas of low topographic relieves consist of sandstone layers with mudstone layers and some coal layers. These layers are classified into soft rocks. Ktg and Ksglt are partially covered with high terrace deposit (Qta).

## 10.2 Existing Studies

### 10.2.1 Existing Studies

The following reports on the landslide in the study area are available:

INGEOMINAS (1996 study in La Capilla area), concerns four assumed models of rotational landslide hazard areas and undertook a stability analysis using modified Bishop's limit equilibrium method. Based on the results of analysis, it proposed mitigation works for different part of the slope.

INGEOMINAS (2000) study undertook a preliminary zoning map for the short term purpose. The zoning map was made using hazard zoning map by INGEOMINAS in 1988, in which Villa Esperanza is not yet figured.

A study made by National University (2004) basically from the viewpoint of urban planning, it includes location of infrastructures such as water pipelines

INGEOMINAS (2006) covers the entire municipality urban area, and is based on geology and geomorphology to identify high risk areas.

There are a few more potentially useful but unconfirmed information at the time of preparation of this document. Any significant landslide monitoring has not been implemented by Soacha Municipality.

### 10.2.2 Past Disasters

According to a study by the Chamber of Commerce cited in the report of Soacha Municipality in 1992, 16,500 people lived in Altos de Cazuca area and 228 people in Villa Esperanza at that time. It was also reported that 163 people or 37 families needed urgent relocation.

In Villa Esperanza, landslide occurred in January 6, 2000 due to the rainy season at the end of 1999. Emergency visit and study was made in February 29, 2000 by INGEOMINAS.

In El Divino Niño area, there was a fall of a rock larger than one meter in size in 2004, with no human injury

According to the record of fire fighter response to landslide disasters in the municipality in the last 5 years, nine times of dispatches to La Capilla area in Altos de Cazuca area were most, and five times of dispatches to El Divino Niño area were second.

All of above-mentioned descriptions about the landslide in the Soacha Municipality do not show the spots of affaires.

The Soacha Municipality implements a special survey program after the landslide event of May 11, 2006, in order to estimate the number of inhabitants (families) and houses affected. The municipality surveyed families for basic household help. Most of houses are not only affected by landslides but also by water and mud flows. Generally, the lack of slope protection after exploitation and improper treatment of sewage water due to shortage of sewer system can be a major inducing factor.

### 10.2.3 Critical Areas in the Study Area

According to the statistic record mentioned above, the number of residential houses that suffered from landslides especially in El Divino Niño area and La Capilla area of Altos de Cazuca area is highest in the Soacha Municipality. Prompt measures should be taken to protect people in these areas.

## 10.3 Landslide Maps

### 10.3.1 Inventory Survey

A disaster inventory survey in Altos de Cazuca area and El Divino Niño area was carried out by aerophoto analysis and site reconnaissance. The results of the disaster inventory survey are shown in Disaster Inventory Map which is compiled in the attached figures. The map shows existing steep slopes, mass movement, traces of collapses and traces of mud flows. Steep slopes which were formed in abandoned quarry and with 30 degree inclination do not constitute disasters; however, rock falls and surface collapses occur frequently on the steep slopes.

Table 10-1 Classification of Inventory Survey

| Topographic Feature | | Classification | Type of Disaster |
|---|---|---|---|
| I. Steep Slope | I-1 | Steep Slope (Active) | Rock Fall, Slope Collapse |
| | I-2 | Steep Slope formed by quarry | Slope Collapse |
| | I-3 | Steep Slope >30 deg | Slope Collapse |
| II. Mass movement | II-1 | Mass movement (Active) | Mass Movement |
| III. Collapse | III-1 | Trace of Slope Collapse | Slope Collapse |
| | III-2 | Trace of Slope Collapse(Old) | Slope Collapse |
| IV. Mud Flow | IV-1 | Mud Flow | Mud Flow |
| | IV-2 | Mud Flow (Potential) | Mud Flow |

### 10.3.2 Steep Slopes in Abandoned Quarries

Steep slopes in the abandoned quarries represent the most critical conditions among many disasters in Altos de Cazuca area. In this project, only steep slopes in the abandoned quarries are the object of the studies, since INGEOMINAS is studying comprehensive landslide disasters in the areas, and steep slopes in the abandoned quarries are most critical areas with respect to mass movements and others.

Quarries were exploited in the 50's and 60's to obtain sand and clay from geological layers; therefore slopes in abandoned quarries are very steep, and they are mostly gentle above and below the slopes, and therefore it is easier to build houses there. There are many residential houses close to the steep slopes. Small rock falls and collapses occur frequently on the slopes. The areas are underlain by alternation of sandstone and mudstone as base rocks in the areas. The base rocks exposed on the steep slopes are soft rocks with cracks. It easy for soft rocks to be weathered, and sometimes gully erosion can be seen on the slopes. Rock falls or small collapses could occur in future and larger collapse or mass movement may occur on steep slopes. This is hazardous for residents living close to the slopes.

### 10.3.3 Critical Zones in El Divino Niño area and La Capilla area

In the study area, the Critical Zones has been set to verify the critical area in the "barrios". In "Barrios" El Divino Niño area and La Capilla area in Altos de Cazuca area where houses are dense, slopes are high and landslides occur frequently.

The Critical Zones are set above and below the steep slopes. Steep slopes are defined in this project as steep slopes of over 5 m in height with an incline of over 30 degrees formed through quarrying. Critical Zone is defined as the area within the distance of twice the slope height (2h) from toe of the slope and the area within the same distance as the slope height from top of the slope as shown in Figure 10- 2.

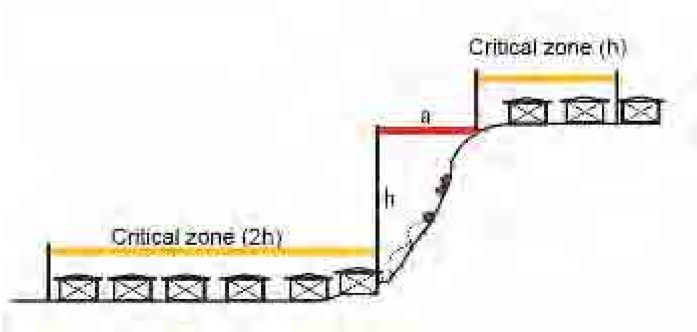



Figure 10-2 Definition of Critical Zone of Steep Slope

The Critical Zones in El Divino Niño area and La Capilla area are shown in Figure 10-3 and Figure 10-4, respectively.

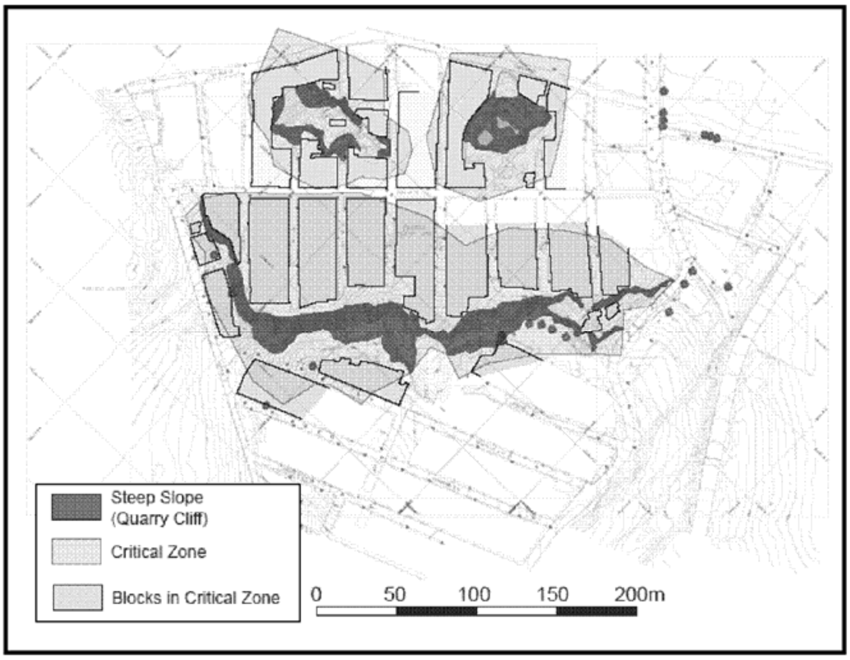



Figure 10-3 Critical Zones in El Divino Niño area

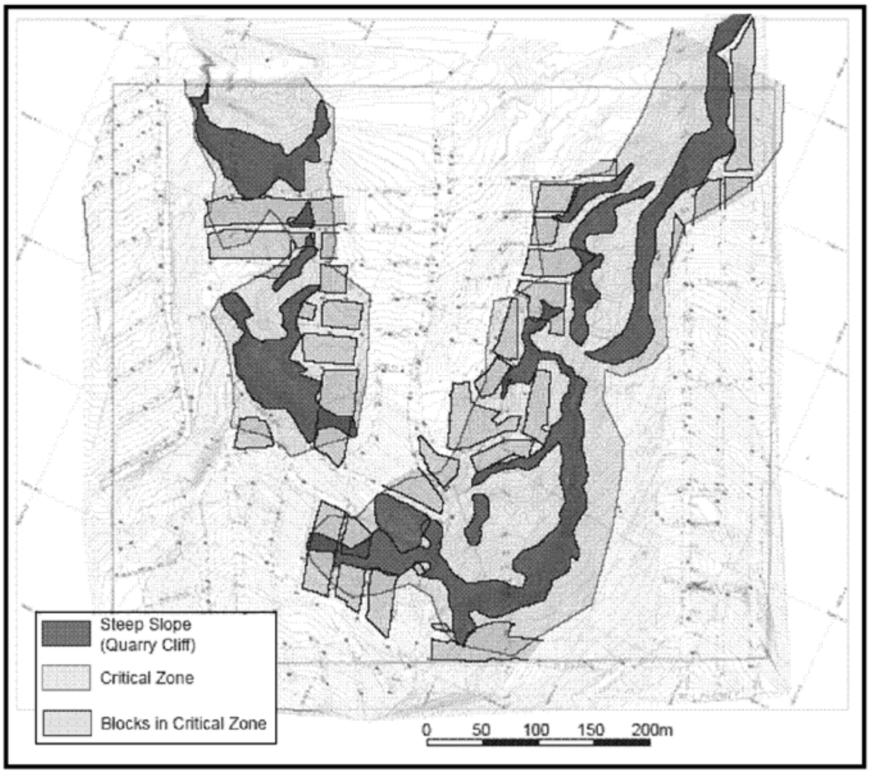



Figure 10-4 Critical Zones in La Capilla area of Altos de Cazuca area

### 10.3.4 Setting of Emergency Zone

The Soacha Municipality introduced a scheme for relocation of houses from high risk areas in a disaster prevention program. The Critical Zone maps could provide useful information for the Soacha Municipality's relocation scheme. It is obvious, however, that the early relocation of houses in the Critical Zones in El Divino Niño area and La Capilla area is difficult, since many houses are settled in the Critical Zones. For the information of the relocation scheme of the Soacha Municipality, the Emergency Zone is set in the Critical Zones in El Divino Niño area where is found the most critical area in Soacha Municipality. It is imperative that the houses in Emergency Zone be evacuated urgently. The criterion of Emergency Zone should be within the limits of 10 m or 2 houses from toe of the slope as shown in Figure 10-5. However, a final decision of Emergency Zone in El Divino Niño area has been adopted by the JICA Study Team with site survey. The Emergency Zone in El Divino Niño area is shown in Figure 10-6.

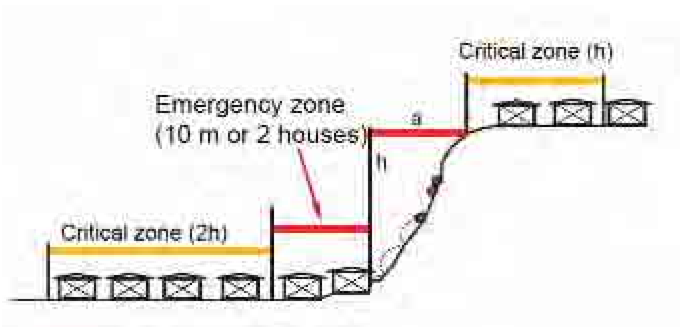



Figure 10-5 Definition of Emergency Zone of Steep Slope

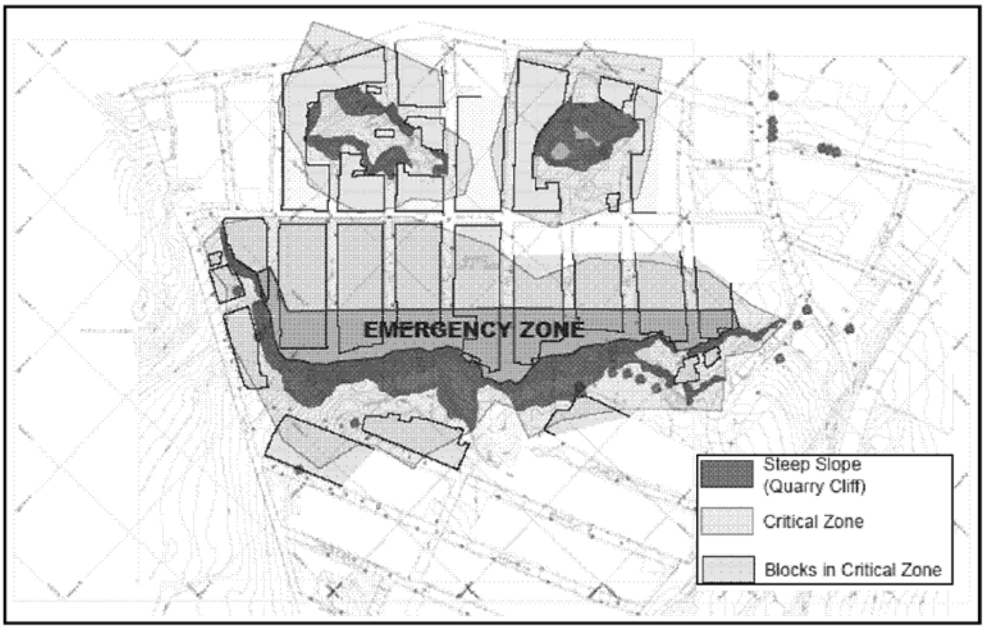


Figure 10-6 Emergency Zone in El Divino Niño area

### 10.3.5 Community Hazard Map

For the relocation program in El Divino Niño area, the relocation of all people from Critical Zones and even from the Emergency Zones may take a long time. Therefore, it is important to protect the peoples who stay in the Emergency and Critical Zones until they are relocated. To this end, the people should know whether they are settled in the zones or not using the Critical Zone Maps. The public in the zones should be well informed by referring to the attached Community Hazard Map.

a) People in Emergency Zones and Critical Zones are always exposed to danger.

b) People should always watch any unusual occurrences on the slopes.

c) People should take care of the slopes in case of rain.

d) If people find any unusual occurrences on the slopes during rain or even in case of fine weather, they should inform the Soacha Municipality and seek refuge according to their own judgments.

## 10.4 Measures for Critical Zones

### 10.4.1 Considerations of Structural Considerations

Many houses were built and people live near the toe and upper part of steep slopes formed through mining in the Soacha Municipality. Rock falls and slope collapses frequently occur in this area even in case of fine weather as well as in rainy weather. These areas have suffered from not only rock falls and slope collapses but also from large mass movements. It is known that quarries, which were exploited until about 50 years ago, triggered the mass movement in Altos de la Estancia in the capital district of Bogota. In Villa Esperanza in the Soacha Municipality, in order to prevent the mass movement at the abandoned quarry, earth-filling works were implemented by the army. It is quite difficult to stop the movement of landslide once it is generated by human activities because the imbalance of landslide body is substantially larger than in any natural circumstances. For example in El Divino Niño area, the steep slopes are covered with clayey material created during the weathering of sandstone and mudstone. Cuboid blocks and boulders through the development of cracks on outcrops can be observed on the slope. These blocks and boulders can fall in situation of rock fall or slope collapses. In addition, open cracks observed on the slopes indicate that the entire body of the slopes has been continuously moving from the past. Therefore, it is necessary to pay attention to the phenomena of transition to mass movement.

It is well known that small-scale slope cut and excavation can trigger mass movements in which slopes have similar topographical and geological conditions to Altos de la Estancia. In reality in Altos de La Estancia, slope cutting and excavation through human activities promoted transition phenomena, and finally triggered the mass movement. Consequently, further cutting on steep slopes in abandoned quarries should not be carried out because the slope is deemed an unstable condition caused by the former quarry activities. For the emergency protection works against rock fall and slope collapse, it is effective to form gentle slopes in order to limit the scale of the rock falls and slope collapses phenomena.

However, forming gentle slopes corresponds to the removal of toe of the slope and this activity increase the risk of mass movement. In that case it is impractical from the viewpoint of prevention of landslide. It is difficult to stop the mass movement after the effect of human activities as for the mass movement which is relatively small as observed in Villa Esperanza. It is theoretically possible to form gentle steep slope with the landslide prevention works such as piling works and anchors, but these stabilization works are quite expensive. As a basic rule, these expensive works should be done after the completion of counter-weight filling works at the toe of landslide. These works would be of large scale on flatland where many houses are presently settled and it would be similar to recovery works to the original land shape. Therefore the “emergency protection works” on steep slopes in abandoned quarries in El Divino Niño area and Altos de Cazuca area are impracticable from the technical viewpoints.

### 10.4.2 Recommendations to Mitigate Landslide Damages

As a measure against slope disasters on steep slopes in abandoned quarries, it is recommended to relocate people from the Critical Zones. The houses found close to the steep slopes should be relocated to safe areas, outside the Critical Zones. The relocation programs should be realized in the following order, because it could take a long time to relocate from many Critical Zones in which there are many houses

a) People in the Critical Zones should be relocated. A priority for relocation should be given to the people settled in the most hazardous area of the Critical Zones.

b) Until all the people in the Critical Zones are relocated, the Soacha Municipality should take care of the safety of people remaining in the Critical Zones.

c) People remaining in the Critical Zones should be informed that they are found in the Critical Zones and they may be affected by danger even in case of fine weather.

d) In case of heavy rain, the Soacha Municipality should stay on alert for people found in the Critical Zones

e) To obtain the basic information about the alert level of rain fall, the Soacha Municipality should collect rain fall data.

### 10.4.3 Process for Relocation

The relocation from all Critical Zones in the Soacha Municipality is necessary to protect the people’s lives and properties. It could take a long time to complete the plan, and the evacuation from more hazardous areas is necessary observing the following measures.

a) Complete the relocation program from Emergency Zone in El Divino Niño area
b) Set up Emergency Zones in La Capilla area. (Critical Zones in La Capilla area have been set up in the study. Figure 10-4).

c) Proceed with the relocation program from Emergency Zones in La Capilla area in accordance with the process in El Divino Niño area.
d) Set up Critical and Emergency Zones in El Arroyo (Villa Esperanza) where they are surrounded by steep slopes formed by mining activities.
e) Proceed with the relocation program from Emergency Zones in El Arroyo (Villa Esperanza) in accordance with the process in El Divino Niño area.
f) Set up Critical and Emergency Zones in other areas where steep slopes in abandoned quarries are found (refer to Figure 10-7), and proceed with the relocation program from the Emergency Zones.
g) After the completion of the relocation program from the Emergency Zones, proceed with the relocation program from the Critical Zones in El Divino Niño area, and continue with the same orders as relocation program from the Emergency Zones.

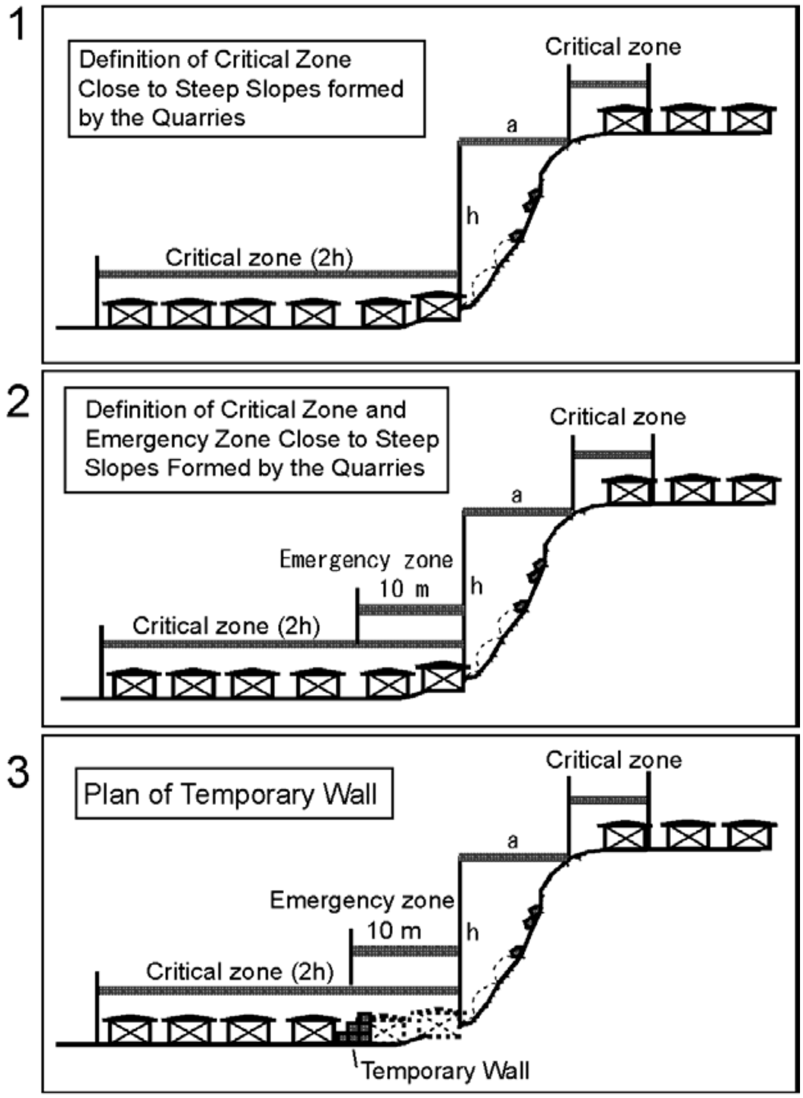



Figure 10-7 Process of Relocation from Emergency Zones

### 10.4.4 Measures until Completion of Relocation Program

In the process of the relocation program in El Divino Niño area, we found that relocation of people could take a long time. Therefore, it is important to protect the peoples who stay in the Emergency and Critical Zones using the Community Hazard Map as mentioned in Section 10.3.5.

## 10.5 Pilot Project

### 10.5.1 Necessity of Precipitation Monitoring and Disaster Records

Many landslide disasters occurred during or after heavy rain in Altos de Cazuca area and El Divino Niño area in the Soacha Municipality. In May, 2006, many houses were affected by the slope collapses and rock falls due to heavy rain. Meanwhile, some landslide disasters occur even in dry season. It may be true that the rain fall causes many landslides in the Soacha Municipality, but this is not certain without any support data. The information collection of precipitation and disasters are critical for prevention against landslide disasters. The following questions should be verified for a future plan of disaster measures, such as early warning systems serving the people remaining in the Critical Zones.

- Is it true that landslides occur more frequently with heavy rain fall?
- How much rain fall triggers off landslides?
- What type of landslides occurs in case of rain fall?
- Do the relations between rain fall and landslides differ in area by area, or "barrio" by "barrio"?
- How many landslides and what type of landslides occur in dry surroundings (without rain)?
- Does occurrence of landslides change by the way of rain fall (less and long / heavy and short)?
- Do intensities of rain fall differ from one small area (barrio) to another?

The relation between rain fall and occurrence of landslides should be studied while collecting information about precipitation and occurrence of landslides.
Precipitation monitoring and record of landslides are undertaken in order to collect the basic information for analysis of the relation between rain fall and occurrence of landslide. In order to install the rain gauges as many as possible for this purpose, the simple gauges of low cost and easy to be read were installed in the pilot project area. The record of landslide is being carried out by the Soacha Municipality, since recording of landslides requires more expertise.

### 10.5.2 Method of Precipitation Monitoring

Precipitation monitoring was carried out in the pilot project area where is Altos de Cazuca area and El Divino Niño area in the Soacha Municipality. Five rain gauges were installed in five schools in the pilot project area.

For the following reason, the schools are selected for the location of rain gauges installation.

- There are more than one school in Altos de Cazuca area.

- Monitoring can be executed during night time by a security guard since security guards stay in the schools for 24 hours a day.

- The rain gauges can be protected against burglaries as securities of schools are adequate.

- The rain gauges may be useful for education among school children, increasing thus the children's awareness for disaster prevention.

The rain gauge consists of funnel and cylinders, and a sub cylinder is attached for a fine reading. This rain gauge is very simple without any mechanical parts and electric power.

Basically, the monitoring works are carried out by a person in each school who is assigned by the principal of the school. During holidays, the person in charge in each school assigns and instructs a security person who stays in the school during holidays to monitor the rain gauge.

The values indicated by the rain gauges are read three times a day, exactly at 6:30, 14:00, and 18:00.

The water in the rain gauge is emptied immediately after the rain gauge is read.

### 10.5.3 Landslide Record

All of landslides in the Soacha Municipality should be recorded immediately after the occurrence of the landslide. Especially, the pilot project areas, Altos de Cazuca area and El Divino Niño area, are emphasized.

Only the landslides which caused damages to persons, houses, facilities and others are recorded.

### 10.5.4 Results

Reading of rain gauge has been done by the school teachers and security guards. In the first stage of the monitoring, some mistake such as in case of failure of the unit may be found in record sheets. A reliable monitoring can be achieved after a workshop to be held following one month monitoring.

Though the precipitation monitoring has been carried out for five months, the precipitation data must be accumulated for longer periods in order to have information on rainfall. At the moment, the following situation is observed in the monitoring.

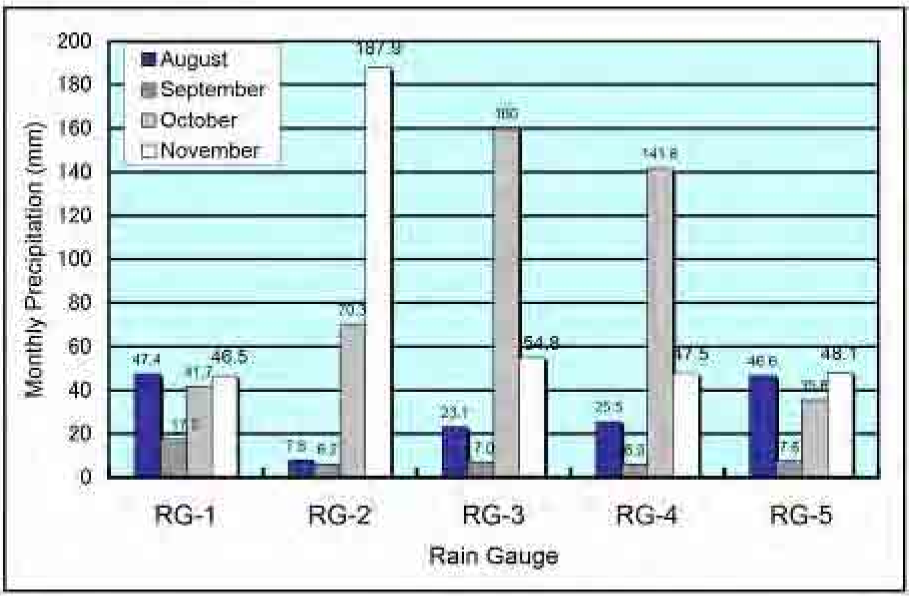



Figure 10-8 Monthly Precipitation in September and October

a) Monthly precipitations in August occur more frequently than in September. This shows different trends from the average normal year.
b) Monthly precipitations are different in each point in August, and are not different in each point in September.
c) Maximum monthly precipitations were observed with RG-4 by 141.8 mm in October.
d) Maximum daily precipitations were observed with RG-4 by 58.2 mm on 13th October.
e) With a lower altitude, rail will fall more frequently, especially in August.

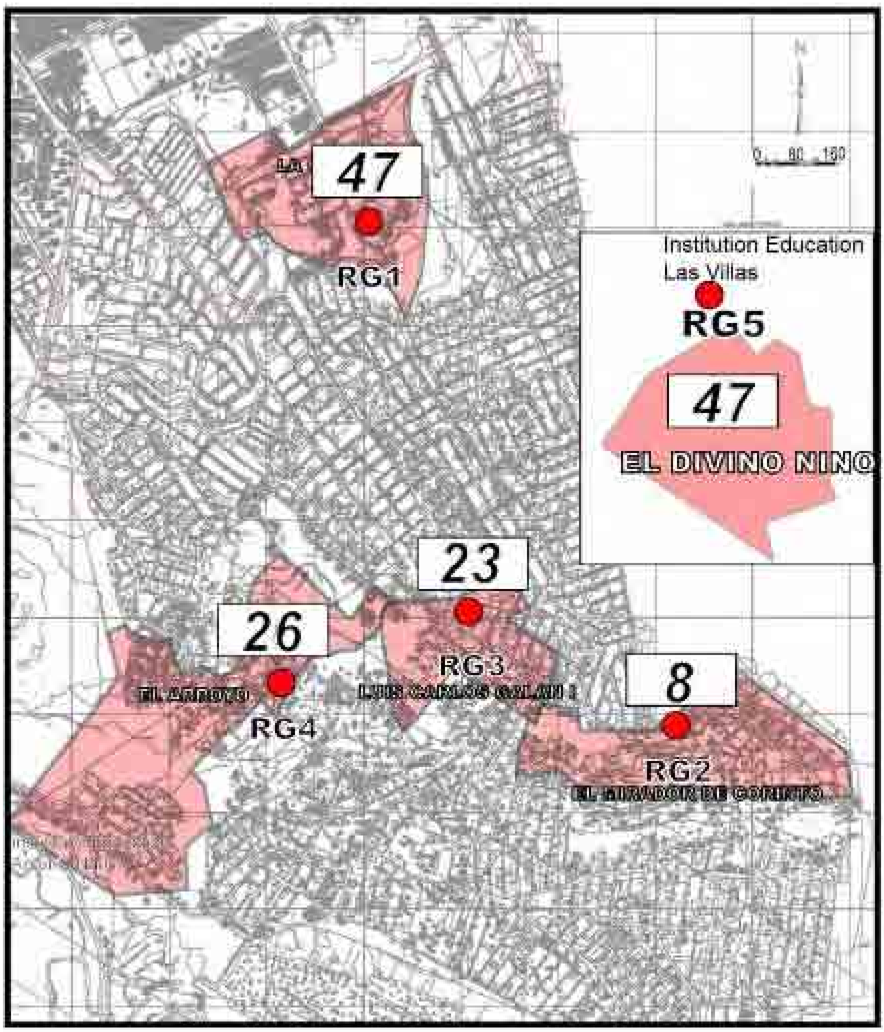



Figure 10-9 Monthly Precipitation of September at Each Monitoring Points

<u>Landslide Disasters</u>

Three landslide disasters occurred in the period from 13th October 2007 to 15th October 2007 in Los Robbles, Terranova and El Capilla area in Altos de Cazuca area. Rain continued falling intermittently from 6th October to 14th October in Altos de Cazuca area. The nearest rain gauge point to Los Robbles is RG-4, to Terranova is RG-3 and to El Capilla area is RG-1. According to Figure 10-10, an excess of 20 mm of accumulate precipitation may be appropriate for Alert Level 1 and an excess of 45 mm of accumulate precipitation may be appropriate for Alert Level 2.

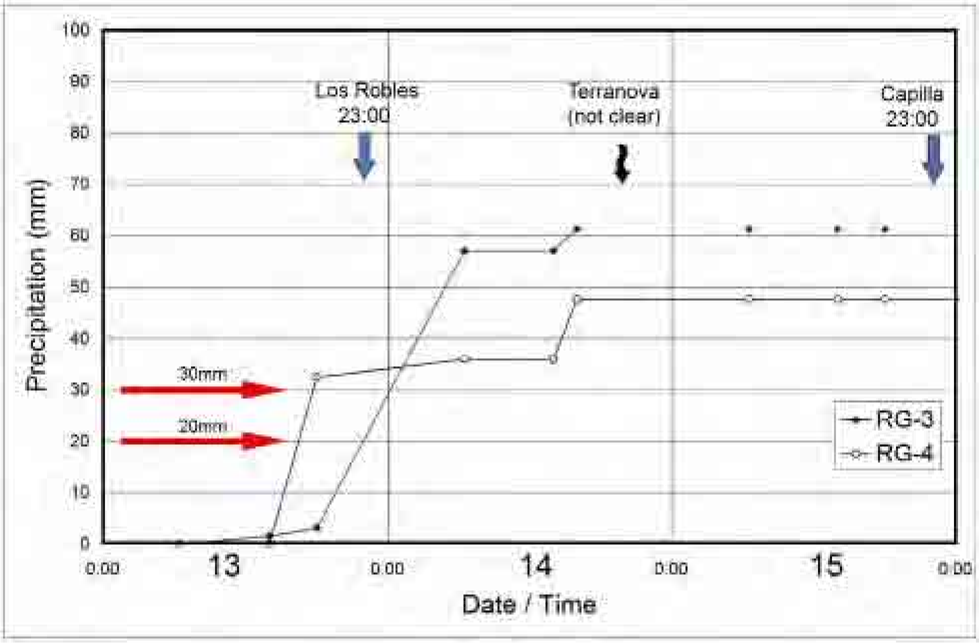



Figure 10-10 Rainfall from October 13 to 15 in 2007

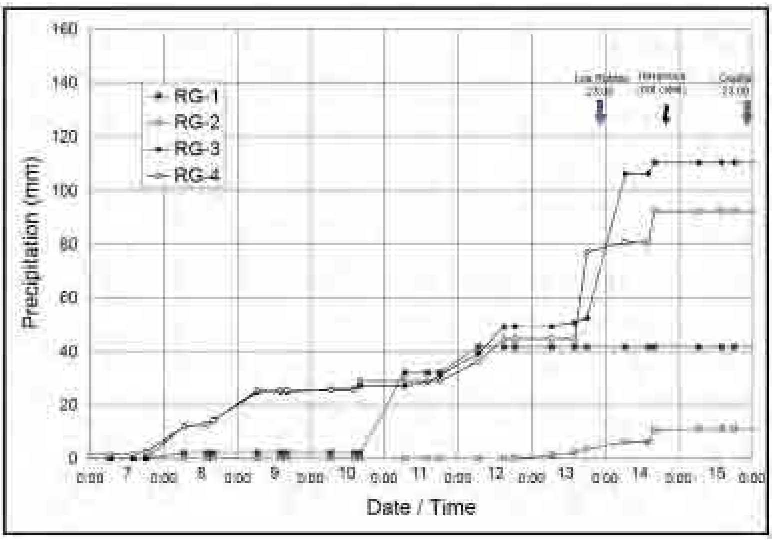



Figure 10-11 Precipitation before Landside Disasters in October 2007

# CHAPTER 11 FLOOD

## 11.1 Rivers in Study Area

The Study Area in Soacha Municipality covers the Soacha River and the Tibanica River. The catchment area of the Soacha river and the Tibanica river is 44.3 $km^2$ and 19.2 $km^2$, respectively. Annual rainfall in San Jorge (IDEAM) which is located in the upper part of the Soacha River is 691 mm as an average value between 1960 and 2002.

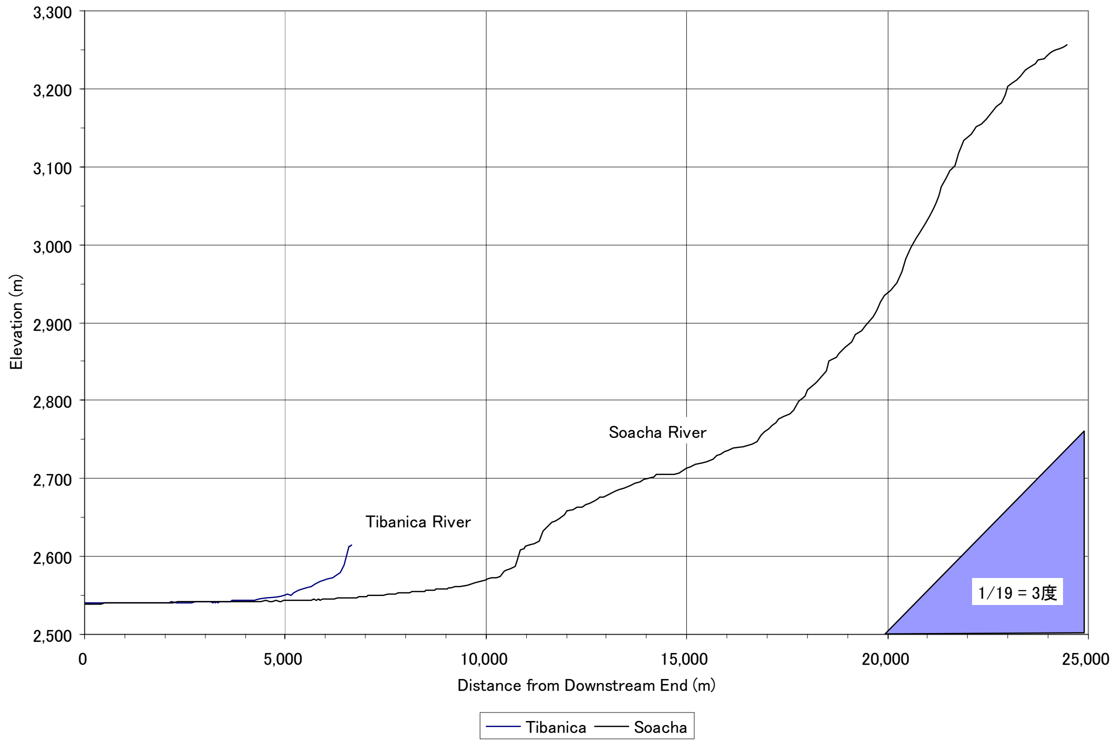



Figure 11-1 Longitudinal Profiles of Target Rivers in Soacha

## 11.2 Past Floods

Figure 11-2 shows the inundated area in the May 2006 flood according to the interview results. The Soacha River was affected more heavily than the Tibanica River. At San Jorge Station (IDEAM, self-recording gauge) the daily rainfall of 20 mm was recorded on May 11, 2006. The hourly rainfall was 7.5 mm from 8:40AM, May 11, 2006. The most seriously affected area in the Soacha River was Llano Grande, which is located in the left bank of the upper stream of the Autopista Sur. The maximum inundation depth was slightly higher than 1 m. A child was rescued by a boat supplied by the Soacha firefighter. The area around Llano Grande is a lowland area compared with the Soacha River. The Soacha River is affected by the sediment runoff from the upstream area, especially from the brick factories. So, the river bed has been getting higher due to the sedimentation, which causes a flood easily. According to the interview results, the inundation was caused by the backwater of sewerage pipe from the river.

The most downstream reach of the Soacha River near the confluence to the Bogota River was also inundated. However, this area is a rural area such as a livestock farming area.

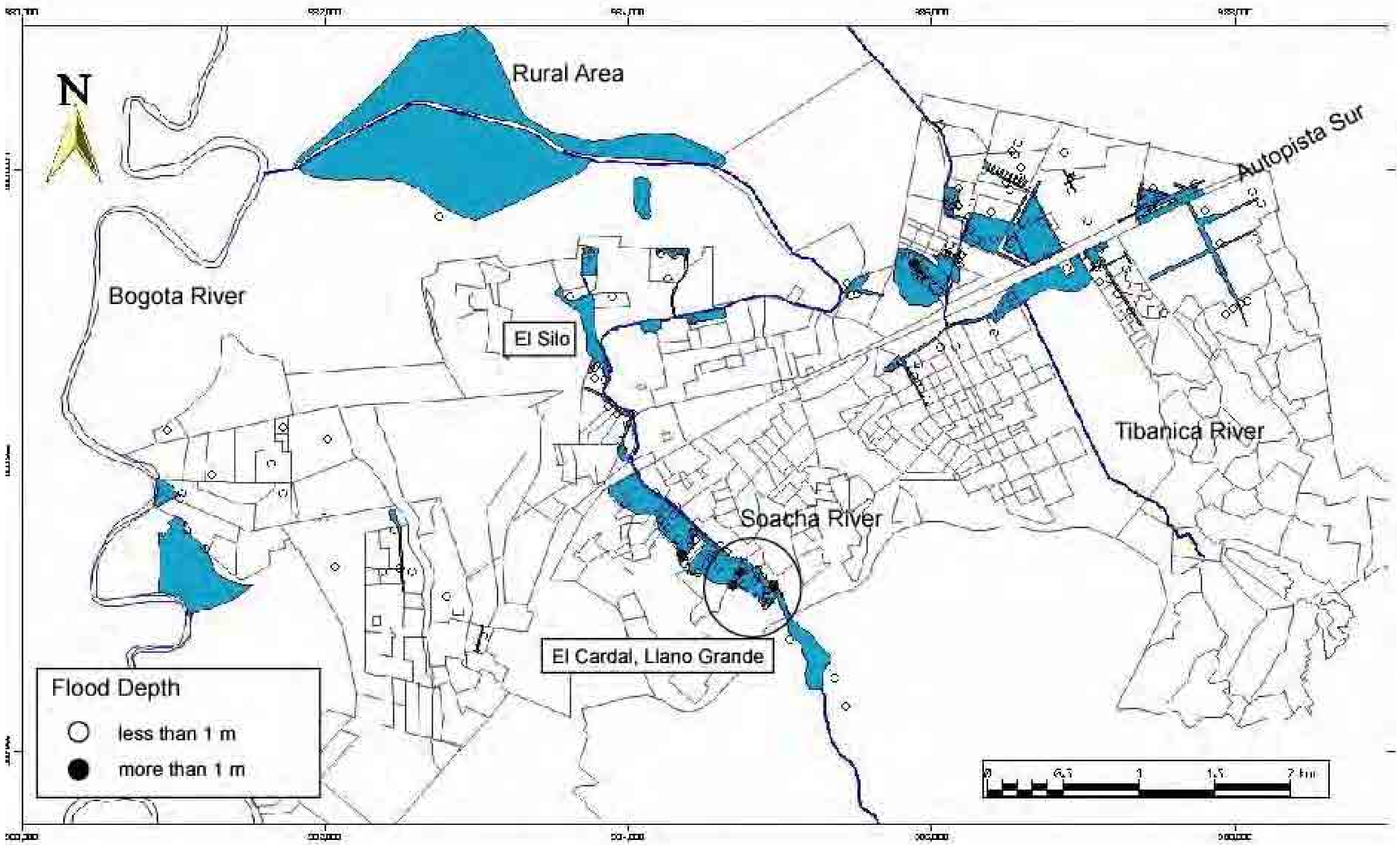



Figure 11-2 Flood Area and Depth for May 11, 2006 in Soacha River and Tibanica River

## 11.3 Existing Monitoring System

In and around the Study Area for Soacha, there are several rainfall stations and water-level stations. Figure 11-3 shows the locations of monitoring stations in and around the Study Area. They are the stations of DPAE, IDEAM, CAR and EAAB. The Soacha Municipality does not have its own monitoring station, even of conventional type. Table 11-1 is the list of currently operating stations, of which the Study Team could collect some data.

Table 11-1 List of Monitoring Stations in and around the Study Area

| Area | Rain/WL | Name | Features |
|---|---|---|---|
| Upstream area of Soacha River | Rainfall | San Jorge(IDEAM) | Conventional gauge with recording chart. Once a month the data is sent to IDEAM by postal mail. |
| | Rainfall | San Jorge(CAR) | Conventional gauge with recording chart. It is maintained by CAR. |
| | WL | San Jorge(CAR) | Staff gauge in mountainous creek. |
| Bogota River | Rainfall | Las Huertas(EAAB) | Conventional gauge with recording chart. |
| | WL | Las Huertas(EAAB) | Automatic gauge with telemeter system |
| | WL | La Isla(EAAB) | Automatic gauge with telemeter system |
| Tunjuelo River | WL | Puente La Isla (EAAB) | Staff gauge |
| Upstream area of Tibanica River | Rainfall | Sierra Morena(DPAE) | Automatic gauge with telemeter system |
| | Rainfall | Minutos(IDEAM) | Automatic gauge with telemeter system |
| | Rainfall | Casablanca((EAAB) | Conventional gauge with recording chart. |

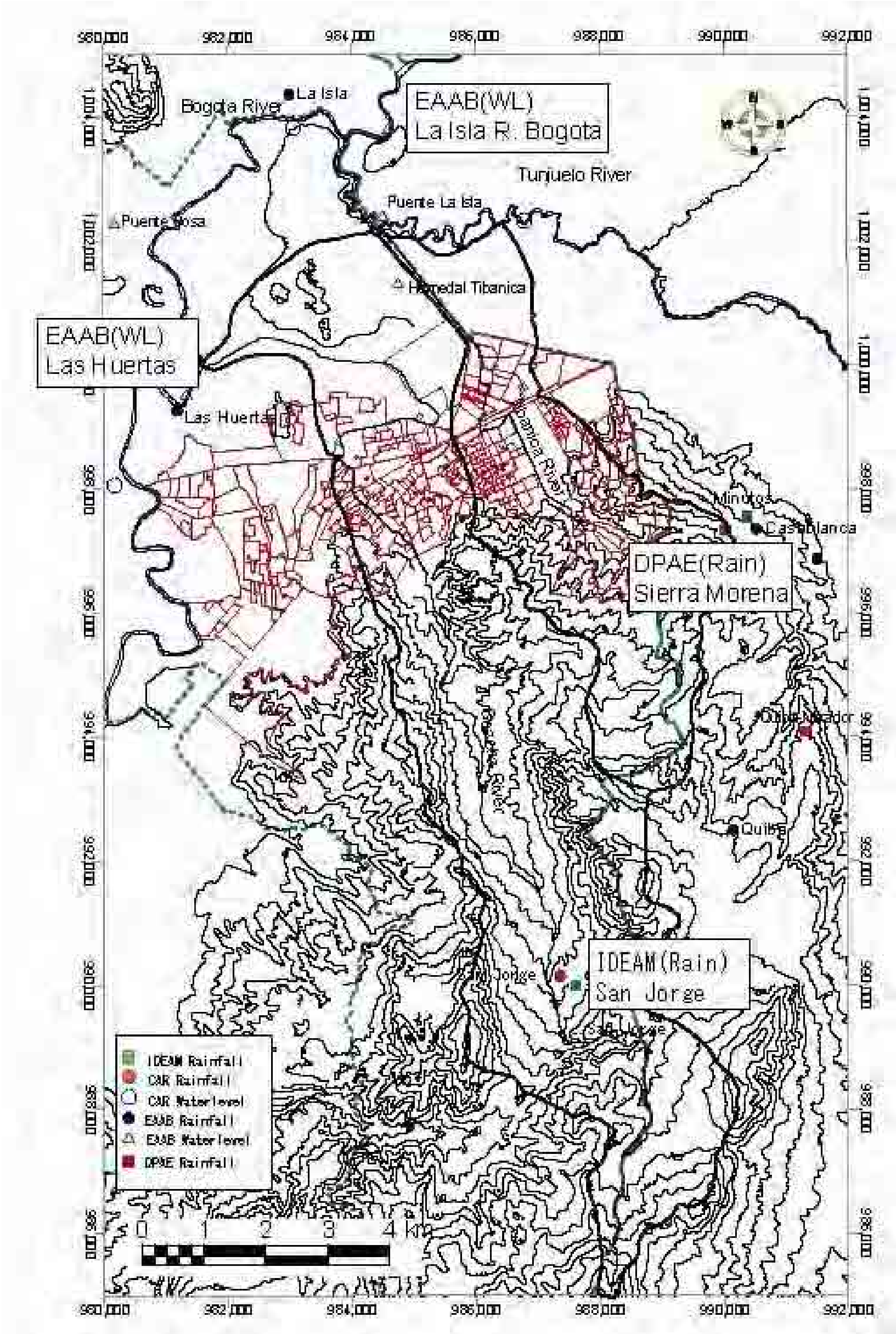



Figure 11-3 Main Monitoring Stations in and around the Study Area

## 11.4 Flood Analysis and Mapping

### 11.4.1 Conditions of May 11, 2006 Flood

In the Soacha River basin, IDEAM's San Jorge Station recorded rainfall during the May 11 flood. San Jorge station is located in the upstream area of the basin. The daily rainfall on May 11, 2006 at San Jorge was 20 mm according to IDEAM interpretation of the self-recording data. The Study Team checked the original recording paper on May 2006. The maximum hourly rainfall on May 11, 2006 was 7.5 mm from 8:40AM to 9:40AM according to the self-recording data.

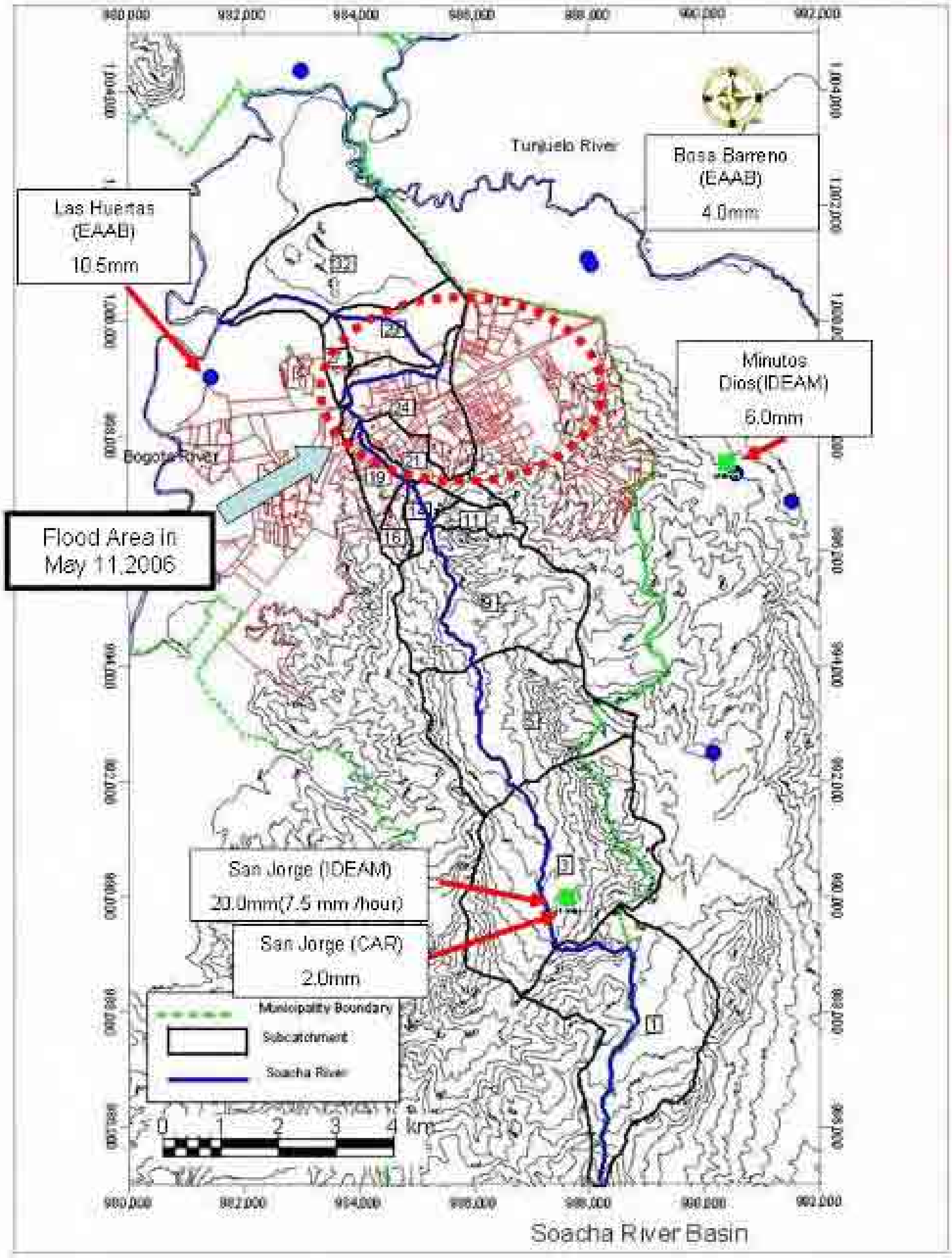



Figure 11-4 Daily Rainfall in San Jorge (IDEAM) in 2006

The flood level at Fusunga was about 50 cm above the left-bank ground elevation. The peak water level took place at 11:45 AM on May 11, 2006 and lasted about 4 hours according to a resident living at the riverside. In the photo below, the water level was just 1 meter 40 cm on the staff gauge at 8:00AM and the heavy rainfall happened at 10:30 AM on that day.

The flooding in Llano Grande (El Cardal to Autopista Sur) took place from 11AM to 12AM. According to the communities in Llano Grande, there was no rain in their area and the river overflow suddenly happened.

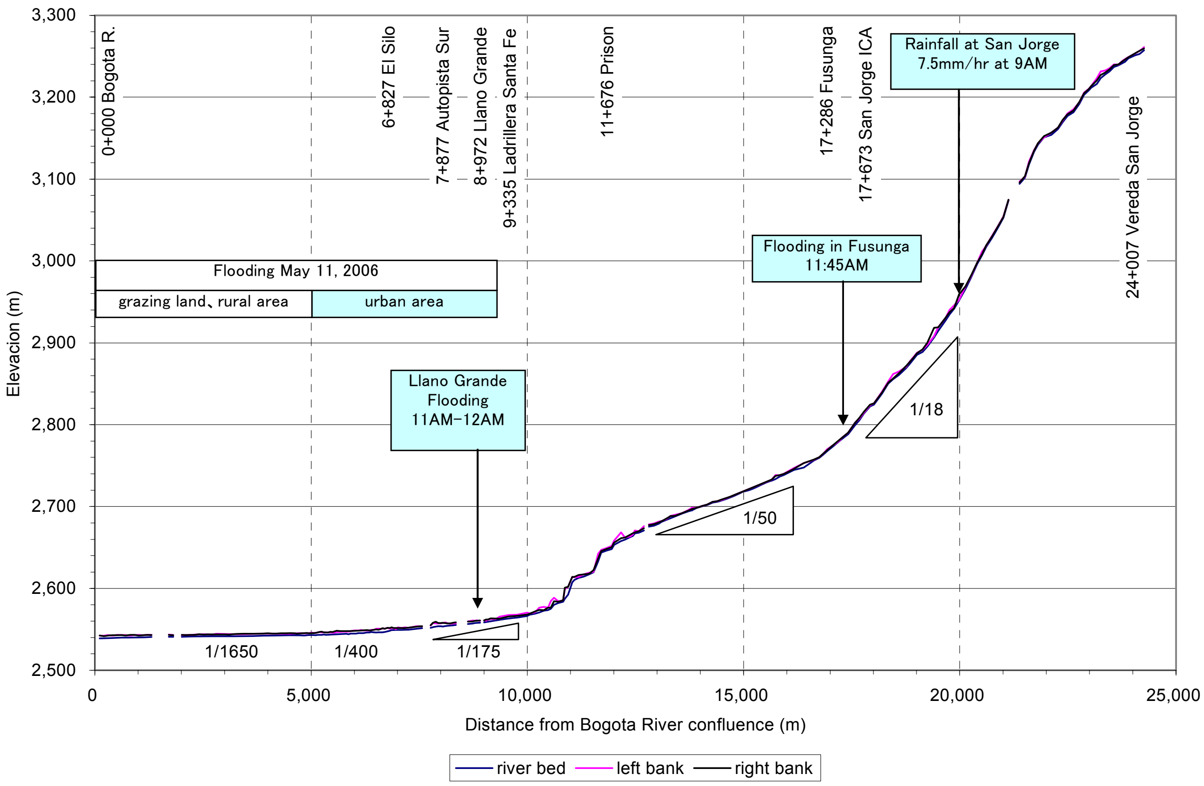



Figure 11-5 Flooding Time in May 11, 2006 in Soacha River

### 11.4.2 Channel Capacity

Figure 11-6 is the longitudinal profile of the channel capacity of the Soacha river. The reach between Fusunga and Carcel has a low capacity due to the mild longitudinal slope. The reach from Ladrillera Santa Fe and el Silo has a capacity of 15 $m^3/s$ at minimum.

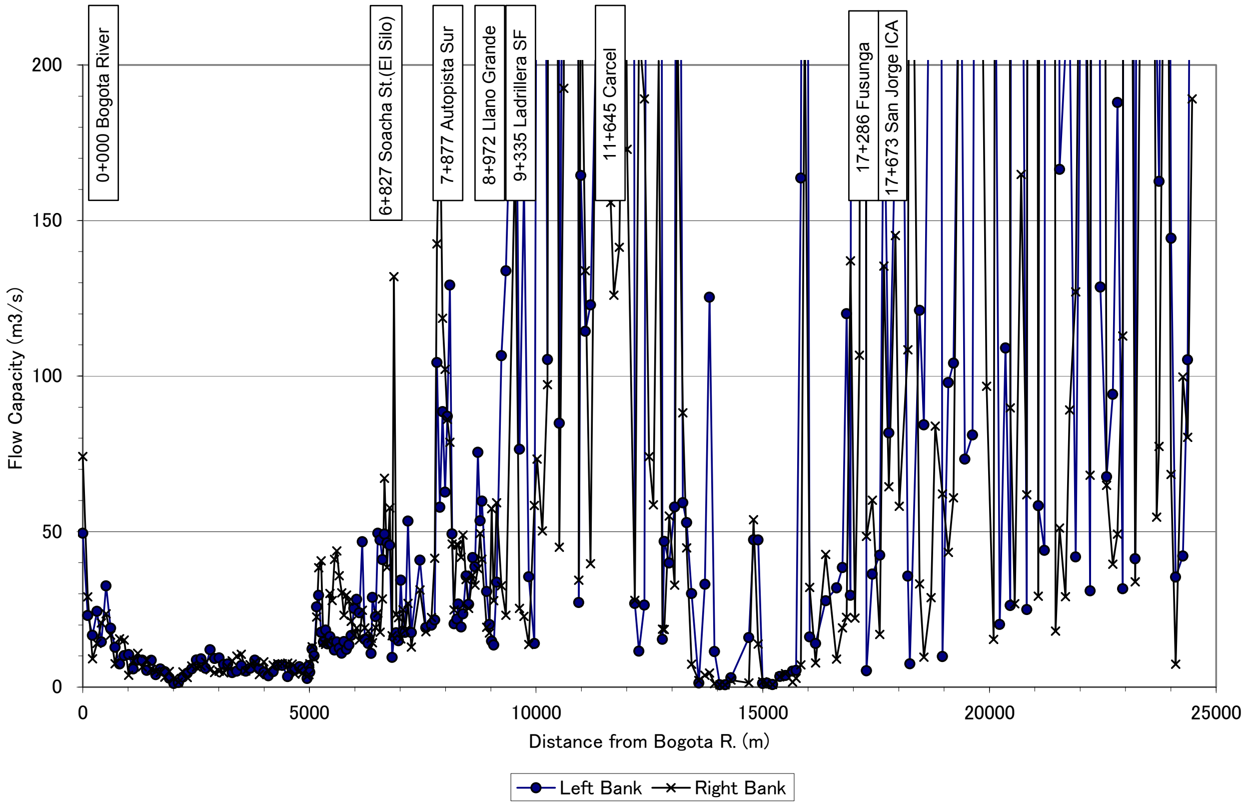



Figure 11-6 Channel Capacity of Soacha River

## 11.5 Monitoring and Early Warning Plan

### 11.5.1 Planning Principle

Soacha Municipality is frequently suffering from flood and landslide disasters. Most recently, floods and landslides occurred in May 2006, and affected thousands of people living near the river and the sleep slope and their economic activities in the municipality.

The plan was prepared for the short, middle and long terms. The target year of the plan is set up for 2020, assuming that the implementation of the plan started in 2007 and will take fourteen (14) years until its completion. The reason why the said plan started in 2007 is that the pilot project(s) in this Study was conducted as a part of the proposed plan.

In order to materialize the above objectives, the Study Team proposed the following basic principles for the plan.

- The purpose of the proposed plan is to protect the people in the previously affected area against similar flood damages in near future, or mitigate the future damages by implementing the plan.
- Thus, it is required to prepare, as a tool for the above plan, equipment for monitoring of hydro-meteorological conditions and a system for early warning based on the monitored data.
- Therefore, it should be pointed out that it is quite important how the people who should evacuate in an event of flood understand the meaning of the early warning system and take necessary actions. In this sense, any expensive equipment for the monitoring and early warning would be meaningless unless the people understand the importance of the system and can make use of the system actually,.
- In the above context, the Study Team has studied and discussed what to do at first in Bogota in order to achieve the study objectives, believing that the monitoring equipment that will only be installed in the

study area is just a tool.

### 11.5.2 Planning Concept

In order to formulate the effective MEWS (Monitoring and Early Warning System) plan, the following planning concepts are applied.

- Provision of warning and evacuation information to communities in a secure and timely manner
- Maximum utilization of existing information monitored by other organizations
- Maximum mobilization of local resources
- Setting of appropriate warning criteria

### 11.5.3 Alternative Studies for Monitoring and Information Dissemination

For hydro-meteorological monitoring for Soacha area, there are hydro-meteorological stations of IDEAM, DPAE, EAAB and CAR. Some of the stations are equipped with a telemetering system. However, the observed data has not been transferred and shared by the Soacha Municipality and the community.

### 11.5.4 Overall System Planning

The proposed MEWS for Soacha Municipality is a total system composed of four sub-systems namely, 1) Monitoring and Data Gathering System, 2) Data Analysis and Processing System, 3) Information Dissemination System, 4) Warning Criteria in accordance with community-based evacuation plans.

The overall system planning (schematic diagram of information flow and system components) is shown in Figure 11-7, and brief descriptions of each sub-system are shown in Table 11-2.

Figure 11-8 shows the outline of monitoring and early warning system for Soacha. The details of each component and warning phase are explained in and after Section 11.5.5.

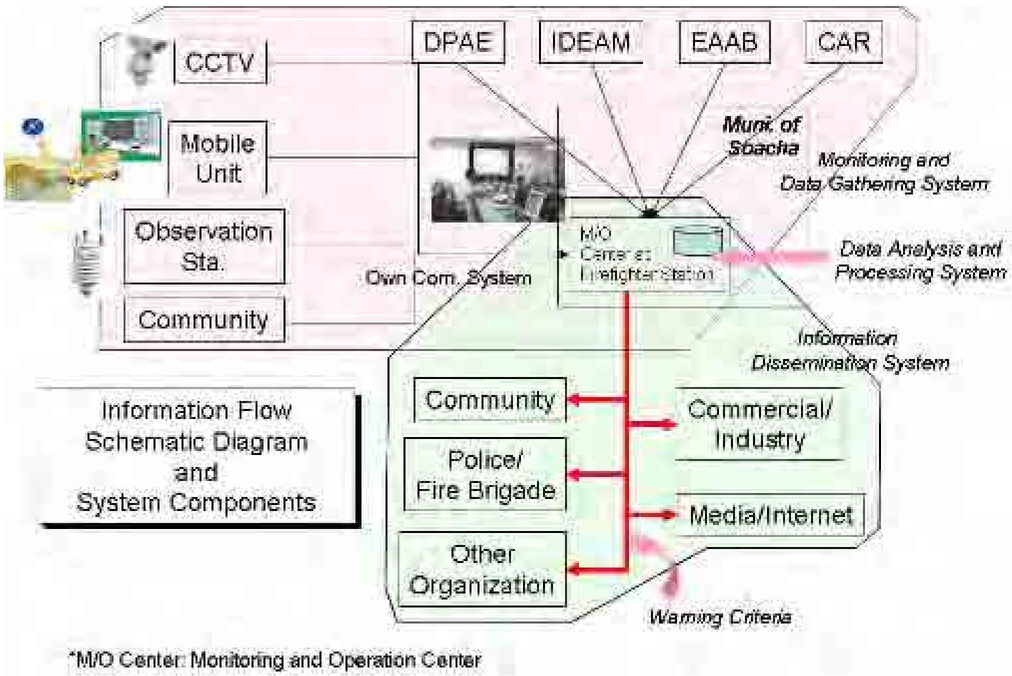
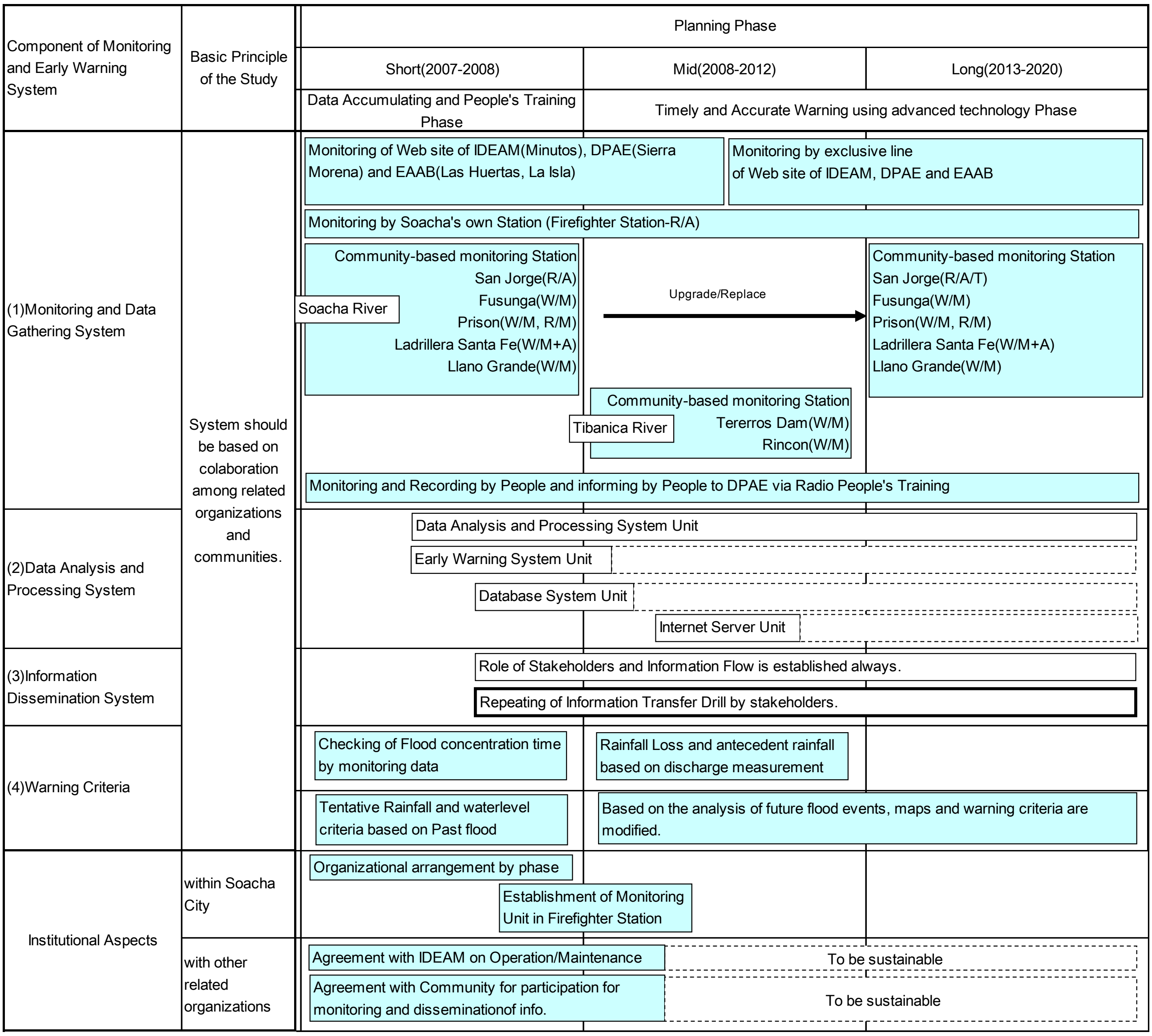



Figure 11-7 Overall System Planning (Future Image)

Table 11-2 Brief Descriptions of Sub-Systems

| Name of Sub-System | Description |
|---|---|
| Monitoring and Data Gathering System | To collect the information for issuing the warning, this sub-system consists of a monitoring network with other organizations, monitoring station, and communication network between stations and Soacha Municipality office. |
| Data Analysis and | The collected information is processed and analyzed in Soacha Municipality |

| | |
|---|---|
| Processing System | office which plays a center of monitoring and operation. Based on the analysis and the Warning Criteria, Soacha Municipality is to issue warnings. |
| Information Dissemination System | To disseminate warnings and related information, the communication network with community people and concerned organizations using certain warning methods is installed. |
| Warning Criteria | Warning criteria includes threshold levels which are determined by hydrological analysis, organizational arrangements by warning phase, and form of warning. |




Remarks: "R" : Rainfall, "W" : Waterlevel, "M" : Manual Monitoring, "A" : Automatic Monitoring/Recording, "T" : Telemeter System

Figure 11-8 Outline of Proposed Monitoring and Early Warning System for Soacha

### 11.5.5 Detailed Planning

(1) Monitoring and Data Gathering System

1) Monitoring Plan

a) DPAE, EAAB and IDEAM Stations to be Monitored

It is proposed that the municipality can make use of the monitoring data available from other related organizations in its own monitoring system. The proposed telemetering stations to be monitored by Soacha are shown in the table below.

| Organization | Stations to be monitored | Main purposes |
|---|---|---|
| DPAE(PG) | Sierra Morena | To monitor the rainfall in the Tererros Dam catchment and Altos de Cazuca area |
| EAAB(LG) | Las Huertas, La Isla | To monitor the flood condition in the Bogota river and backwater effect for Soacha river and Tibanica river downstream. |
| IDEAM(PG) | Minutos | To monitor the rainfall in advance in the eastern part of the Soacha municipality |

b) Soacha's own Monitoring Station

To monitor the meteo-hydrological situation in the city area properly, its own monitoring station will be installed. The Firefighter Station of the municipality which is attended by staff on a 24-hour base, is located along the Autopista Sur, between Tibanica and Soacha Rivers, because it is the best location that the station is near Altos de Cazuca area in terms of rainfall monitoring in the municipality from the view point of initial investment.

The rainfall measurement equipment should be a self-recording type and the measured and processed data should be presented on the personal computer display periodically.

c) Community-Based Monitoring Station

As proposed, the MEWS for Soacha will mobilize local resources as much as possible, and some of monitoring stations will be monitored by community people.

The community-based monitoring stations are proposed in the following locations:

Table 11-3 Overall Concept for Community-based monitoring station in Soacha River

| Station name (Catchment area) | Basic point (distance from target area) | Monitor-ing item | Reason for Monitoring and Hydraulic or catchment feature | Equipment | Reasons for selection of equipment | Security of Equipment | Person in charge of maintenance and Capacity of person in charge of maintenance | Other remarks |
|---|---|---|---|---|---|---|---|---|
| San Jorge ($13.0km^2$)<br>(entrance of ICA,Colombian Agriculture Institute) | Distance of 90 minutes as flood concentra-tion time | Hourly rainfall | Since the flood concentration time at the target area is in the order of 1 hour, the hourly rainfall should be monitored.<br>It is located at the center of the upper stream of the target area. | Automatic rainfall gauge (tipping bucket) and data logger with display | Since short-time rainfall should be monitored, the automatic type with data display was selected in order that people can read the data in real time. | The equipment is installed inside the ICA and the security guard can watch the equipment for 24 hours. | Security guards and their family. (ICA) Soacha city is planning to hold training for the security guards. | This station is intended to promote the spirit of collaboration among people in the upstream to the downstream area. |
| Fusunga ($14.9km^2$)<br>(residential area) | Distance of 45 minutes as flood concentra-tion time | Water level | To confirm the runoff by rainfall in San Jorge, and flood at the upstream area.<br>The distance from the target area is long enough, the concentration time is longer than the time for evacuation (30 minutes) | Staff gauge | People's daily monitoring should be set up. | Resident and her family | Local resident. The resident is the lady who emphasizes the collaboration between the upstream and downstream areas in the workshops and seminars. | |
| Prison ($25.4km^2$)<br>(Prison of Soacha Municipality) | Distance of 30 minutes as flood concentra-tion time | Water level and rainfall | The runoff at Prison is affected by flood in the upstream reach, and the correlation between Fusunga and Prison should be confirmed. Also the rainfall in the mid reach should be monitored.<br>This location is only the location at which the flooding of the downstream area can be forecast. | Staff gauge, simple alarm device for water level, simple rainfall gauge with alarm device | Since this is a temporary station, simple equipment was selected. | The equipment is installed inside the Prison and the security guard can watch the equipment for 24 hours. | Municipality's security guard. Since the prison is now empty, the security guards can concentrate on the monitoring for 24 hours. | |

| Station name (Catchment area) | Basic point (distance from target area) | Monitoring item | Reason for Monitoring and Hydraulic or catchment feature | Equipment | Reasons for selection of equipment | Security of Equipment | Person in charge of maintenance and Capacity of person in charge of maintenance | Other remarks |
|---|---|---|---|---|---|---|---|---|
| Ladrillera Santa Fe (31.2 $km^2$)<br>(brick factory) | Distance of 15 minutes as flood concentration time | Continuous water level | Warning can be issued from this point for the area in the lower stream of Autopista Sur.<br>The catchment area is 70% of the entire catchment area of Soacha river and its course is straight. | Staff gauge, automatic water-level sensor and data logger with display | Continuous water level is monitored to evaluate the discharge and effective rainfall. Warning can be issued from this point for the downstream area of Autopista Sur. | The equipment is installed inside the brick factory and the security guard can watch the equipment for 24 hours. | Security guards of brick factory. Their capacity is very high. | This water level is referred as warning for the Autopista Sur downstream area (El Silo). |
| Llano Grande (31.7 $km^2$)<br>(residential area) | 0 (basic point) | Water level | This location is inside the May 2006 flooding area. | Staff gauge | The two people affected by the flood in 2006 should monitor the water level in order that they can understand the meaning of warning criteria and also the reason of false alert. | People and their family | Local residents (3 persons). The affected residents in 2006 have high awareness for the monitoring and collaboration to the downstream area. | |
| Firefighter Station of Soacha Municipality | | 10 minutes rainfall | | Automatic rainfall gauge (tipping bucket) and data logger with display | It is necessary to evaluate the relation with landslide as well as flood. | Firefighter (24 hours) | Firefighter of Soacha Municipality.<br>The firefighter conducted rainfall measurement using simple rainfall gauge since Dec. 2006 until October 2007 and enriched their monitoring skill. | |

In the Tibanica river, a staff gauge will be installed at the spillway of the Tererros Dam and a staff gauge will be installed in Rincon.

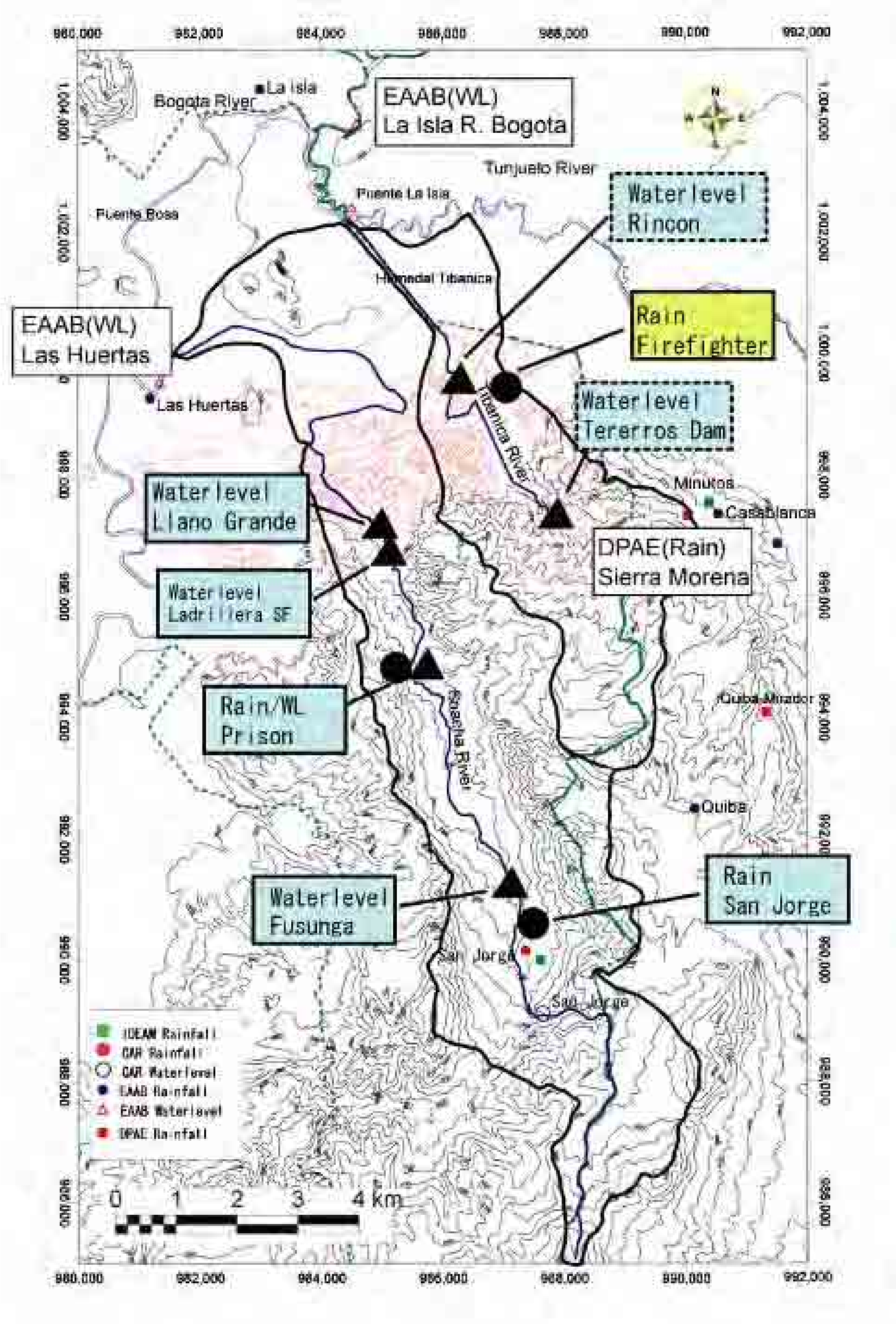



Figure 11-9 Overall Monitoring Plan

2) Communication Planning

The Soacha Municipality and other governmental organizations will start the communications through the Internet website to exchange the monitored information. The Soacha Municipality and the communities will keep the radio communications.

3) Monitoring Frequency

Proposed frequencies of hydro-meteorological monitoring are shown in Table 11-4.

Table 11-4 Monitoring Item and Frequency (Pilot Project Stage)

| Station name | Normal Situation: | Warning Situation: |
|---|---|---|
| Rainfall (Fire Station) | Every hour | Every 10 min. |
| Rainfall (San Jorge Station) | 8 hour | Every 60 min. |
| Rainfall (Community Stations) | 8 hour | Stand-by at equipment |
| Waterlevel (EAAB stations Las Huertas and La Isla) | Half a day | Every hour |
| Waterlevel (Community Stations) | Every 8 hours | Stand-by at equipment |
| Waterlevel (Terreros Dam) | Every 8 hours | Stand-by at equipment |

(2) Data Analysis and Processing System

The community or security guards at each station will inform the monitored data to the Firefighter station by radio. The firefighter will analyze the monitored data and input it in the database, which will be disseminated to the Municipality and other organizations.

(3) Information Dissemination System

Table 11-5 Functions Shared by Stakeholders

| Name | Normal | Watch | Warning | Evacuation |
|---|---|---|---|---|
| | | | Flood Warning 45 | Flood Warning 15 |
| Soacha (CLOPAD) | Monitoring of Informa-tion | Issue of an order to communities and organizations to watch.<br>Continuous monitoring | Issue of warning and Operation for preparedness to<br>release warning | Issue of evacuation order and operation for evacuation<br>Release of evacuation order |
| Communit y Leader | Volunteer for monitor-ing | Watch of situation and monitoring of values<br>Ready to Action | Watch of situation and monitoring of values<br>Necessary action | Leading community people to safer place |
| Communit y | Volunteer for monitor-ing | Watch of situation, communication with communities in the upstream and downstream areas | Transfer of information and operation for countermeasures<br>Ready to evacuate | Evacuation |
| Fire Brigade | | Consolidation of information and informing situation to CLOPAD, and<br>Watch of situation<br>Ready to Action | Consolidation of information and informing of situation to CLOPAD<br>Operation for countermeasures<br>Saving of life | Consolidation of information and informing situation to CLOPAD<br>Issue of order based on the criteria if necessary |
| Police | | Watch of situation<br>Ready to Action | Announcement of warning<br>Security of Site | Security of site |
| Defensa Civil | Volunteer | Watch of situation<br>Ready to Action | Watch of situation<br>Ready to Action | Assistance in evacuation |
| Media | | | Dissemination of information | Dissemination of information |
| Cell Phone | | | Disseminate Information | Dissemination of Information |
| Commerci al/Industry | | | Assistance in operation<br>Providing equipment and resources | Assistance of operation<br>Providing equipment and resources |
| OPAD | Assistance in case of large disaster | | | |

*Note: Roles shown on this table are only the role in the warning activity*

The communication between stakeholders will be done initially by radio and telephone. In the future, in addition to those, Internet, SMS, sirens and speakers will be used.

## (4) Warning Criteria

### 1) General

IDEAM is issuing a daily meteorological bulletin including alert and warning in the regional level in its web site and sending it to CLOPAD. The distribution areas of the bulletin are eight (8) regions in Colombia, and one of them is "Sabana de Bogotá". The bulletin includes the alert and warning regarding landslide and torrential rainfall in a general way. The daily bulletin should be downloaded every day to confirm the current situation of "Sabana de Bogotá", and if there is a warning issue for Sabana de Bogotá, the Municipality should regard it as serious and raise the phase up to organizational arrangement.

### 2) Flood Warning

#### a) General Warning

General Warning will be issued based on the monitored rainfall amount. According to the disaster records and rainfall data in and around the study area, most of the disasters have occurred by a rainfall amount of 5 mm per day. The time distribution of the 5 mm rainfall is not measured, but 5 mm for 1 hour is proposed considering the rainfall characteristics.

Also the water level at Las Huertas (EAAB) can be used for inland flood in the rural area near Bogota River. The water level of 2,541.5 m is a warning level, which can be monitored on the EAAB Web site in real time.

#### b) Specific Warning for Soacha River Basin

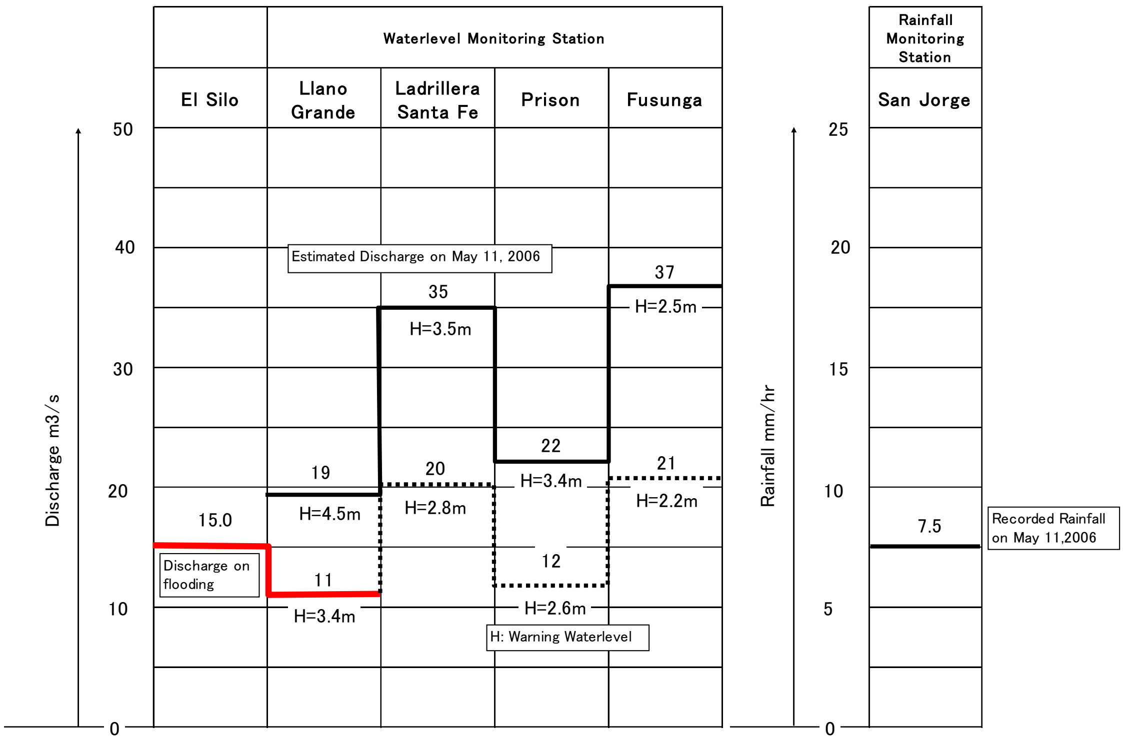



Figure 11-10 Concept for Warning Criteria for Soacha River

Table 11-6 Warning Water Level

| Station Name | Llano Grande | Ladrillera Santa Fe | Prison | Fusunga |
|---|---|---|---|---|
| Warning Water level | 3.4 m | 2.8 m | 2.6 m | 2.2 m |

c) Specific Warning for Tibanica (Claro) River Basin

By evaluating the channel capacity in the critical downstream reach, the warning level can be proposed. The minimum flow capacity in the Tibanica river is 2.7 $m^3/s$, so when the overflow depth at the spillway is more than 20 cm, some downstream sections could overflow.

### 11.5.6 Institutional Aspects

For monitoring meteo-hydrological information effectively, it is proposed to install the Monitoring (and Operation) Unit. Since natural phenomena happen anytime around the clock, the Unit shall operate on a 24-hour base.

Soacha Municipality has no surplus staff for full-time engagement for disaster monitoring and warning operation and there was a good practice of emergency operation when the disaster occurred in May 2006. Therefore, it is also proposed to make use of their existing organizational resources to the utmost.

Since the proposed MEWS for Soacha Municipality requires sharing the information with other organizations, it is necessary to arrange mutual agreements between Soacha Municipality and other organizations to make common use of the information.

During the pilot project, an agreement between Soacha Municipality and IDEAM was prepared and discussed regarding the monitoring station maintenance and information exchange.

For effective operation of the proposed MEWS, the participation by communities in monitoring and dissemination of information is desired. To make sure the participation by communities, it is recommended to have agreements between community organizations and Soacha Municipality.

Based on this proposal, communities and Soacha Municipality prepared an agreement on November 13 in the JICA Study Seminar. The signature of the agreement should be finalized as soon as possible.

### 11.5.7 Implementation Program

The implementation schedule is shown in Table 11-7. The cost is also estimated in US$. The year of the pilot project under the JICA Study was the fiscal year of 2007.

# Table 11-7 Implementation Program for Soacha

unit: US$

| Actions | Short Term 2007 | Short Term 2008 | Middle Term 2009 | Middle Term 2010 | Middle Term 2011 | Middle Term 2012 | Long Term 2013 | Long Term 2014 | Long Term 2015 | Long Term 2016 | Long Term 2017 | Long Term 2018 | Long Term 2019 | Long Term 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitoring and Early Waning System Establishment | | | | | | | | | | | | | | | |
| Monitoring and Data Gathering System | | | | | | | | | | | | | | | |
| Installation of Monitoring Equipment for Pilot Project | | | | | | | | | | | | | | | |
| 1 Monitoring Equipment for DPAE, EAAB, IDEAM via Internet | 10,000 | | | | | 10,000 | (replace) | | | | 10,000 | (replace) | | | |
| 2 Rainfall Gauge at San Jorge (ICA) | 9,300 | | | | | | | | | | 9,300 | | | | |
| 3 Rainfall Gauge at Firefighter Station | 8,400 | | | | | | | | | | 8,400 | | | | |
| 4 Water Level Gauge in Fusunga | 600 | | | | | | | | | | | | | | |
| 5 Water Level Gauge in Ladrillera Santa Fe | 13,500 | | | | | | | | | | 13,500 | | | | |
| 6 Water Level Gauge in Prison | 2,500 | | | | | 2,500 | (replace) | | | | 2,500 | (replace) | | | |
| 7 Water Level Gauge in Llano Grande | 1,600 | | | | | | | | | | | | | | |
| Installation of Monitoring Equipment for Future Stage | | | | | | | | | | | | | | | |
| 1 Monitoring Equipment for DPAE, EAAB, IDEAM, CAR via Exclusive Line | | | | 12,000 | | | | | | | | | | 12,000 | (upgrade) |
| 2 Water Level Gauge at Los Terreros Dam | | 3,000 | | | | | | | | | | | | 3,000 | (replace) |
| 3 CCTV Camera at Critical Point (Flood and Landslide) | | | | | | | | | | | | 5,000 | 5,000 | | |
| 4 Mobile Monitoring and Operation Unit | | | | | | | | | | | | 10,000 | 10,000 | | |
| 5 Installation of Own Communication System | | | | | | | 10,000 | 10,000 | | | | | | 10,000 | (upgrade) |
| Data Analysis and Processing System | | | | | | | | | | | | | | | |
| Data Analysis and Processing System | | | | | | | | | | | | | | | |
| Development of Simplified System (incl. the Pilot Project) | 6,000 | | | | | | | | | | | | | | |
| Development of Complete System | | | | | | 6,000 | 6,000 | | | | | | 6,000 | 6,000 | (upgrade) |
| Early Warning System | | | | | | | | | | | | | | | |
| Development of Semi-automated System (incl. the Pilot Project) | 6,000 | | | | | | | | | | | | | | |
| Development of Automated System | | | | | | 6,000 | 6,000 | | | | | | 6,000 | 6,000 | (upgrade) |
| Database System | | | | | | | | | | | | | | | |
| Development of Information Storage Database | 1,000 | | | | | 1,000 | 1,000 | | | | | | 1,000 | 1,000 | (upgrade) |
| GIS Database for Hazard Map, Disaster Record etc. | 1,000 | | | | | 1,000 | 1,000 | (upgrade) | | | | | 1,000 | 1,000 | (upgrade) |
| Internet Server | | | | | | | | | | | | | | | |
| Internet Server for Disclosing Monitoring Information | | 2,000 | | | | | | | | | | | | | |
| Internet Server for SMS, e-mail generation | | | | 2,000 | 2,000 | | | | | | | | 2,000 | 2,000 | (upgrade) |
| Information Dissemination System | | | | | | | | | | | | | | | |
| Establishment of Information Dissemination System using Existing Method | 1,000 | | | | | | | | | | | | | | |
| Establishment of Information Dissemination System using Future Option | | | | | | 20,000 | 20,000 | | | | | | 20,000 | 20,000 | (upgrade) |
| Set Appropriate Warning Criteria | | | | | | | | | | | | | | | |
| Hydrological Analysis using Past Disaster Record | 10,000 | | | | | | | | | | | | | | |
| Setting of Tentative Warning Criteria | | | | | | | | | | | | | | | |
| Hydrological Analysis using Observed Data during the Pilot Project Period | | | | | | | | | | | | | | | |
| Modification of Warning Criteria | | | | 2,500 | | | 2,500 | | | 2,500 | | | 2,500 | | |
| Institutional Arrangement | | | | | | | | | | | | | | | |
| Institutional arrangement in Soacha | | | | | | | | | | | | | | | |
| Establishment Special Organization/Committee working on Warning Situation | 1,000 | | | | | | | | | | | | | | |
| Establishment Monitoring and Operation Unit and Center | 10,000 | | | | | 20,000 | (upgrade) | | | | 20,000 | (upgrade) | | | |
| Agreement on Data exchange | | | | | | | | | | | | | | | |
| General Agreement with IDEAM | 1,000 | | | | | | | | | | | | | | |
| Respective/Individual Agreement with CAR | | 1,000 | | | | | | | | | | | | | |
| Community Based Disaster Management (CBDM) Activities | | | | | | | | | | | | | | | |
| Training on Hydro-meteorological Observation | 10,000 | | | | | | | | | | | | | | |
| Information Transfer Simulation and Drill | | CBDM activities should be done continuously even after the pilot project completion. | | | | | | | | | | | | | |
| Evacuation and Rescue/Response Drill | | | | | | | | | | | | | | | |
| Community Based Hydro-meteorological Observation | | | | | | | | | | | | | | | |
| River Improvement | | | | | | | | | | | | | | | |
| Rio Soacha Dredging, Drainage with Revetment | | | - | - | (by Soacha and EAAB ) | | | | | | | | | | |
| Rio Tibanica Dredging, Drainage with Revetment | | | - | - | (by EAAB ) | | | | | | | | | | |
| Total | 92,900 | 6,000 | 0 | 16,500 | 2,000 | 66,500 | 46,500 | 10,000 | 0 | 2,500 | 63,700 | 15,000 | 53,500 | 61,000 | 436,100 |

## 11.6 Pilot Project

### 11.6.1 Outline of Pilot Project

The pilot project for Soacha in the study area is implemented for the proposed short-term projects in Section 9.5. These projects are intended for installation / operation of monitoring equipment and monitoring / maintenance activity by Soacha Municipality-supported community, hydrology and hydraulic analysis, and study of tentative early warning criteria.

(1) Simple rainfall gauge installation and operation in Firefighter Station

The simple rainfall gauge with a sound alarm device was installed in Firefighter station on December 2006. The installation was intended to accumulate firefighters' experience in rainfall measurement and start the rainfall monitoring by Soacha Municipality. Since the Firefighter station was planned to be the monitoring center in the monitoring and early warning plan, the Study Team regarded that at first the firefighters should understand the significance of rainfall monitoring and the Municipality should have their own data.

(2) Riverbed Measurement by Community in Soacha River

In Soacha River, after the May 11, 2006 flood, the riverbed dredging was done by Soacha Municipality. People in communities in the basins of the Soacha River have recognized that the sedimentation of the river is serious and despite of the dredging by the Municipality, some people are afraid that the river would overflow by one flood. This is an example of exaggerated understanding of the Soacha river. People should understand the Soacha river's changes and pay attention to the river itself.

The purpose of the riverbed measurement by communities is as follows,

- To monitor the riverbed elevation change
- To promote community's attention to the Soacha river

(3) Installation of Rainfall Gauge and Water-level Gauge

The specifications of equipments are as follows.

Table 11-8 Specification of equipments in SOACHA

| Station | Element of Observation | Type | Specifications |
|---|---|---|---|
| Fire Station | | PC system | Desk top PC : HP Compaq dx2300 Microtorre<br>Lap top PC : HP Compaq nx6320 notebook PC<br>Router : D-Link Air Plus G<br>UPS : POWERWARE 9120 |
| | Rainfall | Tip-bucket | Rain gauge : Texas Electronics TR-525 Rainfall Sensor<br>Resolution : 0.1 mm Metric<br>Accuracy : 1.0% up to 50 mm/hour<br>Collector diameter : 245 mm<br>Logger : MOTOROLA MOSCAD-L Remote Terminal Unit<br>Solar panel : SUNTECH STP080S-12/Bb<br>Battery : VISION 6FM55<br>DC12V 55Ah<br>Regulator : Sun Saver 10 |
| San Jorge (ICA gate) | Rainfall | Tip-bucket | Rain gauge : Texas Electronics TR-525 Rainfall Sensor<br>Resolution : 0.1 mm Metric<br>Accuracy : 1.0% up to 50 mm/hour<br>Collector diameter : 245 mm<br>Logger : MOTOROLA MOSCAD-L Remote Terminal Unit |

| | | | |
|---|---|---|---|
| | | | Solar panel : SUNTECH STP080S-12/Bb<br>Battery : VISION 6FM55<br>DC12V 55Ah<br>Regulator : Sun Saver 10 |
| Fusunga | Water Level | Staff gauge | Water level gauge : APCYTEL staff gauge<br>Resolution : 1 cm Metric<br>Gauge rod : steel<br>Self standing |
| Prison of Soacha | Rainfall | Conventional | Rain gauge : TAKUWA Rain fall gauge with water storage bottle and measure cup<br>Collector diameter : 150 mm<br>Resolution : 1 mm Metric<br>Alarm : Preset the level optionally<br>Stuck on the roof |
| | Water Level | Staff gauge | Water level gauge : APCYTEL staff gauge<br>Resolution : 1 cm Metric<br>Gauge rod : steel<br>Self standing and stuck on the river wall |
| | Water Level | Electrode | Water level gauge : APCYTEL simplified water level gauge<br>Resolution : 20 cm Metric 10 sensors<br>Alarm : Preset the level optionally<br>Gauge device : PVC tubes and telephone cable<br>Stuck on the board fixed on the bridge |
| Ladrillera Santa Fe | Water Level | Staff gauge | Water level gauge : APCYTEL staff gauge<br>Resolution : 1 cm Metric<br>Gauge rod : steel<br>Self standing and stuck on the river wall |
| | Water Level | Ultra sonic | Water level gauge : Sonder Ultrasonic Level Meter<br>Measuring range : 0.5m – 12m<br>Resolution : 0.35% of measured range<br>Beam angle : 8deg. at -3dB<br>Logger : MOTOROLA MOSCAD-L Remote Terminal Unit<br>Solar panel : SUNTECH STP080S-12/Bb<br>Battery : VISION 6FM55<br>DC12V 55Ah<br>Regulator : Sun Saver 10 |
| Llamo Grande | Water Level | Staff gauge | Water level gauge : APCYTEL staff gauge<br>Resolution : 1 cm Metric<br>Gauge rod : steel<br>Stuck on the river wall |

(4) Radio Receiver and Speaker System

As a tool for information transfer among the stations, Soacha Municipality and the community, the Study Team proposes to install the radio system and speaker system for the Soacha River. A total of nine (9) handy radios shall be installed in five (5) stations, and three (3) community leaders and one (1) community leader of the Autopista Sur such as barrio El Silo shall be provided with the speaker system. The radio system shall be compatible with the existing Soacha Municipality radio system (Motorola system).

### 11.6.2 Monitoring and Information Transfer System

The equipment was installed in August-October, 2007 and started to measure the data. The stations at San Jorge (ICA), Ladrillera Santa Fe and Firefighter Station are automatic recording type, but the following manual activities are proposed.

In November 7, 2007 the training for information transfer and evacuation was held in the Soacha river catchment. The participants in the training were communities, CLOPAD, Soacha Municipality (firefighters and counterparts), police, Red Cross and civil defense. The total number of registered families in the participating community was 462.

The information transfer training is the on-the-job training in which the observers at the stations installed and set up by the Study Team in the pilot project inform / report the observed data to the firefighter station and community leaders as well as between the observers through radio receivers. The rainfall and water-level data in the scenario was provided to each station by the Study Team in advance (Figure 11-12).

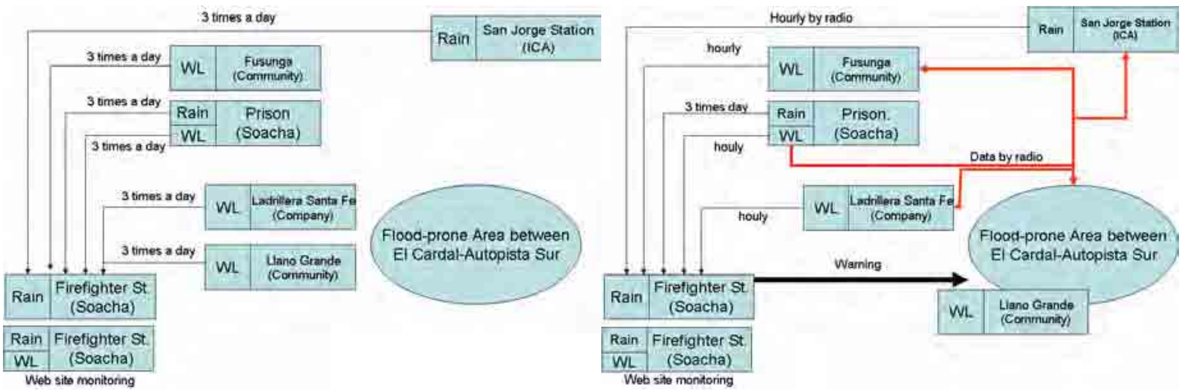



Figure 11-11 Information Transfer Diagram (left: Normal Time, right: Critical Time)

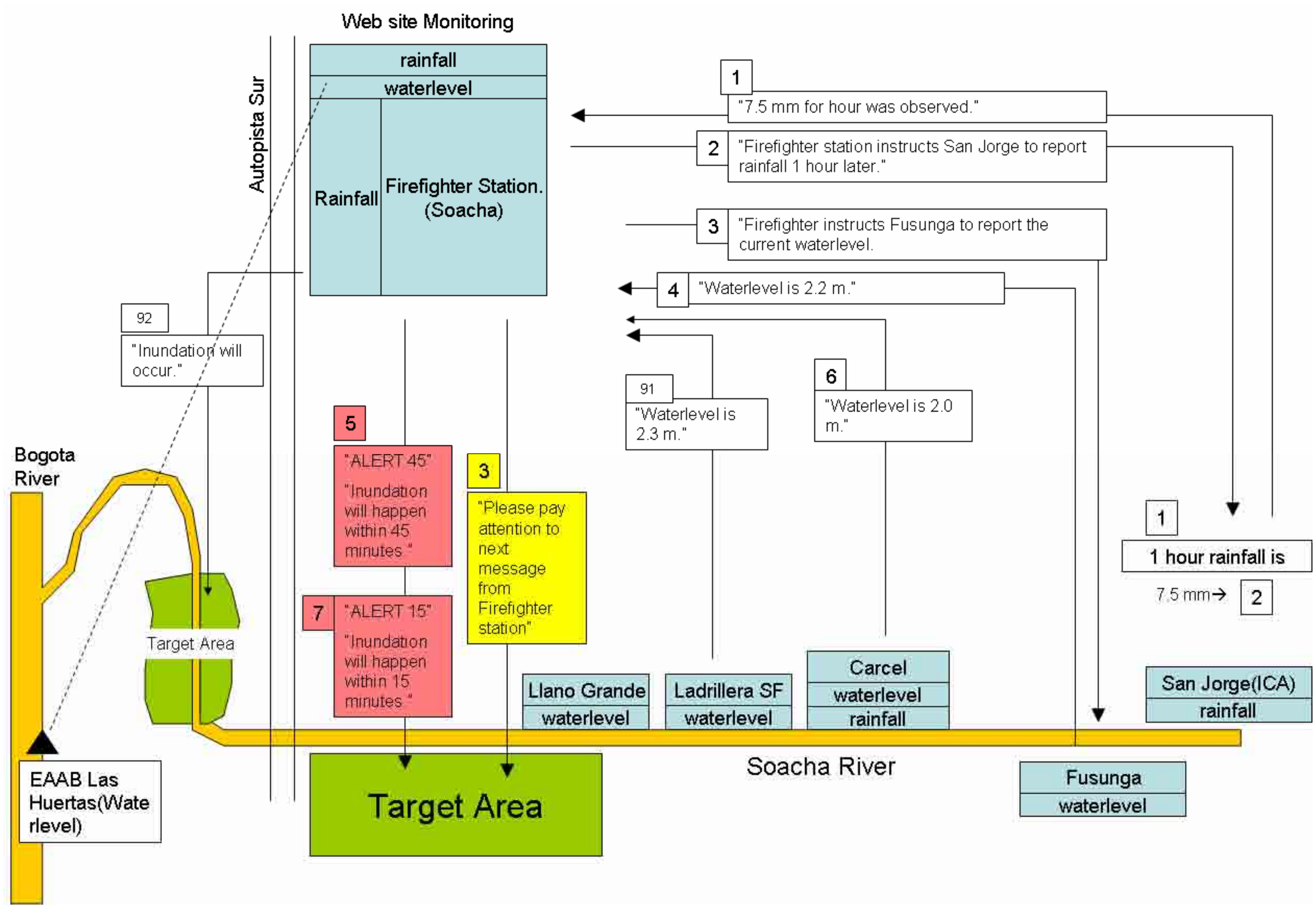



Figure 11-12 Diagram for Scenario of training for information transfer and evacuation

# CHAPTER 12 COMMUNITY DISASTER PREVENTION ACTIVITY

## 12.1 Existing Community Studies in Soacha

Many external organizations including international organizations are carrying out social, economic, educational and cultural activities in the most vulnerable areas in Soacha Municipality and producing a number of social studies and assessments about the conditions and needs that the inhabitants have to face. Most studies focus on Altos de Cazuca area, the hill where the majority of displaced people live and continue to arrive.

One of the studies which was made by the UNIFEM (2005) provided specific and updated analysis of social (education, health) and economic conditions (occupation, unemployment) by age group (youth, elders, adults), as well as infrastructure resources, assets and needs (such as water, sewerage, etc.). The "Doctors without Borders (MSF)" also made a study describing the situation of the inhabitants, particularly emphasizing on the health conditions of displaced people and their serious limitations to access to social services.

With respect to the topics of disasters, the studies of disaster prevention activities involving communities are quite limited. Practically, no community-based disaster prevention activities was found in these areas. Excepting trainings of CLOPAD members done by the OFDA methodology, the communities had not participated in any part of the disaster study or plan. In this sense, it is fair to say that one of the preliminary studies of community conditions from the perspective of disaster prevention was the Community Survey on Disaster Prevention completed by this Study.

## 12.2 Community Survey and Discussions by Focus Groups

### 12.2.1 Community Survey

In September 2006 the Community Survey Field Work in Soacha took place. A total of 24 barrios mainly in Comunas 2, 4 and 6 (only one survey occurred in a barrio of Comuna 5) and five Veredas in the rural areas were surveyed. Prior to the full scale survey, an experimental survey was done to detect inconsistencies. In the full scale survey, a total of three hundred sixty three (363) surveys were completed in the period of September 19 to September 29, 2006.

The Community Survey addressed five topics: Location, Respondent and Housing Characteristics; Experience in Disasters and Risk Perception; Self-help and Community organization for Disaster Prevention; Involvement and Active Participation. All these were surveyed by seventy one (71) questions.

The results of the survey were summarized as follows:

- People in high vulnerability have been only recently living in Soacha (12 years). The majority of respondents were women and elders.
- Households contain large and extended families with unstable income and high illiteracy rates.
- The majority of people surveyed had experienced emergencies or disasters, and expressed that they were fully aware of their exposure to a risk of disaster at the locations where they live.
- Self help and tie-up network appeared insufficient, and their access to information or training on disaster prevention was recognized as neglected. Their willingness to get involved in prevention and preparedness to activities appeared high and the interest of adults was higher than that of the

youth.

- Time availability to voluntarily participate in CBDM was found to be high, particularly in a daily basis.

### 12.2.2 Focus Groups

Focus groups in the participatory research method were used in the planning process. The purpose of the Focus Groups was to expand knowledge on qualitative information that is difficult to gather by other means such as the quantitative survey. Also it served for the purpose to understand the relations among issues (emergency and disaster, development, and resources), and to create a scenario in which the participants could set their own vision of priorities, actions and actors in disaster management activities.

Two Focus Groups: one on each key landslide sector: Divino Niño area and Altos de Cazuca area were selected in the topic of landslide and two Focus Groups were implemented for the flood component: one in the area of Tibanica River and the other one in Soacha River, including people coming from the upper stream as well as those directly affected by May 2006 floods while initially three Focus groups were considered.

Each session started with an explanation about what is a Focus Group. Two questions were addressed in all four events about community perceptions on disaster preparedness for the study: 1) What are the priority actions to be addressed in the area with respect to community-based disaster prevention, and 2) Who are the most likely agents to be involved in the topic of preparedness. In addition, a topic was posed by the facilitators as a free topic because leaders have their own questions and topics to discuss, which tend to stem out from collective discussions. In each session, the last half an hour was devoted to an "emerging" topic, which proved to be convenient in rounding up some of the ideas that were talked about during the session.

Summary ideas of the Focus Groups:

The communities, based on the opinions of their representatives attending the events, appeared to know and be fully aware of their risks and their reality. They understood quite well the need to organize themselves to improve their living conditions and their surrounding environment. At the same time they visualized larger -rather than partial- solutions as acceptable. They preferred physical works rather than software measures. They considered practical training as needed rather than the information and awareness that is only reinforced.

Agreement was found on the need to visually demark the areas of high, middle and low risk. This task is a key as an initial task on community-based disaster prevention work. Ease to understand explanatory messages located in public visual places in the risky areas was regarded as highly necessary. Following this boundary delimitation, public works were needed: sanitary pipes channeling the sewerage effluents from the neighborhood, separately from the river flow, in case of flood disasters; and safety recovery works in slope areas abandoned by former mining practices.

Community members explained and strongly requested for the urgency of resolving the vicious circle (cause-effect) of investment in high risk slope areas and the people's exposure to the risk itself. The lack of infrastructure works to channel fluid drains over the hilltops is one of the most important problems to solve in order to stop the hazards created by these types of water. The exposure of the communities to landslides is caused by the lack of infrastructure works controlling the spontaneous drainage and infiltration of the sewerage, grey waters and rain runoff.

The attendees envisioned the population at risk to be resettled in a different safe place permanently rather than temporarily. With respect to the collaborative efforts, the community members understood and were willing to organize the inhabitants, but they requested for proper promotion and facilitation tools to be accompanied by the willingness of the municipal authorities to address the issues above mentioned.

The final idea was that collaborative efforts between neighboring barrios are possible. Coordination was regarded as highly necessary. Collaborative settings would lead community leaders and municipal authorities to work side by side. This framework would allow building trust amongst each other, setting a consensus-based agenda and advancing on the improvement of the hazardous conditions in an organized manner, again, under clear communication settings between all stakeholders.

## 12.3 Community Based Disaster Management (CBDM) Activities

### 12.3.1 Planning Process

During the third and fourth field works of the Study, a set of activities were done to advance the Community Based Disaster Management Plan in the pilot area of Soacha River Basin as a pilot activity.

The activities were mainly done in the area that was affected during the May 2006 flood disaster. At that time eight neighborhoods were inundated and all neighborhoods are located at the left bank of the Soacha River. The neighborhoods affected were El Cipres, Florida II, Cohabitar, Cien Familias, Pradera I, Pradera II, Florida I, Llano Grande and El Cardal. The population in this affected area was roughly estimated to be five thousand (5000).

During the execution of the CBDM activities, the most responsive communities were Florida II, Cohabitar, Cien Familias, Pradera II, Florida I, Llano Grande and El Cardal. In some sessions, the leaders from Pradera I, Panamá Neighborhood and El Cipres as well as the leaders from the downstream basins attended the activities.

These activities were mainly community-based workshops intended for community hazard and resources maps for disaster prevention; field visits to confirm the existing situation or to learn about the upper stream conditions of the watershed; community based monitoring trainings, interagency coordination meetings, and self-prepared neighborhood meetings.

At the same time, community activities (mainly including meetings, field inspections and workshops) took place with respect to landslide issues, both in Divino Niño area and Altos de Cazuca area locations.

The most constant activities were a set of community workshops - an iterative process in which most of the leaders of the neighborhood associations (JACs) collaborated to wrap up the contents of their Community Disaster Prevention Plans. The workshops were initiated by identifying the hazard conditions, the flood scenario and their exposure to risks during the May 2006 emergency. They went through their recollections on what happened, how they acted, what were the types of hazard. This information was reflected on the Community Maps by river basin.

During the following activities, the Community Maps would be improved until the current status of the river basins is reflected on them for disaster prevention.

During the months of May and June, the leaders started building and setting up their prevention strategies and the action plans in order not to repeat their experience in the regretful situation and consequences suffered during the May 2006 disaster. The process of workshops allowed creating an environment where they can strengthen their capacity and confidence.

The community members and leaders established themselves responsibilities for prevention activities; monitoring of weather on rain and water-level gauges and of river bed elevation, setting and testing of communication equipment, learning of the procedures of formal communication between stations and with the Fire Station, and also learning how to get acquainted with neighbors and how to get aware of the family members in the neighborhood through informal means. Through the radio communication system, the leaders were able to communicate with each another and inform the conditions of the river to the Firefighters' Station.

During the workshops, knowledge was collaboratively constructed, whether coming from community members, firefighter, Red Cross volunteers, JAC leaders or CLOPAD/Alcaldía officers. A sense of wide cooperation was gained over time during the month of June. This consequently leads the community leaders to commit to prepare and execute community meetings during the month of July on their own. All the spatial information collected and created during the workshops was consistently added to the set of community maps and used for the community meetings. At the same time, handouts were given out to the members from the neighborhoods together with specific data such as contact persons and phone numbers of the leaders of their areas. The handouts contained also a photo of the map of their area and simple key messages explaining how to be prepared.

A First Respondent Training Course coordinated by Red Cross Trainers, an Evacuation Simulation Session and several preparation meetings led to the first Community Based Flood Evacuation Drill which took place on September 22nd. Six neighborhoods of Florida I, Cien Familias, Florida I, Pradera II, Llano Grande and El Cardal participated in the Drill. Approximately 530 people participated in the evacuation led by 50 to 60 leaders.

An evaluation session held after the Drill revealed both their satisfaction with their growth experience and their desire to improve key aspects. Some aspects as mentioned by the participants were more community involvement, improved encouragement strategies towards the public, better coordination between JAC leaders and street and meeting point coordinators, better assessment of families at the meeting points. The presence of the police or security persons was mentioned as a factor that could have given confidence to the families that refused to participate, to leave their homes and join the evacuation exercise.

On November 8, 2007, the second and complete evacuation drill took place. All the Early Warning System, the upstream stations and the Firefighter Station as well as the information center and the affected communities in the downstream basins were included in the exercise. The evaluation of this exercise suggests the important lessons learned from the experience, shedding light on final recommendations for the future activities to be continued by the CLOPAD members and Community Leaders themselves (see Supporting Report S7).

The final activity to wrap up the entire CBDM Plan was the Seminar held on November 13, 2007. CLOPAD members and community leaders, DPAE, OPAD and other officers attended the Seminar and were able to listen to the contributions offered by the selected lecturers who were a community observer from the upstream area of Soacha River, a JAC leader from the affected downstream area, the firefighter head officer and a Civil Defense representative. At the closing of the Seminar, all parties signed a Commitment Agreement to continue the monitoring work, the improvement of the river and the inter-community and inter-institutional coordination for disaster prevention.

## 12.4 CBDM Plan

This section addresses the eight components of the Community Based Disaster Management Plan.

(1) Rainfall, Water and Riverbed Level Monitoring System
(2) Information Transfer System
(3) Early Warning System
(4) Operation and Maintenance
(5) Considerations of Lead Time for Early Warning Criteria
(6) Evacuation Plan
(7) Community Disaster Prevention Map
(8) Meeting Points and Shelter for Evacuation

In the following pages, the output in each of the components of the Plan is discussed. The information reflected on the plan is based on the options, possibilities and desires from the engaged community leaders and active neighbors.

(1) Rainfall, Water-level and Riverbed-level Monitoring System

Monitoring of rainfalls and water levels

Rainfall and river water level monitoring by community is one of the most important CBDM activities. To monitor the river behavior, several rainfall and water-level monitoring stations were installed in the Soacha river basin.

At the most upstream point of the basin, a rain gauge was installed inside the property of the ICA (an agriculture institution). The IDEAM weather station is also located within the ICA property. The rain gauge installed in the pilot project has been monitored by the family living inside the ICA.

The second highest station is installed in Vereda Fusungá. Some houses are located at the points close to the river which are relatively easy to monitor the behavior of the river.

The next monitoring point is located in the middle reach of the river and managed by the municipality; the Zaragoza Prison. Three guards are taking charge of monitoring in their work shifts to cover 24 hours of surveillance.

The next downstream point is the Ladrillera Santa Fe. River water levels at checking points are permanently monitored by the security guards at the entrance of the brick company.

The last river monitoring point is in the neighborhood known as Llano Grande. This community is not located in the "upstream" area in a technical sense, but mostly in the middle or downstream area. It is actually in the most affected area. A monitoring station was installed here in order to raise awareness of the water-level condition and to improve the emergency response in case of an imminent flood. Houses in Llano Grande are built closely and in the flood plain, in lower grounds than other neighborhoods. Llano Grande was one of the communities most affected during the May 2006 disaster. Community leaders live in convenient locations close to the observation points along the river.

All these observation points have a person which is able to communicate regularly with the Fire Department of Soacha, to inform three times a day on a regular basis about the conditions of the river. The role of the observers is to permanently watch, write down and inform the monitored readings. Through the workshop meetings, the community leaders along with the institutional officials and private enterprise supervisors (from Ladrillera Santa Fe) selected the main persons in charge of the monitoring tasks. A complete list of the persons in charge is shown in the Chapter 10 of the Main Report of this Study.

Regarding the Firefighter's Station, the main responsible person is the head of Soacha's Fire Department. Nevertheless all staff (eight) firefighters in Soacha will do the same task of monitoring the rain gauge daily as well as receiving the data sent from each of the monitoring locations in the upstream and downstream areas. The situation for the Ladrillera Santa Fe employees is similar and if the main responsible person will not be in the post, other security employees will undertake this task. The Prison of Zaragoza also rotates three municipality employees for this task.

At the two community monitoring sites, Fusungá and Llano Grande, women have accepted the responsibility for monitoring the water level gauge installed in the Pilot Project under this Study. Also in both cases, the main responsible persons live at the locations near to the river. At each of the river points, the observers use the provided radio communicator to make a report to the Firefighter's base.

In addition to the monitoring of rainfalls and water levels, in order to check the sedimentation behavior of the river, five points (Bridges: Carrera 2A, Carrera 2Este, Carrera 4 Este, Carrera 7 Este, Carrera 9 Este) in the pilot community were identified as the monitoring points. The riverbed monitoring is being conducted every two weeks by community members.

(2) Information Transfer System

Regarding the existing communication system in communities in the flood area, the study team members made an assessment of the current conditions in order to determine an appropriate community-based communication system for flood warning including locations of alarms.

According to the assessment, most of the communities did not have a collective alarm system installed while some barrios had a speaker system, by which they communicated internally along the adjacent streets. The types of message they use to deliver through their existing system are messages about community activities such as calling to neighborhood meetings or relevant information that require all people's attention for the betterment of their neighborhood.

(3) Early Warning System

Considering the community-based flood early warning system, close relationship and collaboration work between upstream community and downstream community has been strongly stimulated. Community leaders living in the upstream basins have set up the workshops, providing inputs and support in formulating the Plan.

The leaders from Vereda Panamá, located between Fusungá and El Cardal, in the middle catchment of Soacha river, attended the workshops of June 23 and 27, 2007, expressing concern and interest in being part of the monitoring and early warning system. The members of Vereda Panamá had a meeting in July 2007 through which their situation was made clear, in particular, how they have become part of the warning system and the prevention plan.

Community leaders from the flood-prone areas of the Soacha river attended the workshops and expressed concern about their situation, and interest in becoming part of the pilot project as well. Community members from El Cipres and Prado de las Flores attended one workshop. Leaders from Portalegre and El Silo, from downstream also joined the discussions. They expressed willingness to coordinate a meeting with the Comuna 2 board and representatives and requested that Alcaldía staff could be at this event.

To complete the early warning system in the community, further discussions and trainings were needed. Trainings were carried out using the monitoring and radio equipments for early warning which were installed in late August and September 2007.

As a result of the collective works between upstream and downstream communities in the workshops, the means of communication and information flow for the community-based early warning system were established. This community-based communication system could support the official early warning communication.

Community leaders living in the Tibanica watershed were invited to attend the workshop held in June, and two leaders were present. They were invited as observers in the planning process related to the Soacha river to stimulate some initiatives in their own communities, because the CBDM activities in the Soacha river is the only activity in the pilot project; a starting point for the Soacha municipality and the community members to increase and expand their disaster preparedness work with local stakeholders. Through the existing channels of communication with the UNDP project coordinators, invitations were delivered to those leaders to attend the workshops and subsequent drills.

(4) Operation and Maintenance

The maintenance of the equipment installed has been discussed with the municipality representatives with IDEAM. Particularly important is the proper maintenance and battery replacements of the radios. The rain gauges and the monitoring poles are part of the equipment to be used by the community leaders. Some leaders expressed interest in setting more staff gauges in order to monitor the behavior of the river in the best way, because there are depths in some places and other sections are very shallow.

(5) Considerations of Lead Time for Early Warning

As input data for the Early Warning Criteria, the community members and leaders determined how much time is needed for evacuation: a) to inform all community members of the urgency of evacuation, b) to prepare items and actions to evacuate individually and collectively, and c) evacuating time for leaving each house, walking on the streets through the evacuation routes, and gathering in the Meeting Points.

The required time for evacuation stated by the community members and leaders is varied from 50 min to 105 min depending on the community's situation. It is clear that these times need to be finely adjusted through exercises, and fed with the accumulated data from the upstream monitoring stations. After the implementation of the two drills, it was made clear that the time actually used during the exercises was beyond the time stated by the members and leaders.

(6) Evacuation Plan

Regarding the Evacuation Plan, several sets of planning items were advanced. A preliminary estimation of population in the neighborhoods added 5,730 persons in the pilot project area. No health infrastructure is present in the area, and three kindergartens are located in three barrios (sixteen (16) children attend each of two kindergartens). Based on this kind of information, the responsibilities of the leader groups were determined. The warning messages were created. The Evacuation Routes were defined.

The evacuation routes and locations of meeting points and shelters were discussed in the workshops. Most of the meeting points are open spaces. The Evacuation Drills led leaders to reconsider the meeting points according to the following considerations: safe distance to the hazard, difficulties in accessing to the Shelter point; delays in obtaining permission to use a given space owned by some other neighbors.

Based on the considerations, for example, Florida II, Cien Familias and Cohabitar shifted their locations from the Sports Open Space next to the Divino Niño Parish Church, to the opposite side of the neighborhood, the high grounds in the back east sector called as the former "Ladrillera of Dr. Murcia". In Llano Grande and El Cardal, one Meeting Point originally defined was Parques del Sol II. During November 7th meeting and during the November 8th Drill, this location was changed to Parques del Sol I. During the evaluation of the November 8th Drill, there were comments that the chosen Meeting Point was too far for an evacuation. This place was not recommended for elders, ill people and other special needs population.

Through the workshops discussions, it was made clear that the entire area had insufficient options to shelter a large number of people in event of disaster. An agreement between the Soacha municipality and the JAC administration concerning the Community Center to accomplish the role of a public shelter in case of emergency is a task that should urgently be done. With this arrangement, funds could be made available in order to provide infrastructure investment by the municipality. The municipality can also request for donations from third parties. The Social Development Secretariat of the municipality has temporary shelters identified. It is recommended to avoid sending people to shelters far from their houses. The required items for shelters operation were also discussed in the workshops.

(7) The community disaster prevention map

The community members and leaders collectively gathered the information pertinent to the prevention plan. The Community-based Workshops including field activities were a baseline towards building better knowledge on the territory (Figure 12-1).

A walk around the streets to study the possible evacuation plan in each barrio was coordinated with Red Cross volunteers and the JAC leaders who visually explained the areas flooded during May 2006. The streets, routes and shelters were identified and inspected in Cien Familias, Florida II, Cohabitar and Florida I. Another field visit identified the number of floors and type of roof (flat with terrace or not). This data was added into the draft maps, (lower left) and later incorporated into the GIS database for the Community Map.

Figure 12-1 Community Activity for Preparation of Community Disaster Prevention Map

During the field visit, the buildings affected by the 2006 flood were also identified and visualized on the map. Not all the one-story houses have to evacuate. Some houses have small walls built in the entrance that prevent water from flowing into the houses. But some two- and three-story buildings require evacuation. While the information needs to be more refined, it provides a good basis for a general overview of the conditions of buildings and houses.

The information (on the hazards that community people are facing and the recourses that they have, the routes and places for evacuation, etc.) which they shared and agreed upon was written into the draft community disaster prevention map (Figure 12-3) and the information on the draft map was corrected during the process until completion of the final map.


Figure 12-2 Draft Community Disaster Prevention Map

(8) Meeting Point and Shelter for Evacuation

In the Community Disaster Prevention Maps, the evacuation routes are marked with green arrows. The Meeting Points are marked with a circled green “E” letter.

The information visualized on the draft map was transferred into the GIS database and finally produced as the community disaster prevention map as shown below.

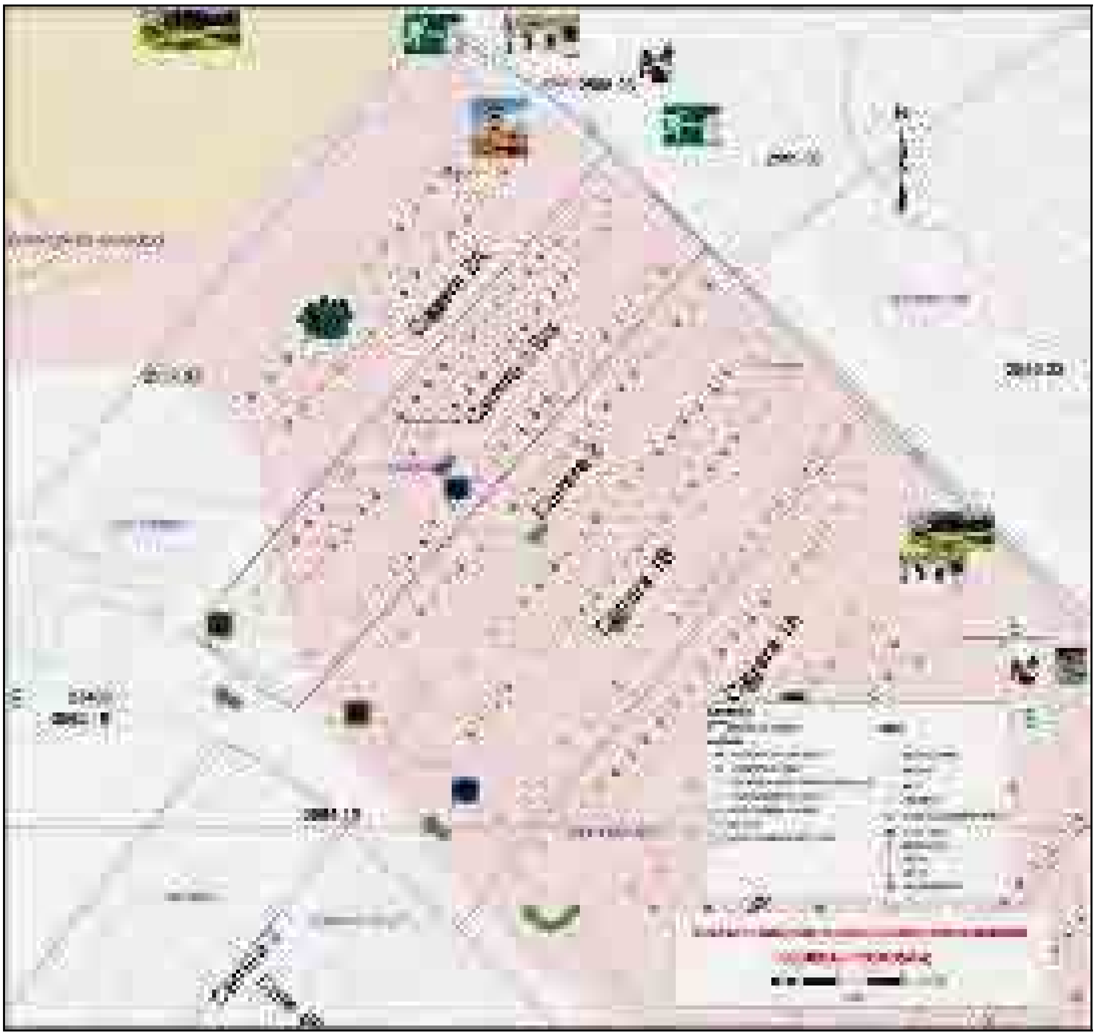


Figure 12-3 Example of Community Disaster Prevention Map

## 12.5 CBDM Manual

A draft manual has been prepared as a result of discussions held in this Study. The following concepts were applied for preparation of the manual.

- Each barrio has its own material with specific information pertinent to their area.
- The manual is the simplest possible version for community members. Visual and written sections are balanced for representing clear ideas in simple language and easy to read sentences. The manual is designed for easy use and to easily be posted in an easy to see place such as on the refrigerator door, a window or wall in each house.
- Each manual contains a map of their area with the evacuation routes, the meeting points, the affected area and the number of stories of the buildings. It includes also the names of the leaders in their barrio with phone numbers, and other contact list such as the Firefighters, Alcaldía and Red Cross. The manual contains the common recommendations regarding what to do in event of a flood emergency.

An example of the Manual is shown in Annex 10 -3 of the Main Report.

# CHAPTER 13 TEMPORARY WORKS

## 13.1 Background

In the Territorial Ordering Plan (POT) of the Soacha Municipality, the Municipality classifies El Divino Niño area as a "Hazardous Zone by Landslide", and the Municipality will implement a relocation program of houses located in the hazardous zone.

At the preparatory stage of this study (September 2005), the Soacha Municipality requested a study and the implementation of emergency measures for slope protection of the El Divino Niño area, and the Study Team carried out the study and investigation. The Study Team concluded that the relocation of houses is the only way to ensure the safety of residents and any other measures are impractical, and some of them may induce a further dangerous situation. The Soacha Municipality agreed on this conclusion.

As mentioned above, the El Divino Niño area has been designated as an hazardous area by the Soacha Municipality. However, the dangerous area has not been specified yet concretely. Therefore, the Study Team examined and decided the Critical Zone using the following criteria, and details are shown in Chapter 10 in this report.

- The slope angle is not less than 30 degrees, and the slope height is not less than 5 m
- The distance from the slope toe is within twice the height of slope.

Since many houses must be relocated in the Critical Zone, their relocation may take some time. With this situation in mind and to give a priority of relocation, the Critical Zone was classified into two (2) zones, namely Emergency Zone (the area within 10 m or 2 rows of houses from the toe of the slope) and the remaining zone.

Although the Soacha Municipality implements the relocation program based on this priority and the relocation of houses in the Emergency Zone is completed, many remaining houses may be affected in the Critical Zone. It is recommended therefore to proceed with temporary works in order to reduce any risk of small-scale slope failures and rock falls on the remaining houses. The main works of the temporary works concern the construction of a protection wall on the boundary of the Emergency Zone once the houses are relocated, and the drainage channels.

In this connection, the Study Team carried out the plan and design of the temporary works in the third and fourth field works of the Study, and the results are presented in the following sections.

### 13.1.1 Purpose of the Temporary Works

The purposes of the temporary works are:

- To reduce the risk of small-scale slope failures and rock falls on the remaining houses in the Critical Zone

- To inform the neighborhood that a critical zone remains hazardous, and

- To act as an emergency measure to prevent new settlement in the critical zone.

### 13.1.2 Items and General Plan of the Temporary Works

The temporary works are composed of four major items as described below:

- Construction of a temporary protection wall along the boundary of the Emergency Zone against small-scale slope failures and rock falls

- Construction of a drainage channel in front of the temporary protection wall
- Construction of a conventional drainage channel at the upper part of the El Divino Niño area
- Installation of sign boards to inform about the risks

The general plan of the temporary works is shown in Figure 13-1.

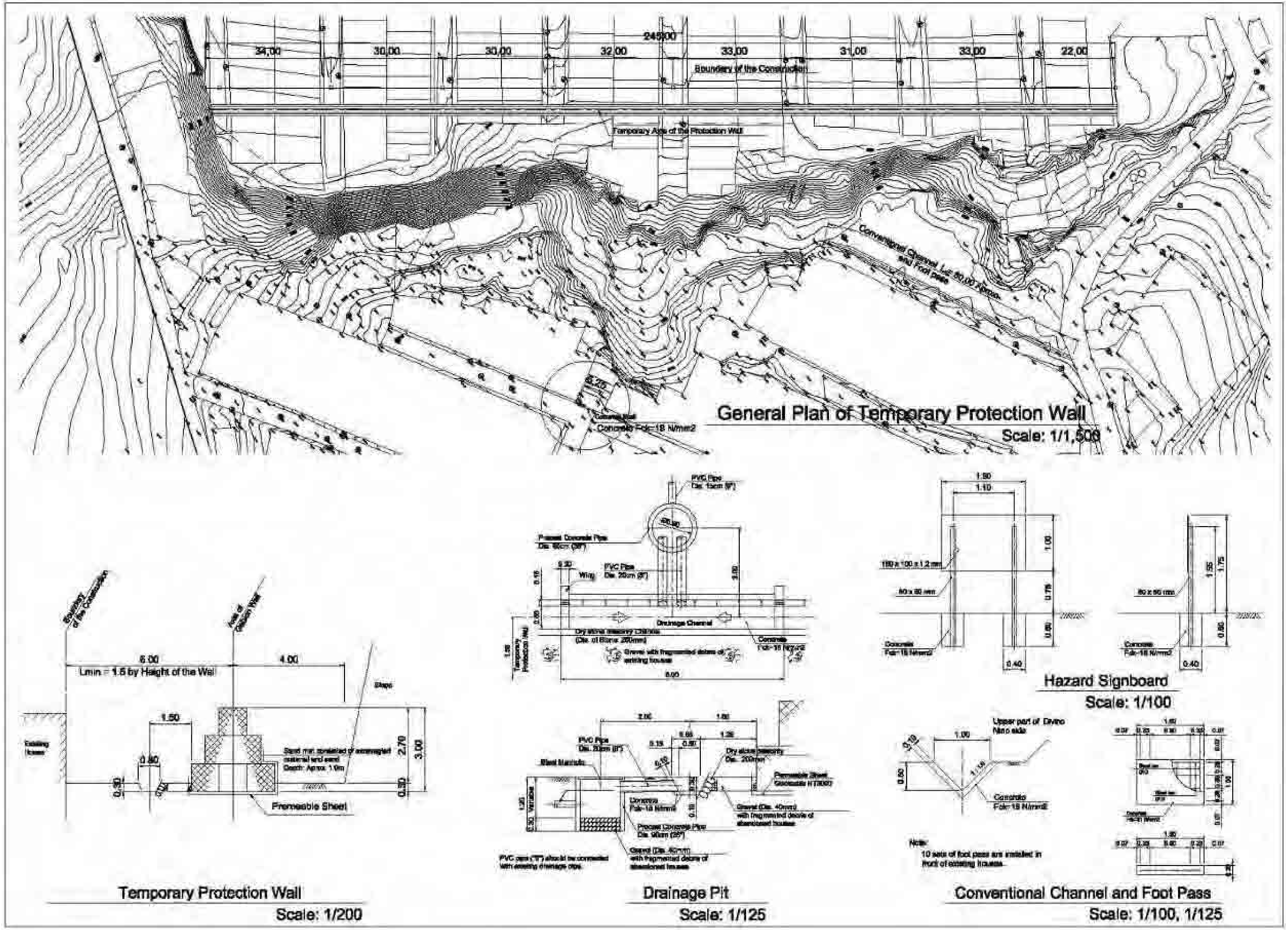



Figure 13-1 General Plan of the Temporary Works

## 13.2 Plan and Design of the Temporary Works

### 13.2.1 Present Condition

The El Divino Niño area is located 1.4 kilometers south of the center of the Soacha Municipality. In the housing estate located in front of the cliff, there are nine (9) blocks and 165 houses and small factories have been found in these blocks. In the 80s, this area was used as a borrow pit for construction materials. At the completion of the activities of borrow pit, it has been abandoned and a steep cliff remained. Later on, inhabitants started immigrating from outside the Municipality and settled in the area mostly without legal titles for about 15 years.

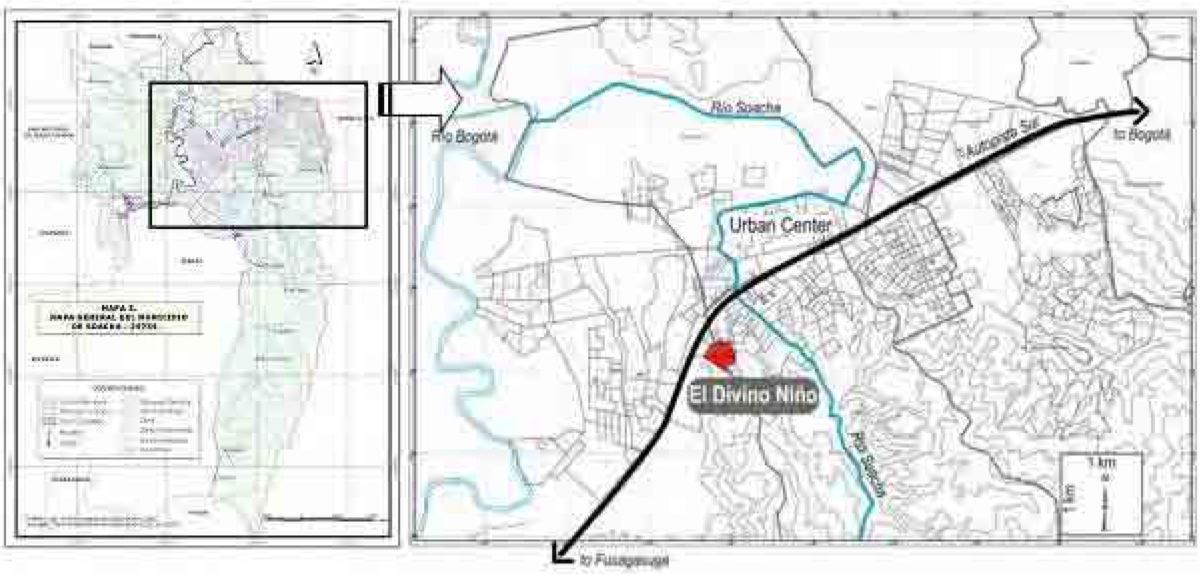



Figure 13-2 Location of the El Divino Niño area

On the cliff surface, several landslides occurred in the past from the positions of rocks and materials on the slope. The bedrock is developed in the direction of the cliff and sediments such as sand and gravel have been deposited in the space between rocks on the bedrock through the movement of landslides. At present, the rocks are supported by the bedrock and these sediments. There is a possibility of rock falls and landslides if these supporting materials are eroded due to rainfall.

### 13.2.2 Plan and Design of the Temporary Works

The method used for the temporary works is applicable to another area in the Municipality. A gabion wall was recommended for the temporary works in the Minutes of Meeting signed on November 20th, 2006.

(1) Temporary Protection Wall

The function of the temporary protection wall is to absorb and stop the kinetic energy of: a) sliding, b) rolling c) free falling, and d) bouncing of falling rocks in several sizes which are on the slope surface. The energy produced by movement of a falling rock is in proportion to its size and height of the slope.

**1) Design Rock fall**

a) Design Rock Size

The design rock size was decided based on the field investigations of rocks on the slope surface and the actual sizes of the fallen rocks. On the stereo pictures prepared by this Study, a total of 271 rocks which may fall in the future were detected. As for the rock size, a total of 275 existing rock falls were measured at nine (9) residential blocks. The rock size accumulation curve displaying the size distribution of rock falls was obtained from this measurement.

For the Temporary works, the diameter of 175 cm ($D_{100}$) which was the largest to be recorded was adopted as the design size of fallen rocks.

b) Bouncing Height of Rock fall

The required technical data to estimate the bouncing height of falling rocks were not available at the site, and the design bouncing height of falling rocks was thus estimated based on the empirical knowledge.

In experiments in Japan, 80 to 85% of the total bouncing heights recorded were confined within 2.0 m and it is rare that the falling rocks bounce over the height of 2.0 m from the slope surface. In this Study, the maximum bouncing height of falling rocks was set at 2.0 m from the slope surface.

**2) Design of Temporary Protection Wall (Gabion Wall)**

a) Form of Gabion Wall

The wall height was decided from the design bouncing height by adding a radius of target rock size since the bouncing height meant the height from the ground surface to the center of a falling rock. The bouncing height and the radius of the target rock are 2.0 m and 87.5 cm (r=175 cm/2) respectively. Therefore the protection wall is constituted by three (3) layers of gabions each of which has a standard height of 1.0 m. The terraced layer arrangement was applied to the gabion wall taking into account its flexible characteristic and the sand-mat cushion utilizing the materials produced through demolition works was installed behind the protection wall in order to decrease the impact force of falling rocks. The depth of 1.0 m was considered appropriate for the sand-mat cushion in the Rock shed structure.

The form of the gabion based on the above-mentioned is shown in Figure 13-1.

b) Axis of Gabion Wall Installation

The baseline of the cliff meanders following a disorderly excavation in the past. However, the axis of gabion wall is in a straight line disregarding the shape of the baselinedue to the construction cost, the easy installation of the wall and other factors.

(2) Drainage Channel in front of the Temporary Protection Wall

The drainage channels and drainage pits were installed on the house side of the temporary protection wall to drain the runoff water from the slope. The water collected in a drainage pit located in each street is drained through the filter in the pit to the existing drainage pipe.

(3) Conventional Drainage Channel on the top of the El Divino Niño area

In order to minimize the erosion of the materials which supported the rocks on the slope, the conventional channel was installed at the top of the slope in the El Divino Niño area. Due to the topographic conditions of the land, a channel with a length of approximately 80 m was installed between residential blocks Nos. 7 to 9. In the other section between residential blocks No. 2 and 6, since the runoff water at the upper part of the slope was discharged from the access road which did not have curbs installed, concrete walls acting as curbs were installed. Because of these walls, the access road has become a waterway road to drain water in rainy season.

(4) Landslide Hazard Sign Board

The temporary protection wall does not provide a perfect protection to the illegal residents in the future. Therefore, the hazard sign boards were installed to announce the neighborhood about the meaning of the construction of a temporary protection wall and that they are living in a dangerous zone.

## 13.3 Implementation of the Temporary Works

### 13.3.1 Implementation Concept of the Temporary Works

The implementation of the temporary works will start at the completion of the housing relocation by the Soacha Municipality without causing any social problem.

(1) Organization for the Execution of the Temporary Works

In principle, a notice regarding the progress of the relocation should be given by the Soacha Municipality to the Study Team. The Municipality was to request the installation of the temporary works to the Study Team when one (1) or several residential blocks were completely evacuated without any trouble. The Study Team would order the installation of the wall to the Contractor after the site investigation following the request.

In the execution of the temporary works, the responsibilities of the parties concerned were as follows.

Table 13-1 Responsibilities in the Execution of the Temporary works

| Category | Municipality | Study Team |
|---|---|---|
| 1. Relocation | | |
| 1) Relocation of families | O | - |
| 2) Demolition works of abandoned houses | O | - |
| 3) Care of the community | O | - |
| 4) Permission required by the environment law | O | - |
| 2. Construction Works | | |
| 1) Warranty of existing infrastructure in the critical zone | - | O |
| 2) Permission required by the construction law | - | O |
| 3) Construction of the temporary protection wall | - | O |

(2) Packaging considering the Progress of the Relocation Activities

Three (3) months are required for the temporary works after the completion of the relocation activities by the Municipality. Depending on the progress of the relocation, there was a possibility that some items of the temporary works could not be executed during the construction period and the construction works were to be carried out together with the relocation activities. Therefore, the temporary works were divided into the following 10 packages in accordance with the number of residential blocks, the roads, and work items.

Table 13-2 Details of the Packages of the Contract

| Package No. | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Residential Blocks* | - | *No. 2* | *No. 3* | *No. 4* | *No. 5* | *No. 6* | *No. 7* | *No. 8* | *No. 9* | *Streets* |
| 1. Protection Wall | - | 31.8 | 25.4 | 25.3 | 26.9 | 27.7 | 25.5 | 27.8 | 22.0 | 34.8 |
| 2. *Drainage channel | - | 31.8 | 25.4 | 25.3 | 26.9 | 27.7 | 25.5 | 27.8 | 22.0 | 34.8 |
| 3. Drain pit | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 4. Sign Board | - | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 5. Conventional Channel | 80.0 | - | - | - | - | - | - | - | - | - |

Note: *Drainage and conventional channels mentioned in the table were installed in front of the wall and at the top of the slope, respectively.

(3) Modification of the Temporary Protection Wall Axis in relation to the evacuated residential blocks

The axis of the temporary protection wall was provisionally set at 6.0 m from the construction boundary. If the space between construction boundary and the wall axis increases after the relocation, it would be necessary to modify the position of the axis based on the opinion of the Municipality and the community for the settlement of new immigrants in the said space.

(4) Method of Contract

There are two (2) types of contracts for the implementation, which are 1) unit price contract and 2) lump-sum contract. In this Study, the lump-sum contract method was adopted because of the short construction period and a large number of construction packages. Since there was a possibility of suspension of the construction works due to problems in the relocation activities, the unit prices of the work items were also fixed between the Study Team and the Contractor for disbursement for the works executed by the contractor.

Table 13-3 Conditions of the Temporary Works

| Item | Description | Specifications |
|---|---|---|
| 1. Temporary Protection Wall | 1.1 Gabion Wall | Structure: 3 layers of gabion blocks |
| | | Length: 245m |
| | 1.2 Sand mat | Structure: Excavated material and debris |
| | | Length: 245m |
| 2. Drainage Channel | 2.1 Drainage Channel | Structure Earth channel with dry masonry |
| | | Length: 245m |
| | 2.2 Drain Pit | Structure: Precast concrete pipe |
| | | Units: 8 sets |
| 3. Conventional Channel | 3.1 Conventional Channel | Structure: Concrete channel (180 kN/mm$^2$) |
| | | Length: approx. 80.0 m |
| 4. Hazard Sign Board | 4.1 Hazard sign board | Structure: Steel board |
| | | Units: 8 sets |

(5) Selection of the Local Contractor

For an immediate construction, the Study Team selected the Local Contractor in advance through a tender that includes 1) prequalification of contractors, 2) evaluation of contractors' technical proposals and 3) economic evaluation for the execution. After receiving the request by the Municipality and confirming the site conditions, the contract between the Study Team and the Contractor was concluded.

## 13.4 Construction Plan

Based on the request by the Municipality, the temporary works was implemented under the following conditions.

- Site: El Divino Niño Sector
- Borrow pit for the temporary works: Cantera Recurso and/or Cantera Cueva de Zorro
- Spoil bank for the temporary works: La Maya
- Construction Period: 3 months (90 days)
- Conditions for commencement of works: When the residential blocks have been evacuated by the Municipality

### 13.4.1 Temporary Works Operation

The temporary works were executed in two (2) phases. The first phase was for the preparation of the documents which consisted of the design and tender documents and the details of prepared documents were modified and/or supplemented through the monitoring of the relocation activities by the Municipality. In the second phase, the Study Team selected and employed a Local Engineer for the construction supervision that includes 1) operation control of the schedule, 2) quality control of materials, 3) control of the executed production and 4) design change and instruction to the contractor according to the site conditions.

### 13.4.2 Procurement of Construction Materials

The investigations for procurement of the materials revealed that all materials to be used for the temporary works could be obtained from the Soacha and Bogota Municipalities.

### 13.4.3 Schedule of the Temporary Works

The following schedule had been modified in accordance with the progress of the relocation activities by the Municipality.

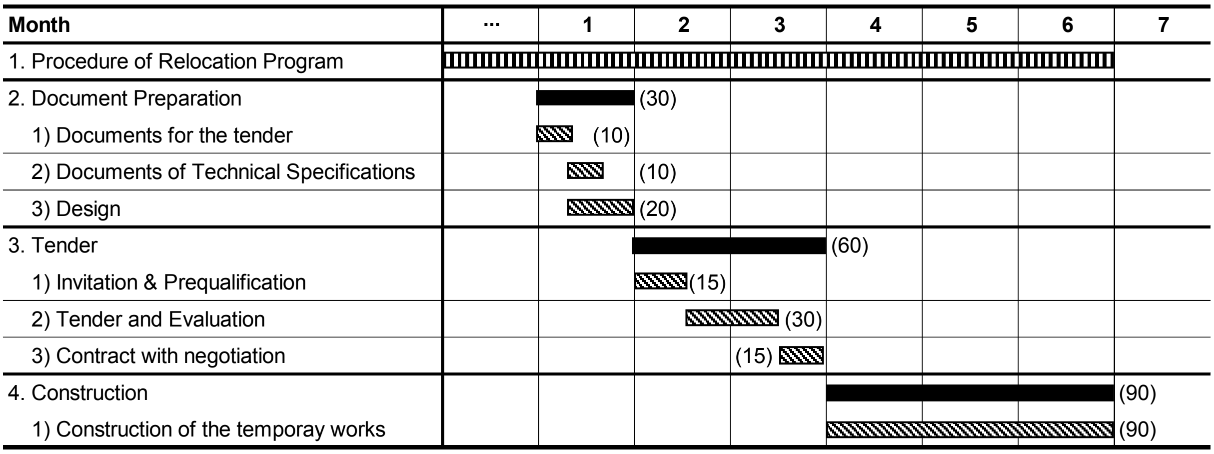



Figure 13-3 Schedule of the Temporary works

## 13.5 Implementation of the Temporary Works

The Municipality relocated the small scale families in the Quintanares area from November to January 2008. On the other hand, the apartments for the relocation of large scale families are under construction; therefore the Municipality relocated them in temporary lodgings until 3rd of February 2008, using subsidy. At the request by the Municipality, the Study Team started the temporary works.

### 13.5.1 Contract

(1) Selection of the Local Contractor

Before the completion of the relocation program, the Inversiones G&R S.A. in Bogotá was selected as the local contractor through a public tender.

(2) Contract for Implementation of the Temporary Works

Based on the request letter by the Municipality, the Study Team executed the following contracts of temporary works with the selected local contractor after the site investigation with the Municipality's counterpart.

Table 13-4 List of Contracts for the Temporary Works

| | | |
|---|---|---|
| Contract Number | 1st Contract<br>EQUIPO ESTUDIO – G & R S.A – 2007 – 11. | 2nd Contract<br>EQUIPO ESTUDIO – G & R S.A – 2008 – 02. |
| Date of Contract | Nov./22/2007 | Feb./04/2008 |
| Contracted Package | Packages No. 9 + No.1 (50%) | Packages Nos. No.1 (50%) to 8 and 10 |
| Period | Nov./22/2007 to Feb./19/2008 (90 days) | Feb./04/2008 to Feb/29/2008 (26 days) |

### 13.5.2 Construction Control

The construction works is generally undertaken under the instructions stipulated in the Specifications, and the whole construction works are controlled by 1) operation control, 2) quality control, 3) control of completed works, 4) labor management and 5) safety program and practices.

(1) Executive Organization for the Temporary Works

The Temporary Works were carried out under the following organization in both contracts. In the Article of General Specifications, the Contractor should employ 30% of labor from the community, but a lot of labors were employed from the community in the 2nd Contract , as shown in Figure 13-4. On the other hand, the security of the construction site was secured by community people employed by the Contractor; however, for an increased security, the construction site was under the control of the National and Military Police.

The number in parenthesis in the Figure gives the employment situation in the 2nd Contract.

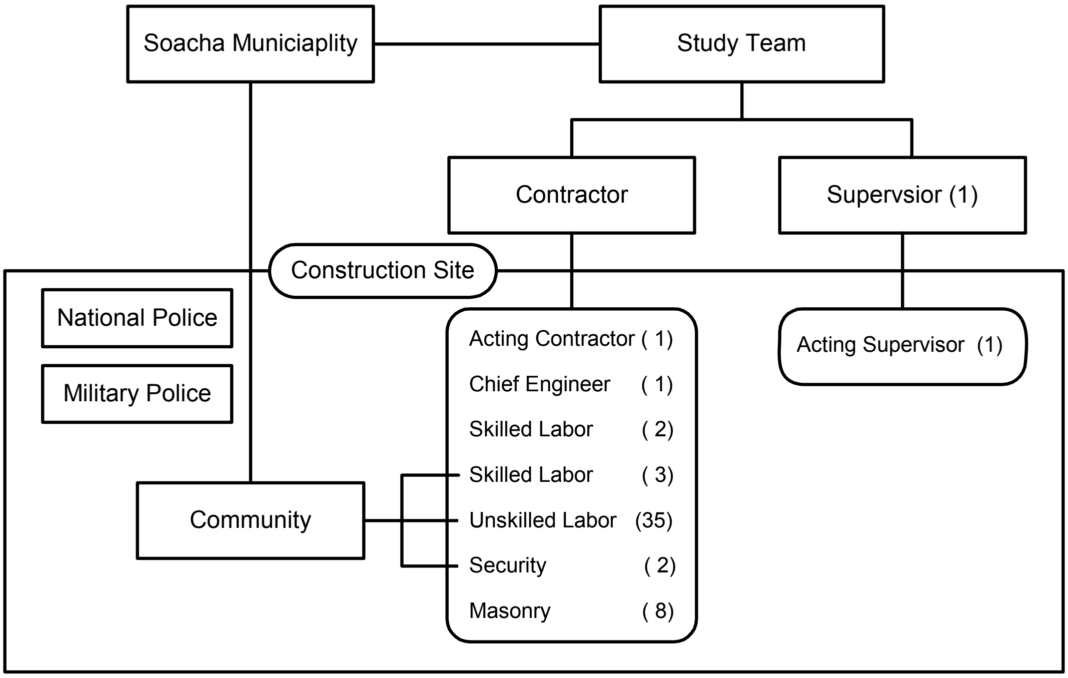



Figure 13-4 Organization of the Temporary works

(2) Operation Control

1) Construction Method

The temporary works are installed in the vacant area through the relocation program; therefore, the vacant area is divided into two (2) areas by the wall when construction works are completed. Since the wall should be closely installed toward to the remaining houses in the Critical Zone, there is no sufficient area for the construction materials and heavy machinery. Consequently, the construction by manpower was applied to both 1st and 2nd Contracts.

In the 2nd Contact, the contractor organized a team consisting of one (1) skilled and seven (7) unskilled labors and committed five (5) teams to the works of the gabion wall.

The construction method and its process are shown as follows.

(a) Gathering of the debris toward to the steep slope side for the security against falling rocks from the steep slope

(b) Gathering of the excavated material by the earth work to steep slope side

(c) Transportation of the cobble stone to the site and installation of form works for gabion

(d) Installation of the stone to gabion net by manpower

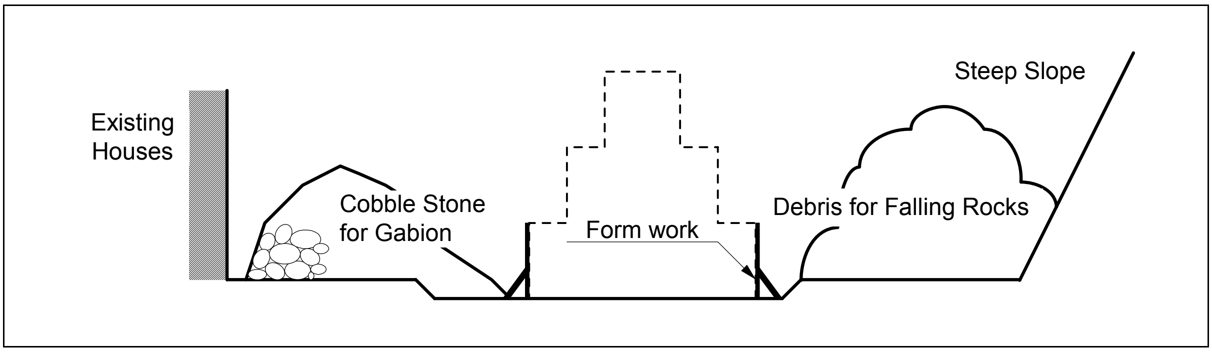



Figure 13-5 Construction Method

2) Operation Control

The deadline of the temporary works was until February 2008 due to the period of the Study. According to the progress of relocation program, the 1st Contract started on November 22, 2007 includes 90 calendar days until February 19, 2008. However 26 calendar days were only available in the 2nd Contract started from February 4, 2008. The construction works in the 2nd Contract was on the "Critical Pass" from its beginning. Therefore, the execution of the 2nd Contract was done by following items of operation control.

a. Construction Schedule

The principle work item of the temporary works concerns the gabion wall and the construction schedule in the 2nd Contract was thus controlled by the gabion quantity per day. At the beginning, the ability of the labors to install the gabion wall was evaluated. Based on their measured ability, the construction schedule was verified every day by the contractor and supervisor. When a delay was confirmed on the schedule, the construction method and working hours were also revised.

b. Network of Construction Material Supply

Since it was impossible to transport all requires materials in the site due to insufficient space, the supply of required materials was controlled according to the construction progress.

c. Inspection by the Supervisor

In order to avoid building again the structure due to misunderstanding by the Contactor, an urgent inspection was carried out at all times.

(3) Quality Control

In order to secure the quality of temporary works, the materials to be used were confirmed and approved based on the Article 4.9 in General and Technical Specifications.

(4) Control of Completed Works

In order to avoid executing again the completed products and to maximize the utilization within a short construction period, numerous appropriate inspection were carried out according to the progress of construction works. Since several defects and misunderstanding could be encountered through this inspection, large additional works could be avoided. Furthermore, technical instructions could be given to the community people.

Technical instructions given to the community people were follows.

- Installation of form work to avoid bulge out the gabion wall
- Selection of the cobble stone to avoid openings between stones
- Placing of the cobble stone in the gabion net to avoid openings between stones

The general view of the Temporary Works is shown as follows.

Figure 13-6 General View of Temporary Works

(5) Site Management

Telegraph poles controlled by CODENSA and TELECOM existed on the wall axis. Therefore, the Study Team coordinated these private companies in cooperation with the Municipality and these poles were taken safely out by the owner company without any trouble to the contractor's works.

In the vacant area produced by the relocation program, an obligation to plant trees is stipulated in Article 262 of Territorial Ordering Plan (POT). During the construction period, the Study Team prepared the meeting to establish the concept of tree planting between the Municipality and CAR.

(6) Labor Management

In the 2nd Contact, 40 labors were employed from the Community. From the beginning of the construction works, the Contractor rented some rooms of a house at street No.3 in the Critical Zone as his office. This office served preparatory accommodations; therefore two (2) specialists of gabion wall stayed their office 24 hours in order to manage the conditions of labor's health and working hours.

(7) Safety Program and Practice

1) Security against falling rocks

The construction area is hazardous due to falling rocks and landslide; therefore, the construction works were suspended on a rainy day. Furthermore, as the safety measures against falling rocks, the debris and excavated materials were put toward to the steep slope to absorb the impact force of falling rocks. The cobble stone for gabion wall was loaded from existing house side.

2) Safety in the site

Before commencement of the works, the contractor put all labor under obligation to wear safety equipment such as helmets. As to the security toward to the community, a security tape to prohibit entering the construction area was installed around the construction area. Furthermore the construction site was protected 24 hours by the community people employed by the Contractor. The security against criminal acts in and around the construction site was ensured by the National Police and Military Police Battalion No.13.

### 13.5.3 Design Change

The site conditions were cleared after the demolition works of houses by the Municipality. The differences between the original design and actual site conditions were adjusted by means of "Design Change".

Items modified by design change are described as follows.

(1) Temporary Protection Wall

1) Axis of Temporary Protection Wall

In the construction stage, the topographic survey for establishment of the wall axis was carried out along the boundary of vacant lots after relocation program. The area where the Municipality executed the relocation and demolition of houses covers not only the Emergency Zone but also some part of the Critical Zone. To that end, a wall axis was provided under the following criteria with topographic survey result.

- to install in the Emergency Zone and toward to the boundary of vacant lots as much as possible
- to be straight line along the boundary considering technical level of community people as labor
- to keep the distance of more than 4.0m between steep slope and wall axis, based on the design

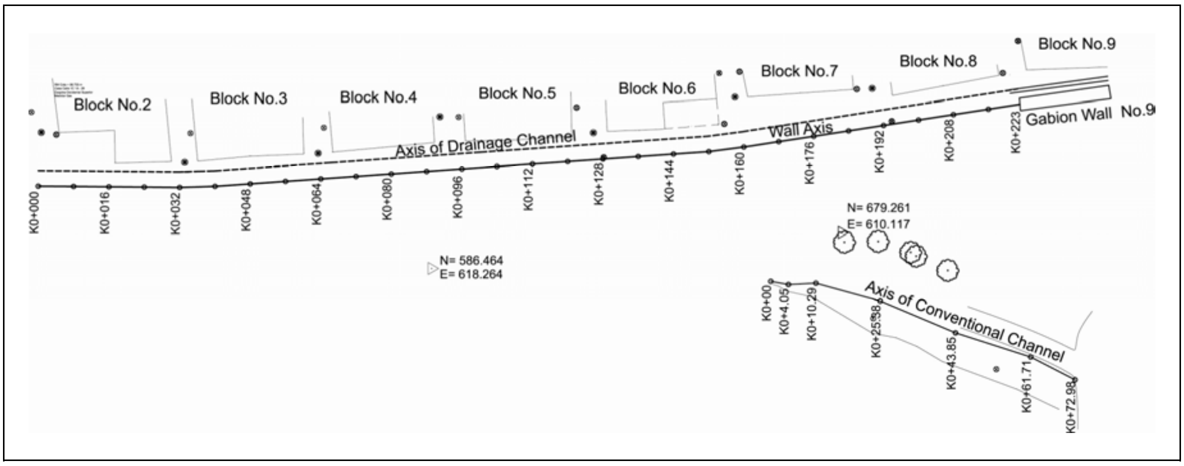



Figure 13-7 Axis of Temporary Wall

2) Gabion made of Debris

In the original design, the debris by the demolition works were applied as material of gabion installed in the center of the first floor. However since re-used materials of houses were delivered to community people who helped the demolition works, the debris decreased compared to the estimated quantity of the design stage. Consequently the cobble stone was applied to the gabion at the center of the first floor instead of the debris.

3) Additional Protection Wall

There is a private lot for sale found between the residential block No.9 and the sloping road to the upper part of the El Divino Niño area. There was a boundary wall made of concrete installed by landowner at right angle to the temporary protection wall axis. However, the wall height was lower than the temporary protection wall after the demolition works of houses.

In order to avoid new settlement from this place, the temporary protection wall with a length of 8.0 m was considered in the 2nd Contract.

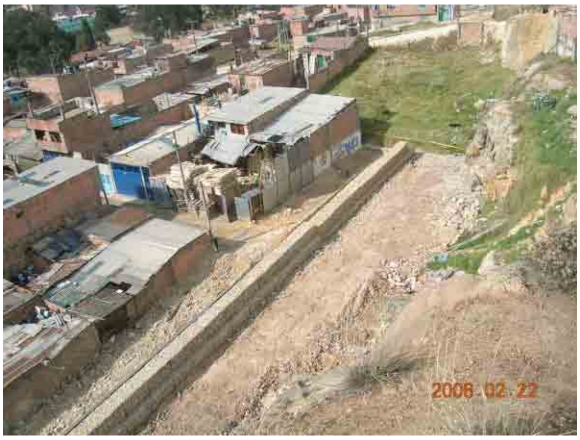
|  |  |
|---|---|
| Before the installation | After the installation |

Figure 13-8 Additional Protection Wall

4) Sand Mat

Since the quantity of debris decreased with respect to the estimate in design stage, most of the material for sand mat was covered by excavated and homogenous material produced by the construction works.

(2) Drainage Channel in front of the Temporary Protection Wall

1) Drainage Channel made of Dry Masonry

In order to drain rainwater from steep slope through the opening of gabion wall, a channel slope in front of the gabion wall is made of dry masonry to ensure the infiltration of rainwater. In the construction stage, it was found out that channel slope made of dry masonry could not be ensured in long term. Therefore, the top of channel was fixed with concrete.

2) Drainage Pit

In the original design, a precast concrete pipe with a diameter of 900 mm was applied for the drainage pit for an easy connection with the existing pipe and a good progress was observed. The exiting pipe and drainage pit would be connected making a hole on the concrete pipe wall.

In the construction stage, an existing pipe with a diameter of more than 6 inches was found through the excavation works. Furthermore, 2 or 3 pipes were found in the streets. It is technically impossible to make some holes on the concrete pipe and the pit made of bricks was built in order to facilitate the connection with the existing drainage pipe.

(3) Conventional Drainage Channel on the top of El Divino Nino area

A conventional channel is installed in front of the houses; therefore 10-foot passes were considered on the channel in original design. In the construction stage, it has been found that the number of houses were eight (8), two (2) of which had their garage. Consequently, a foot pass which has twice the size of width was installed in two (2) houses with garage considering the size of the car. For the remaining houses, one (1) foot pass was installed.

(4) Hazardous Sign Board for Landslide

In order to facilitate the understanding of community people, the expression of the hazardous sign board was written using an easy style and illustrations. Furthermore, considering the Municipality's activities in the area after this Study, the words to be used for the hazardous sign board are followed to the POT by the Municipality.

### 13.5.4 Technology Transfer to the Community

After the relocation program, some 100 families remained in the Critical Zone in the El Divino Niño area. Some 40 persons from these families have been employed by the Contractor in the 2nd Contract. The temporary works did not include any engineering works which require technical experience; however, these employed people did not have any experience in engineering works.

At the beginning, the gabion body that is baggy at its face was often confirmed, and this phenomenon was due to the stone pressure by the manner trhough which the stone and form work were executed. Therefore the Contractor and the Study Team carried out On-the-Job Training to the community people.

(1) Placing of the Cobble Stone in Gabion Net

For the gabions in Colombia, two (2) sizes of stone are normally used. The large one is placed in the face of gabion, and the small one is placed inside. If these stones are not good combination in the net, the face of gabion body is buggy due to horizontal pressure when the form work is removed. In order to avoid easily this problem, the supervisor instructed the labor to fill small size stone in the opening between the stones.

(2) Form Work for the Gabion Net

Other causes that make the gabion face baggy are related to the support capacity of form work that is not sufficient for the installation of the stones. Consequently, the supervisor shook the form work to confirm the fixing condition. When the fixing conditions of form work is not sufficient, the supervisor indicated to the labors the point to fix of form work.

### 13.5.5 Temporary works Information to Related Organizations

In order to introduce the temporary works as an example of countermeasure for risk area, the Study Team invited the related organizations such as CAR, INGEOMINAS, United Nation, OCHA and DIAKONIE to the site in the construction stage. And the relocation program by the Municipality and the details of temporary works were explained to the organizations.

## 13.6 Social and Environmental Consideration

### 13.6.1 General

During the discussion with the JICA Preparatory Mission for this Study in September 2005, the Soacha Municipality requested JICA to conduct some countermeasures for landslides in the Study Area. After the 1st phase of the Study started in June 2006, the Study Team concluded in the discussion of the JICA Monitoring Mission in November 2006 in Bogota that, as described in 13.1 Background of this Chapter, the relocation of houses was the only way to ensure the safety of the residents, that no other measures were practical, and that some measures may even induce a further dangerous situation. The Soacha Municipality agreed on this conclusion.

Independent of the conclusion, the Soacha Municipality had been implementing the relocation program within the risk area., The Study Team proposed the implementation of the temporary works, whose objectives were described in 1.3.1 of this Chapter, if the relocation from the emergency zone in the El Divino Niño area, which was the most critical area in the Study Area, was completed in the Study period. Due to extensive efforts of Soacha Municipality, the partial relocation from the Emergency Zone in the El Divino Niño area was completed by end of November 2007, the Study

Team started the Package 9. The relocation from the rest of emergency Zone was completed by end of January 2008; therefore the Study Team conducted the remaining packages and finished the temporary works in the Study period. In this context, the relocation was an initiative solely of the Soacha Municipality, or, in other words, the Soacha Municipality did not implement the relocation just for the temporary works through JICA.

The temporary works were completed by end of February 2008 during the Study period according to the original plan in terms of work volume.

### 13.6.2 Socio-Economic Aspects

According to the limited statistical information provided by the Municipality, there was a total population of 2,353 inhabitants and 576 families in the El Divino Niño area. An average family size was calculated at 4.1 persons per family. The population density in the area was 269 inhabitants per hectare, and the density of the area was 1.25 times higher than the average population density of Commune 6. The buildings had one or two stories and were closely clustered near the slope. As to the infrastructure, the electricity and water were supplied only by CODENSA and EAAB, respectively.

### 13.6.3 Procedure of Environmental Consideration

(1) Legal Framework

There are no laws or guidelines on EIA procedure in Colombia. In the opinion of the Ministry of Environment, House and Land Development (MAVDT), the Environmental License or Permission based on the guidelines stipulated in Decree 1220 April 21, 2005 under Law 99,1993 is required as an alternative to EIA. On the other hand, the CAR Soacha has been established in November 2006 in order to manage the environmental issues in the Soacha Municipality.

(2) CAR's Technical Suggestions for the Temporary Works

With the technical site visit on February 26, 2007, and Letter No. 887, the CAR evaluated the temporary works based on Decree 1220 of April 21, 2005 related with the environmental license. According to the evaluation of CAR Soacha, the environmental license is not required for the temporary works, as there are no environmental concerns including tree species, forests or water in the area to be installed with the temporary works.

Furthermore, the CAR Soacha gave the Municipality and the Study Team three (3) suggestions for the measures to be considered for prevention and reduction of the risk in the area; 1) to provide drain system for rain water; 2) to plant plants between slope and the protection wall; and 3) to remove rocks about to fall down.

### 13.6.4 Anticipated Environmental and Social Impacts and Monitoring Results

In the Progress Report 2, the anticipated impacts described below were listed. In fact, the temporary works are quite small civil works relying on manual works and during the implementation period of the fifth field work in Colombia, any negative impacts were checked. The followings are the anticipated impacts and monitoring results during the Study period.

(1) Social Impacts

Job opportunities

The temporary works were conducted as a sub-contracting work in the Study. The Study Team specified in the technical specifications for the contractor that at least 70 percent of the laborers for the temporary works had to be employed from the El Divino Niño area. As a result, 40 people from El Divino Niño area participated in the works, which contributed to the local economy (Photo 11-1 and Photo 11-2).

Traffic disturbance

The temporary works were mainly of the work in which laborers stack boulders and gravels on the leveled ground to make a gabion wall and the usage of heavy machinery was limited only to the installation of sand mat behind the gabion wall and the excavation of drainage pits. Once the boulders and gravels were transported to the site, the traffic of the vehicles for material transportation was light, therefore there was no complaint from the people living near the site.

Avoidance of troubles

All the residents to be relocated from the Emergency Zone in the course of the relocation program by the Soacha Municipality agreed with the relocation, following a series of workshops held by the Soacha Municipality and the Study Team during the Study Period, in which people understood the risk of rock falls, and the residents agreed with the relocation because the new houses which the Soacha Municipality had prepared for them were better than those in the El Divino Niño area. In addition, the temporary works contributed to the local economy. Thus, there was no trouble with the residents. This was because the Soacha Musicality set up a special section for people's matters in the Municipality in advance and collaborated with community leaders in the El Divino Niño area.

Landscape

According to the POT, the area which is declared by the Soacha Municipality as land for public use should have trees or grass. The Soacha Municipality, together with the CAR, is planning to plant trees in the space between the slope and the temporary wall.

Photo 13-1 Local People working manually for the Temporary Works

Photo 13-2 A lot of Local People working for the Temporary Works

(2) Environmental Impacts

Vibration, Noise, Dust and Offensive Odor

The temporary works were mainly activities in which laborers stack boulders and gravels on the leveled ground to make a gabion wall and the use of heavy machinery was limited. Therefore, vibration, noise, dust or odor did not cause any trouble

Waste

The materials for the temporary works were boulders/gravels, wire nets for gabions, geotextile and concrete for drainage channels. Other than the boulders/gravels, only required amounts were procured, so that surplus material as waste was not produced. As the surplus boulders and gravels were used for the sand mats (cushion) between the slope and the temporary wall, the work did not produce any waste.

(3) Monitoring of the Relocation Program by the Soacha Municipality

The relocation conducted by the Soacha Municipality was not provided for the implementation of the temporary works in the Study period. Therefore, the background and monitoring results of the relocation were attached in the Appendix of this Report.

### 13.6.5 Environmental and Social Impacts, Mitigation Measures and Recommendations for Future Implementation of Temporary Works

The temporary works implemented in the Study in the El Divino Niño area has the objectives described in Section 1 in this Chapter. In the Soacha Municipality, there are still a lot of people living in critical zones of landslides, and the basic policy of the mitigation measures of damage was recommended in Section 4 of Chapter 8. If the Soacha Municipality studies the critical zones in other areas based on the recommendations in the Study in future by itself, the implementation of temporary works can be applied in order to conduct the necessary relocation smoothly.

Table13-5 is the summary of negative impacts, mitigation measures and recommendation for future implementation of temporary works prepared based on the results of the El Divino Niño area's temporary works in the Study.

Table 13-5 Environmental and Social Impacts, Mitigation Measures and Recommendations for Future Implementation of Temporary Works

| Impact | Mitigation Measures | Recommendations for Future Implementation |
|---|---|---|
| Traffic Disturbance<br>Traffic disturbance will be raised by incoming and outgoing of construction vehicles and equipment. Traffic congestion and traffic accidents are possible issues at narrow streets in the community. | In the construction plan in the future, the work should be done by labor basically and the usage of heavy machine should be minimized; for example, the frequency of material transportation by trucks into community area should be minimized.<br>In the construction plan, the installation of traffic signs at the entrance and exit gates of vehicles and heavy equipments, and providing of adequate parking lots, appointing of staff in charge of traffic control and giving of instructions the drivers should be included. | The control of frequency of transportation of construction material and truck is possible by reducing of daily work volume considering a longer construction period. |
| Avoidance of Troubles<br>The relocated people could complain regarding the conditions of new houses and relocation procedures and the neighborhood residents could complain regarding the environmental deterioration. | Distribution of hazard map and holding of community workshop should be done in order to let people know about the danger of rock falls and the necessity of temporary works. Also the consensus regarding the condition of relocation should be obtained among the people and the Soacha Municipality. When setting up the conditions of new houses, a lot should be applied to ensure the fairness as well as the conditions of large families and handicapped persons should be considered.<br>Regarding the complaints of the neighborhood residents, the choice of man power works and implementation of the mitigation measures for Traffic Disturbance should be prioritized. | -ditto-<br>For the area where rock falls and landslide disasters are expected in near future, the national declaration of disaster should be considered from the viewpoint of saving of life. |
| Landscape<br>The temporary works could generate an oppression to the residents and unpleasant landscape in communities. | The temporary works have a objective to let people know about the danger of rock falls and prevent the invading of new houses, the oppression to the residents can not be helped. Regarding the unpleasant landscape, based on the POT of Soacha Municipality, the relocation area should consider planting trees. | Based on the articles of POT, Soacha Municipality should coordinate with CAR to formulate a land use plan for each relocation area. |
| Vibration, Noise, Dust and offensive Odor<br>Loading and unloading of materials, activities of vehicles and machineries could generate vibration, noise disturbance spread of dust pollution and offensive | In the construction plan in the future, the work should be done by labor basically and the usage of heavy machine should be minimized, for example, the frequency of material transportation by trucks into the community area should be minimized. Regarding the noise and dust to be generated, in the construction plan, setting of screen between the construction site and residential area and spraying of water at the | The control of frequency of transportation of construction material and truck is possible by reducing the daily work volume while considering a longer construction period. Also since the work volume is reduced, the size of construction vehicle can be also reduced. |

| | | |
|---|---|---|
| odor from exhaust gas. | access road and loading/unloading sites. | |
| Waste<br>Solid waste and waste water could generate insect breeding, disease and offensive odor. | In the construction plan, the procurement of construction material should be based on requirements in order not to generate waste materials. Also one kind of the construction materials, gravel, should be used as sand mat cushion between the slope and the temporary wall.<br>In the temporary works, the use of water is limited to the works of concrete for drainage channel in front of the gabion wall, and the quantity is so small that the problem of waste water cannot be generated. | Prior to implementation of temporary works, anticipated waste material in the construction site should be checked in advance and the corresponding disposal method should be decided with the related organizations such as CAR. |

### 13.6.6 Monitoring Plan for the Environmental and Social Impacts

Among the environmental and social impacts for the future implementation of temporary works, the "Traffic disturbance", "Vibration, Noise, Dust and Offensive Odor", "Waste" can be deemed the impacts found in each temporary work implementation plan. Regarding the "Avoidance of troubles", as shown in the Table below, the distribution of hazard map, people's understanding of danger of rock falls and landslide and importance of the temporary works through repeated community workshops and preparation of relocation manual based on the experiences in the El Divino Niño area, and the confirmation of relocation process are important matters. These items are under the responsibility of the Soacha Municipality. Regarding the "Landscape", the Soacha Municipality should continue to coordinate with CAR as well.

Table 13-6 Monitoring Plan for Environmental and Social Impacts on Implementation of Temporary Works

| Impact | Monitoring Plan |
|---|---|
| Traffic disturbance, Vibration, Noise, Dust and Offensive Odor, Waste | As the implementing body of temporary works, the Soacha Municipality should consider the mitigation measures in the future construction planning, referring to results of temporary works in the Soacha Municipality El Divino Niño area. During the construction period, the Soacha Municipality as implementing body should monitor the impact on Traffic disturbance, Vibration, Noise, Dust and offensive Odor, Waste. |
| Avoidance of troubles | The Soacha Municipality should monitor the followings for each 6 months.<br>Progress of distribution of hazard map in the critical areas<br>Progress of holding of community workshops<br>Progress of Preparation of relocation manual based on the experiences in The El Divino Niño area relocation, and progress of relocation in the future temporary works area. |
| Landscape | Based on the articles of the POT, the Soacha Municipality should monitor the coordination with the CAR to formulate a land use plan for each relocation area. |

| | | |
|---|---|---|
| odor from exhaust gas. | access road and loading/unloading sites. | |
| Waste<br>Solid waste and waste water could generate insect breeding, disease and offensive odor. | In the construction plan, the procurement of construction material should be based on requirements in order not to generate waste materials. Also one kind of the construction materials, gravel, should be used as sand mat cushion between the slope and the temporary wall.<br>In the temporary works, the use of water is limited to the works of concrete for drainage channel in front of the gabion wall, and the quantity is so small that the problem of waste water cannot be generated. | Prior to implementation of temporary works, anticipated waste material in the construction site should be checked in advance and the corresponding disposal method should be decided with the related organizations such as CAR. |

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| Avoidance of troubles | The Soacha Municipality should monitor the followings for each 6 months.<br>Progress of distribution of hazard map in the critical areas<br>Progress of holding of community workshops<br>Progress of Preparation of relocation manual based on the experiences in The El Divino Niño area relocation, and progress of relocation in the future temporary works area. |
| Landscape | Based on the articles of the POT, the Soacha Municipality should monitor the coordination with the CAR to formulate a land use plan for each relocation area. |

# CHAPTER 14 RECOMMENDATIONS FOR SOACHA

## 14.1 General

(1) Integration of Information

The existing and future information and data, for example, hydro-meteorological data, disaster records, social survey results as well as cadastral data of the Municipality, should be arranged in accordance with their intended uses (objectives, for example, setting of early warning criteria by accumulating rainfall and disaster records and confirmation of present conditions of communities).

(2) Capacity Development of Fire Station

The Fire Station of the Soacha Municipality is proposed as the monitoring center of the early warning system in the Municipality. As the present station has lack of human resources and operational capacity, the Municipality should consider further capacity development of the station. The office space of the present Fire Station should be extended urgently and the security for the installed monitoring equipment should be strengthened.

(3) Dissemination of monitored hydrological data

The data monitored at the Fire Station, Llano Grande Station, Ladrillera Santa Fe Station, Prison Station, Fusunga Station and San Jorge Station should be disseminated in the Soacha website periodically in order that ordinary people and other organizations can have access to them without any restriction.

(4) Cooperation with CREPAD

The pilot project activities done in the Study are very useful and should be extended to other municipalities which have similar landslide and flood problems in the Cundinamarca Government. Soacha Municipality should support other municipalities, in cooperation with CREPAD, regarding the preparedness for disaster prevention activities.

## 14.2 Landslide

(1) Non-structural measures against Landslides

It is recommendable to relocate people from Critical Zones as a measure against disasters on the steep slopes in the abandoned quarries in Soacha Municipality to use the experiences in the relocation in El Divino Niño area to advantage. The houses close to the steep slopes in the abandoned quarries should be relocated to safe areas. But it could take a long time to relocate them from Critical Zones because there are many steep slopes in abandoned quarries and houses in Critical Zones. The following non-structural measures are recommended.

a) The people in Critical Zones should be relocated. Priority of relocation should be given to the people in the greatest danger in Critical Zones.

b) Until all the people in Critical Zones have been relocated, Soacha Municipality should take care of the safety of the people remaining in Critical Zones.

c) The people remaining in Critical Zones should be informed that they are in Critical Zones and always are at risk even in fine weather.

d) In heavy rain, Soacha Municipality should be on the alert for the people in Critical Zones

e) To obtain the basic information about alert level of rainfall, Soacha Municipality should collect rainfall data.

**Process for Relocation**

Relocation from all Critical Zones in Soacha Municipality is necessary to protect the people's lives and properties. As it could take a long time to complete the plan, relocation from more dangerous areas with the following steps is necessary.

a) Complete the program of relocation from Emergency Zone in El Divino Niño area

b) Set up Emergency Zones in La Capilla area.

c) Proceed with the program of relocation from Emergency Zones in La Capilla area following the process in El Divino Niño area.

d) Set up Critical Zones and Emergency Zones in El Arroyo (Villa Esperanza) which is surrounded by steep slopes also formed by mining activities.

e) Proceed with the program of relocation from Emergency Zone in El Arroyo (Villa Esperanza) following the process in El Divino Niño area.

f) Set up Critical Zones and Emergency Zones in other areas where steep slopes in abandoned quarries exist, and proceed with the program of relocation from Emergency Zones.

g) After completion the program of relocation from Emergency Zones, proceed with the program of relocation from Critical Zones in El Divino Niño area, and continue the relocation from Critical Zones in the same order as that from Emergency Zones.

**Measures up to the Completion of the Relocation Program**

In the process of the relocation program, it is important to protect the peoples who stay in Emergency Zone**s** and Critical Zones using Community Hazard Map until the relocation program has been completed.

(2) Monitoring of Landslides in Soacha

Precipitation monitoring and records of landslides which commenced in the pilot project of this study should be continued in order to collect and accumulate the basic information for the analysis of the relation between rainfall and occurrence of landslides and to study landslide disaster prevention measures. The results can be analyzed with the methods mentioned in Chapter 10. In order to improve the resolution of precipitation monitoring, installation of automatic-record-type rain gauges is recommended in Altos de Cazuca area once the precipitation data have been accumulated and analyzed. The number and locations of installation of the automatic rain gauges should be decided with the data accumulated.

(3) Other recommendations

The steep slope in the abandoned quarry site has unstable rocks of several meters in diameter, which could fall down toward the houses below the slope. On the backside of the slope, there is landslide area, therefore slope cutting cannot be conducted. As the existence of unstable rocks is an urgent issue, the Soacha Municipality has been conducting removal of large rocks by blasting above the houses as a temporary measure. There is a possibility that the remaining rocks fall down to the houses. It is also anticipated that, in the slope, next to the rock layer which was taken out, there are other unstable rocks. In this sense, a substantial countermeasure such as relocation is necessary and such program should be promoted. Soacha Municipality must implement actions to prevent construction and extension of residential houses in these areas according to Law 388 of 1997, Decree 564 de 2006 and POT of Soacha with the recommended steps mentioned in Section 14.2 (1).

## 14.3 Flood

The activities carried out in this Study, such as monitoring of rainfall, water level and riverbed elevation, information transfer/evacuation drill, etc. should be continued with the Soacha Municipality's initiative. Soacha Municipality and the communities within it will take necessary actions and/or measures, if issues arise in the activities.

(1) Continuous Monitoring of Rainfall and Water level

Equipment installed in Fire Station, Llano Grande Station, Ladrillera Santa Fe Station, Prison Station, Fusunga Station and San Jorge Station, which will be the property of Soacha Municipality, should be maintained by each station with the support of Soacha Municipality.

Data recording sheets for each station, which have been provided by the Study Team, should be provided by the Soacha Municipality after the Study.

The data recording sheets of each station filled by the observers should be collected by the Fire Station once in two weeks. The data should be inputted into the Fire Department Database by the Fire Department.

The data stored in the database of Fire Station should be disseminated periodically so that the data should be shared by IDEAM, CAR and EAAB.

(2) Enhancement of People's Understanding of Monitoring Activities

The automatic stations (San Jorge Rainfall Station, Ladrillera Santa Fe Station and Fire Fighter Station) have data displays to indicate the currently monitored data. The actual data should be monitored through the data display of the data logger continuously.

The observer at Fusunga should visit the upstream station (San Jorge Rainfall Station) periodically in order to understand the hydrological response. Also the communities in Llano Grande should visit the upstream water level station (Ladrillera Santa Fe Station) periodically in order to monitor the warning criteria.

In Ladrillera Santa Fe, both a staff gauge and an automatic water level sensor were installed. The monitoring of the staff gauge and the data display should be done in parallel instead of relying solely on the automatic sensor's data.

(3) Training on Information Transfer and Evacuation

The Soacha Municipality should organize and conduct continuous training on information transfer and evacuation. In an early warning system, "information transfer" and "evacuation" are very important. Especially, information transfer, which means how to transfer the monitored data timely and accurately and how to make people understand their meaning correctly, is significant. Soacha Municipality has been doing the evacuation well, however it should organize training on such information transfer continuously.

(4) Dredging of the Soacha River and the Tibanica River

Management and maintenance of the Soacha River and the Tibanica River including dredging should be done by CAR, EAAB and Soacha Municipality. Regarding the dredging, it is important to consider the longitudinal balance of channel flow capacity. In the case of the Soacha River, at the moment, the downstream of the Autopista Sur should be dredged extensively since the flow capacity there is lower than the other reaches.

## 14.4 Community Disaster Prevention Activities

(1) Role of Soacha Municipality

In the course of a series of community workshops held in the Study, Soacha Municipality recognized the importance of its role as facilitator between CLOPAD and communities. It means that Soacha Municipality should put an emphasize on creating a supportive, inclusive and safe working environment for disaster prevention, rather than setting top-down rules or limiting information sharing to a minimum. Soacha Municipality should confirm its role and maintain and develop the disaster prevention activities.

(2) Expansion to other communities

Through the repeated community workshops in the Study, interaction among the communities in the study area developed significantly and disaster-prevention-related-organizations made significant progress. The communities participated in the monitoring and disaster prevention activities, and the community leaders in particular, also became interested in the Soacha River itself and hydrological data, as well as gained some confidence in holding workshops by themselves. Soacha Municipality should expand the community disaster prevention activities in cooperation with the community leaders involved in the pilot project.

## 14.5 Temporary Works

The Study Team sincerely expresses full respect for the Soacha Municipality's efforts of relocating people from the landslide emergency zone.

Even though the temporary works have been completed, the Study Team does not guarantee the safety in the remaining critical zone in El Divino Niño area. Therefore, the Study Team recommended that the relocation program should be continued by the Soacha Municipality.

The temporary works were implemented in the Emergency Zone after the relocation program by the Municipality. In this situation, the following recommendations are given.

(1) Manual for the Relocation Program

Until this relocation program, the Municipality had not had any experiences of the relocation of people from hazardous areas and the relocation in El Divino Niño area is defined as the first such experience for the Municipality. The processes and methods in the municipal relocation program; for example 1) informing the community of the risk in the hazardous area through seminars, 2) examination of the legal process, 3) solutions of problems at new settlement areas, etc., were legally implemented. The results of the relocation works which the Municipality has examined and decided are very useful for other dangerous areas of the Municipality. A relocation manual which includes the experience and results of the relocation activities up to now is required in order to facilitate their application to other relocation programs.

(2) Countermeasures including Temporary Works

In the period of this Study, several countermeasures were executed by the Municipality in response to disasters. The countermeasures for the disasters require suitable and adequate execution in a short time. In order to respond promptly to disasters, it is recommended that a unified management system which is based on the measures so far executed by the Municipality is prepared.

ANNEX

RELOCATION PROGRAM OF SOACHA MUNICIPALITY

## 1 General

Soacha Municipality consists of six (6) communes and several organizations carried out the studies of the risk areas in the municipality from 1992 to 2006. Through these studies, the Territorial Ordering Plan, which covers all the area of the municipality, has been established based on the Agreement 046, 27 of December 2000. In May 2006, El Divino Niño area was designated as a Landslide Risk Area under the POT due to the disaster caused by intense rainfall. Because of this situation, the Municipality carries out the relocation program of families in the risk areas, especially El Divino Niño area area, based on the POT and other technical recommendations. In the JICA Study, hazard maps were prepared for El Divino Niño Area and La Capilla area in Altos de Cazucá in 2006 to facilitate and prioritize the municipality's relocation program.

## 2 Monitoring of Resettlement Program by Soacha Municipality

The relocation process of the Municipality was divided into two (2) phases by the urgent measure in May 2007 in which the Municipality removed a huge rock in El Divino Niño area to prevent the disaster. The 1st phase of the relocation process was conformed to the precedent of Bogotá due to its inexperience. The 2nd phase after the urgent measure was based on "the Public Calamity" situation declared by National Office for the Attention of Disasters (hereinafter "DNPAD").

### (1) Families to be relocated in El Divino Niño area

Based on the topographic survey in December 2006, an emergency zone in the area has been established according to the following criteria agreed upon on 20 of November 2006. Fifty-six families in the zone were identified in the census conducted by the Municipality.

In February 2008, four (4) vacant lots were detected by the Municipality through the cadastral data and documents by the owner.

- Slope angle is not less than 30 degree and slope height is not less than 5m
- Distance from the slope toe is within twice the slope height

### (2) Emergency Measure by Soacha Municipality in May 2007

On 17 of May 2007, some cracks in the rocks which supported a huge rock were detected in El Divino Niño area. As, in the opinion of the Municipality, stability of the huge rock could not be guaranteed in the coming rainy season, the Municipality decided to remove the rock as an urgent measure. On the following day, 18 of May, 11 families who lived at the residential blocks Nos. 5 and 6 under the rock were evacuated to the school in the area following the instruction of the Municipality. The Municipality commenced the urgent measure in cooperation with related municipal organizations. The targeted rock was estimated at approximately 96 tons based on its form and general specific weight, and the method adopted by the related organizations was to break the rock by blasting and hoist broken pieces with heavy machinery in consideration of the execution period and procurement of the materials.

## 3 1st Phase of the Relocation Process in El Divino Niño area

The process of the relocation program consisted of 1) identification of prioritized area and houses, 2) allocation of budget for relocation, 3) negotiation with targeted families and 4) their relocation to no risk areas. As options for the relocation, 1) provision of the apartment houses and 2) houses with land were considered. The policies on the relocation sites incorporated the followings; 1) lots and houses for the relocated families should be with legal titles, 2) relocation sites would be found in cooperation with real estate agencies in the urban area and 3) publicly announce prices would apply to the plots.

In the Municipality, establishment of a task force supporting its relocation program was considered due to its inexperience. However this scheme was renounced because the establishment of the task force would have taken place in a period of the election activities and the terns of the incumbent municipal administration would have expired on 31 of December 2007.

## 4 2nd Phase of the Relocation in El Divino Niño area following the Calamity Declaration

After the urgent measure in May 2007, the Municipality realized that there existed some latent risk caused by falling rocks in the area, therefore the Municipality decided to request a declaration of "Public Calamity" situation stipulated in Article 48 of Law 919, 1989 to DNPAD in the Ministry of Internal and Justice from the viewpoint of saving human lives in El Divino Niño area.

### (1) Declaration of Public Calamity Situation by the Municipality

The Article 48 of Law 919, 1989 for "Public Calamity Declaration" provides extraordinary faculties to organize the national system for prevention of disasters in disaster-stricken areas. And these faculties are given solely to the President of the Republic of Colombia.

Based on the technical information prepared by the Municipality, the "Public Calamity Declaration" was announced by DNPAD on 25 of June 2007 as Resolution No. 11. The resolution No. 11 states that approximately 71 persons in El Divino Niño area were affected by the disasters caused by falling rocks from the slope and approximately 56 families in the area should be relocated.

### (2) Municipal Activities based on the Public Calamity Situation

The concept of the relocation program was that required activities by the Municipality had to be lawfully carried out. Therefore, the Municipal Agreements to control the activities were issued by the Municipal Council. After the declaration of Public Calamity Situation by DNPAD, the following Resolution and Agreements have been issued.

- Municipal Resolution No. 1509 dated 17 of July, 2007
- Municipal Agreement No. 26 dated 5 of September, 2007
- Municipal Agreement No. 30 dated 8 of November 2007
- Offering System of Immovable

### (3) Request of Institutional Tutelage by the Community in El Divino Niño area

Based on the Agreement No. 26 mentioned above, the municipal administration carried out sensibility investigation in El Divino Niño area and negotiated with a bank that possessed an apartment building. On the other hand, the community in El Divino Niño area requested to Justice the Institutional Tutelage based on the "Public Calamity Situation" declared on 25 of June 2007.

Based on the request of Institutional Tutelage by the community, the Court gave the following sentence to the Municipality on 1st of November.

- The Municipality should relocate the families who are living in risk area within 10 days of the provisional solution
- The municipal council should approve the documents based on the Offering System of Immovable and the municipal administration should complete resettlement of targeted families within three (3) months
- The municipality should appoint a supervisor to complete the sentence of Institutional Tutelage.

### (4) Relocation in El Divino Niño Area

By the juridical sentence based on the institutional tutelage, the municipal administration started procedure of acquisition of houses for relocation with banks. As sites for permanent relocation, Urbanization Quintanares and Lagos de Malibu were selected.

1) Apartment Building for Relocation

In condominium-type apartments, several problems related with difference in economic and social standings between the existing residents and relocated families are normally observed. In order to minimize these problems, the municipal administration selected a terraced-house-type apartment as the apartment building for relocation.

2) Allocation Method of the Apartment to the Targeted Families

The targeted families were classified into two (2) categories, small- and large-scale families. According to the sizes of the apartments, Quintanares and Lagos de Malibu areas were allocated to small- and large-scale families, respectively. As to the apartment allocation, the families who have a handicapped and/or an old person were given priority and allocated to the 1st story. For the other families, the lottery system was applied for the apartment allocation for the sake of fairness. The relocated families were allocated apartments as shown in Table 1.

Table 1 Allocation of the Apartment

| Resettled Site | Location | Application | No. Families |
|---|---|---|---|
| Urbanization Quintanares | Commune 5 | For small scale families | 38 |
| Urbanization Lagos de Malibu | Commune 6 | For large scale families | 9 |
| Total | | | 47 |

*(Source: Soacha municipality)*

3) Relocation Activities by the Families

For the relocation of families, the municipal administration prepared two (2) trucks for transportation of household effects and one (1) back-hoe for demolition of their houses. According to the progress of disposition of household goods and furniture, the keys of apartments in Quintanares area were delivered to the small scale families from 10 of November 2007. On the other hand, the apartment building in Lagos de Malibu is under construction until the end of February 2008, therefore the large scale families moved to a temporal apartment building on 3rd of February 2008. The demolition work was commenced with mutual aid between the communities and a local contractor. The reusable materials produced in demolition works were supplied to the communities in reward for the demolition works.

(5) Disposal of Abandoned Houses

In the area under the relocation program of the Municipality, there were three (3) abandoned houses and ten (10) vacant lots. The Municipality carried out the estimate of these abandoned houses for expropriation of land and expropriated the abandoned houses by paying the estimated values to the owners. On the other hand, it was not necessary to expropriate about ten (10) vacant lots to ensure public use of the Land.