Photo3.5.58 Model 1 Short Column Failure(3) Photo3.5.59 Model1 Long Column Failure

Photo 3.5.60 Model 2 Photo 3.5.61 Model 2-Shear Failure of Short Column (1)

Photo 3.5.62 Model 2-Shear Failure of Short Column (2)

Photo 3.5.63 Model 2-Shear Crack of Long Column

Photo 3.5.64　Model 2-Long Column Failure (2)

Photo 3.5.65　Model 2-Short Column under Grade Beam

Photo 3.5.66 Model 3　Photo 3.5.67 Model 3-Diagonal Shear Crack of Short Column

Photo 3.5.68　Shear Failure of Column and Clay Brick Wall (1)

Photo 3.5.69　Shear Failure of Column and Clay Brick Wall(2)

Photo 3.5.70 Separation of Wall and Frame **Photo 3.5.71 Model 4**

Photo 3.5.72 Separation of Concrete Block Wall without Re-bars from Frame

Photo 3.5.73 Failure of Column and Concrete Block Wall

Photo 3.5.74 Shear Failure of Column and Concrete Block wall with Re-bars(1)

Photo 3.5.75 Shear Failure of Column and Concrete Block wall with Re-bars(2)

Photo 3.5.76   Failure of Concrete Block Wall with Re-bars

Photo 3.5.77   Demolition of Models

CHAPTER 4

SEDIMENT DISASTER STUDY

"Basic plan of prevention of disasters in Caracas –

Base for the measures of prevention"

Michael Schmitz

CHAPTER 4. SEDIMENT DISASTER STUDY

4. 1 Sediment Disaster Hazard Analysis

4. 1. 1. Definition of Scenario Sediment Disaster

(1) Features of the Mountain Streams

1) Topography

[El Avila Mountain Range] The name of El Avila Mountain Range designates the mountainous land that separates the Valley of Caracas from the Caribbean Sea as shown in Figure 4.1.1.1. This mountain range extends from the sea level to reaching height of 2,765 meters in the Peak of Naiguata. The North flank and the South flank, have very steep slopes, with more than 20º (Figure 4.1.1.4), and cut by a series of drainages of very short courses, which constitute deep valleys in V forms that have a north-south direction, approximately orthogonal to the axis of the mountain range that has an East-West direction. Structurally, El Avila Mountain Range is a horst or tectonic pillar, flanked by two faults that have an east-west direction: the Avila fault to the south, and the Macuto fault to the north.

The area of study, corresponding to the morphologic unit of the Avila mountainous area, includes all the South flank of El Avila, limiting towards the east with the course of the Caurimare River, towards the west with the stream Agua Salada; towards the south with the Cota Mil or Boyaca Avenue, and towards the north with the line dividing the North flank and the South flank. The study area has been subdivided into two morphologic units that include: the mountainous area of El Avila and the Valley of Caracas, formed by the alluvial fans deposited by different drainages that have their origin in the South flank and end at the Guaire River. It is observed that these alluvial fans get coalescence and they get mixed with the alluvial sediments of the Guaire River.

[Drainage System] Generally, a river and its tributaries constitute a network whose pattern can be influenced by the position and shape of boundaries separating the various rocks within a catchment. The drainage pattern can be classified into following the six (6) typical drainage patterns (Figure 4.1.1.3, Imamura et al).

a. Dendritic pattern : uniform condition of drainage
b. Feather like pattern
c. Parallel pattern

d. Radial-centrifugal pattern
e. Radial-centripetal pattern
f. Trellis/Angular pattern

The trellis/angular type drainage pattern is distinguished in the south slopes of El Avila Mountain. It is related to the development of faults in the area. Taking account the debris flows in the area, it is anticipated that the energy of debris flow could be weaken in the trellis/angular type drainage pattern. However, the drainage systems in the Catuche and Cotiza basins seem to be the dendritic pattern instead and more complicated than the drainage systems in other basins.

[Grade of Streams] Figure 4.1.1.4 shows that the profiles took along the course of the streams. The profiles are irregular curves that are steeper when the river crosses rocks more resistant and flatter when it flows over more easily eroding rocks, because the streams in El Avila Mountain are geologically young and actively eroding.

The profiles of streams in the western side from the Chacaito basin are gentler than the streams in the eastern side from the Chacaito basin because they are in more mature stage. This may lead to lower capability to convey debris.

Making a comparison between the Chacaito and Tocome basins, the profile of the Tocome Stream has a steeper curve from lower basin and some steps. The profile of the Chacaito Stream is gentle in lower basin and become steeper in the upper basin. There is no step in the Chacaito basin. And the Chacaito basin is deeper than other basins. This may be because of the existence of the Chacaito Fault along the bottom of the Chacaito Stream.

The Catuche Stream has no flatter portions in its profile as well as the Tocome Stream.

According to Prof. Andre Singer of UCV, most of the debris in the Tocome basin was deposited at the flatter portions of the stream in year 1999 disaster. This shows that the flatter portions has buffer against debris flow.

2) Geology

[General] The rocks that form the study area are of metamorphic nature, and they belong to the Avila Metamorphic Association, which is described by RODRIGUEZ et al. (2002) and URBANI (2002) as follows:

The Avila Metamorphic Association covers all of the study area. It limits to the north with La Costa Metamorphic Association, at the highest levels of the northern flank of the mountain, and to the south with the Caracas Metasedimentary Association. A fault (Avila Fault System) is responsible for the contact between the Avila Metamorphic Association and the Caracas Metasedimentary Association. The contact between La Costa Metamorphic Association and the Avila Metamorphic Association is also through a fault.

Metamorphic rocks of San Julian Complex and Peña de Mora Augengneiss mainly form the Avila Metamorphic Association. Quartz-plagioclase-micaceous schists, of gray color on fresh surface and greenish or brownish colors on weathered surface mainly compose the San Julian Complex. It also presents quartz-plagioclase-micaceous gneisses, with a quick gradation in their foliation. In addition, there are also minority lithologies such as marble, quartzite and mafic-metaigneous rocks (amphibolite, gabbro, diorite, tonalite and granodiorite).

The characteristic lithologies of Peña de Mora Augengneiss are the coarse grain-banded and quartz plagioclasic-epidotic-biotitic-gneisses, associated to amphibolic rocks.

In addition, AUDEMARD et al. (2000) points out the presence of serpentinites and lithologies from Antimano Marble on the southern flank of El Avila. Antimano Marble is composed by quartz-micaceous-graphitic schists and epidotic schists intercalated with marbles. These lithologies outcrop in the area between Blandin and San Bernardino. However, recent studies indicate that these lithologies are not so common in the southern part of El Avila Mountain (Figure 4.1.1.5, from Ostos 1985).

[Lineament] Many lineaments can be seen in the study area. The lineament from northeast to southwest is most distinguished in the area and from northwest to southeast is next. The Tocome and Gamboa basins have relatively less lineament.

Generally, most lineaments are topographical manifestation of faults. According to the geological map shown in Figure 4.1.1.6, the faults from north-west to south-east are more distinguishable and the faults from north-east to south-west are less. It is not clear at the moment if there are many faults from north-east to south-west which have not been found, or that lineaments in this area do not show faults.

The major lineament which is consistent with a fault is the lineament along the Chacaito Stream–Chacaito Fault. Lineament is not clear on the major fault that runs along the Tocome basin from north-west to south-east.

The lineament shows that there may be another big fault along the Quintero Stream which is not shown in the geological map.

[Fault] The study area is dominated by 2 main faults (Figure 4.1.1.6):

1. The Avila Fault, oriented E-W, normal and right lateral, located almost on the same course of the Cota Mil. It puts the lithologies from the Avila Metamorphic Association and the Caracas Metamorphic Association in contact. It starts on the Tacagua Fault (at the west) and ends in the east coast of Carenero, near Cabo Codera, for an estimate extension of 110 km.

2. The Chacaito Fault oriented N-S and left lateral coincides with the Chacaito stream course. It extends almost 4 km from the Avila Fault to the top of the mountain, and it also extends to the shore of the Caribbean Sea at Vargas, coinciding with the San Julian River course.

The Chacaito Fault marks the limit between several characteristics observed along El Avila Mountain southern part. For example, AUDEMARD et al. (2000) says that the lithological distribution varies from one side to another. On the east side of the Chacaito Fault there are schist (from the San Julian Complex) and gneisses (from the Peña de Mora Augen gneiss) outcropping. These rocks are competent forming big blocks. However, at the west side of the fault, there are schists from the San Julian Complex, marbles and graphitic schist (from the Antimano Marble) and also serpentinites. The latter three (3) lithologies are more susceptible to chemical and mechanical weathering; therefore, they are considered as unstable material.

As evidence of these observations, there are more scars of landslides in the western side of the Chacaito Fault than in the eastern side. Moreover, the material founded in the east side is mainly formed by big blocks (schists and gneisses), while in the western side, the material is mainly trees, boulders and not so big blocks.

AUDEMARD et al. (2000) also says that the presence of organic matter (wood, plants, trees) on the west side is caused by the presence of saprolitic soils, on which the roots of the plants and trees grow in a shallow level. This causes that the vegetation in the western side of the Chacaito Fault be not so anchored to the soil.

3) Meteorology

The general climate data in and around the Caracas valley is shown in Table 4.1.1.1.

There are four (4) significant weather synopsis other than the ITCZ that could bring heavy storm to Caracas, namely Wave of the East, Low Pressure Zones on High altitude, Cold front and Hurricane / Tropical depression Trail as illustrated in Figure 4.1.1.7.

Waves of the East are produced normally between April and October, moving from the east (the Atlantic) to the west (Columbia), with heavy rainfall along the axis of the wave. The Waves of the East are a kind of trough produced by the pressure condition in the Caribbean Sea, which can migrate east-westward approximately 29 days cycle. The rainfall generated by the easterly wave generally has short duration, high intensity and locally-concentrated.

Low Pressure Zones (called Vaguadas in Spanish) on High altitude occurs in any time of the year, but are more frequent at the beginning and the end of the rainy season, moving from the west toward to the east. Generally they produce rains, but according to their position and movement they might produce several days of fine weather.

The cold front is a typical weather pattern when high pressure is located in the Atlantic Ocean (the astronomic winter). They tend to produce 3 to 5 days of drizzles, but in some occasions, if the front is too unstable, they might provoke torrential rainfall in the north coastal zone. The weather condition of December 1999 and February 1951 can be grouped into this pattern. For those periods, the heavy rainfall lasted a few days to saturate catchment and generated debris flows by concentrated storm.

Generally Venezuela is not much affected by hurricane, having been crossed by a tropical storm only three to four times on record. Its affectation on the country is complicated, in occasions the tropical storm affects with heavy rains the coastal zone and other times. When a hurricane / tropical depression passes by the Caribbean Sea near the coastal zone, the trail wind into the center of the depression causes heavy rainfall in Caracas.

The 1999 and 1951 floods in Caracas valley took place in December and February, respectively. These are the storms associated with the cold front situated in the Northern part of the country (Figure 4.1.1.8). December and February are the rainy season in Vargas whereas they are the dry season in Caracas. It means that these heavy storms that brought out serious floods in the Avila in Caracas were associated with the cold front meteorological structure in the Caribbean Sea.

The meteorological structure in Vargas can be expressed by the north-northeast trade wind bringing moisture air mass from the Caribbean Sea to the land and the topographical effect of the Avila Mountain. The stormy cloud that produced rainfall on the northern part of the Avila could cover the Avila Ridge, however the cloud in Caracas side that comes beyond the ridge cannot have much water vapor as it has in the Vargas. The ridge elevation lowers as it goes westward. So these conditions suggest the western part in Caracas can be affected more by the weather condition in Vargas. However as happened in 1951 the rainfall was distributed from western to eastern part of the Avila Ridge depending on the cloud scale and the position of cold front. Since the spatial scale of those four (4) meteorological synopsis are much larger than the scale of Caracas Valley, it is difficult to make significant difference of rainfall amount among the east and western parts of the Avila Mountain.

4) Hydrology

The watersheds of the mountain streams are located on the southern slope of El Avila Mountain and of the alluvial fans of the Caracas Valley. The main hydrographic basins, based on the size of catchment, are from east to west the streams Caurimare, Tocome, Chacaito, Anauco, Cotiza, and Catuche. All of them end at the Guaire River, the main drainage of the Metropolitan District of Caracas. The annual rainfall distribution is strongly affected by the topography.

Figure 4.1.1.9 shows the annual rainfall distribution in the Guaire River Basin derived from the "Atlas of Climatology and Hydrology in the Caracas Valley, UCV". The annual rainfall ranges from 850 mm, in the low area, to over 1,150 mm in the eastern part of El Avila, within the mountain stream watershed.

There had been over thirty (30) rain gauge stations in and around the Caracas Valley as shown in Figure 4.1.1.10. Among them, La Mariposa Station and Cagigal Station are the primary key meteorological stations in terms of the observation period. However, in Venezuela for the hydrological analysis of the south slope of El Avila, the following five (5) stations have been referred in the Avila Project: Maiquetia, San Jose Avila, Teleferico, Los Chorros and Caurimare.

Table 4.1.1.2 shows the maximum daily rainfall for these five (5) stations. For the Caracas Valley, the historical maximum daily rainfall is 141.6 mm occurred in 1971 at the Teleferico Station.

In the Guaire River, the discharge measurement has been conducted by AYALA, MARN(R) and INOS. According to the measurement conducted by AYALA between 1939 and 1981, the annual maximum discharge was 824 m^3/s at Los Caobos (catchment area 360 km^2) and took place in 1945.

5) Vegetation

Figure 4.1.1.11 shows the infrared band Satellite Image. As shown in the Figure, the upper part of El Avila Mountain is covered with vivid red color. The vivid color indicates thick vegetation and it is above an altitude of 1,700m. The top of El Avila Mountain, above 2,400 – 2,500m altitude is brownish color and shows changing of vegetation.

Satellite Image matches with the vegetation distribution also shown in the same Figure. It is easy to discern different types of vegetation arranged in horizontal stripes in El Avila Mountain.

The Catuche and Cotiza basins are in relatively lower altitude. The vegetation of the basins of Catuche and Cotiza are thinner because most of the catchment areas are below 1,700m altitude.

Many traces of collapses in the north slopes of El Avila Mountain in Vargas can be seen in Figure 4.1.1.11. They may be the collapses in 1999 which has not recovered yet. It seems that there are not many collapses in the upper part of El Avila Mountain. It may show that less collapses occur in thick vegetation above 1,700m altitude.

Gray patches in lower and western part from the Tocome basin are trace of forest fires. Herbage covers that part.

HUBER & ALARCON (1988, in STEPHAN 1991) defined 8 different kinds of vegetation on El Avila Mountain: Littoral xerophytic bushes, deciduous lower montane tropophytic forests, sub-montane ambrophytic forests, seasonal semi-deciduous, sub-always green montane ombrophytic forest (or transition forest), sub-montane ombrophytic forest and montane always-green (or cloud forest), coastal sub – high barren plain (paramo), savannas and other herbal plants and gallery forests.

However, STEYERMARK & HUBER (1978, also in STEPHAN 1991) proposed a basic classification of the vegetation and its distribution in the southern part of El Avila Mountain. Figure 4.1.1.11 shows two transitions, the first figure along the cable car's way and the other one from Altamira to the Oriental Peak.

As Figure 4.1.1.11 shows, the higher plants are located around the middle altitudes (*transition forest and cloudy forest*), where there is more humidity caused by the cloudy conditions (about 1500 to 1800 MSL). In this forest, palms and orchids are common. At the higher part of the mountains (1800 MSL and more), the vegetation is adapted to the poor hydric conditions and the strong winds (*Mid barren plain*). At this level, the conditions are dry and the temperature is low, and the plants are about 1 to 3 meters tall (moss, little bamboos, Avila rose and some herbaceous plants are common). In the lower part of the mountains (from 900 to 1600 MSL), the temperature increases and the soil is drier. At this level the vegetation doesn't grow so much, it also loses about 25 to 75% of its leaves during the drought season, and harvests or reforestations have occurred by man action on these areas (*savanna* or Sub-montane Ambrophytic Forests).

6) Summary

Table 4.1.1.3 shows the summary of features of the mountain streams in terms of topography, geology, vegetation.

(2) Past Sediment Disasters in the Area

1) General

The historical sediment disasters are summarized in the following reports:

- PNUD (Edicion 2000), "Efectos de las lluvias caídas en Venezuela en diciembre de 1999"
- MARN-UNDP-Switz (Mayo 2001), Proyecto PREVENE, Informe Final
- Programa Preventivo y de Actuación en caso de lluvias, 2000, Defensa Civil, DF

The latter report "PREVENE" describes the history based on the contents of the former report by PNUD.

Chapter 9.2.2 of PREVENE report mentions the historical event on debris/sediment flow in Caracas. Table 4.1.1.4 shows the historical debris or sediment flood damage for each stream. The urbanization of Caracas started in the 16th century along the present area between the Catuche and Caroata streams. Early times disaster registration comes from the Catuche and Caroata streams, because people settled only in those areas.

According to the description, there has been no event in Caracas, since its foundation in the 16th century, like the Vargas disaster in 1999.

The "Programa Preventivo y de Actuación en Caso de Lluvias" has been published annually by the Civil Protection of the Caracas Metropolitan Government. Its content focuses on disasters such as landslide, slope failure and inundation associated with heavy rainfall in Caracas, mainly in the Libertador Municipality.

Number of Affected Houses and Families in the Libertador Municipality

Period	Number of Affected Houses	Number of Affected Families
Jan.1984-Dec.1999	10,263	11,265

Inventory of Rainfall Associated Events in Libertador Municipality in Dec. 1999

Landslide / Slope Failure	Inundation	Collapsed Houses	Affected Houses

110 areas	41 areas	1,842	2,261

In Libertador, more than 60 % of the houses and families affected by rainfall-associated landslide and inundation were concentrated on Parishes Antimano and Sucre, which are located in the western part of Libertador.

2) February 1951 Disaster

[Weather Condition] The bottom graphic in Figure 4.1.1.8 shows the pressure distribution on 17th February, 1951. The cold front from the West Atlantic Ocean reached the northern part of Venezuela like in Dec.1999. But the position of the cold front in Feb.1951 was toward the south as compared to that in Dec.1999. Although the situation was very similar to the event of Dec.1999, the cold front in Feb.1951 caused more rain over the Caracas area.

[Rainfall]Figure 4.1.1.12 shows the rainfall distribution over the Caracas area during February 15-17, 1951. Remarkable difference of the rainfall cannot be seen between western and eastern areas in the study area. The maximum daily rainfall was 193.0 mm in Maiquetia, 72.9 mm in Cagigal and 36.2 mm in UCV.

[Affected Area] According to Table 4.1.1.4, from PREVENE report, the damages produced by the February 1951 flood affected streams were widely distributed between the Anauco and the Tocome streams. The affected streams were the Anauco, Chacaito, Sebucan and Tocome.

3) December 1999 Disaster

[Weather Condition] The top graphic in Figure 4.1.1.8 shows the pressure distribution of December 14th, 1999. A cold front, whose length was several thousand kilometers, was located at the West Atlantic Ocean. It had stayed on the coastal line of Venezuela for about 20 days.

[Rainfall] The rainfall observation for the event of Dec. 1999 in Caracas only took daily measurements. Figure 4.1.1.13(1/2) shows the location of the operating rainfall stations in Caracas at that time. At UCV station, the 63.7 mm daily rainfall was recorded on Dec. 15, 1999. Cagigal and La Carlota stations recorded minor amount than UCV data. On the other hand, the daily rainfall in Dec. 15 at Maiquetia was 380.7 mm. The three (3) stations in Caracas are located on the lower Caracas Valley, so that the rainfall in El Avila Mountain was not reflected in those data. Indeed, the return periods for the data from these three (3) stations were quite low.

The United States Geological Survey (USGS) disclosed the satellite image interpretation on the total rainfall around the Avila during Dec. 14-16 in 1999 on his web site (Figure 4.1.1.13(2/2)). Regarding the rainfall amount over the southern slope of the Avila, they range from 350 mm to 100 mm.

[Affected Area] An interview survey was conducted in the 1st and 2nd week of June 2003 to obtain information on the sediment flow condition in Caracas, especially along the Cota Mil downstream.

The following items were included in the interviews to residents in Catuche, Anauco, Chacaito and Tocome streams and in the Guaire River, all of which reportedly suffered from flood damage in 1999. The interviewed items included some general questions on their past flood experiences to check the flood frequency in the area. The number of houses interviewed was approximately 10-20 for each stream. This interview survey was conducted by the JICA Study Team.

General	**Hydrologic Info. (Dec. 1999 flood)**	**Damage Info. (Dec. 1999 flood)**
Town name Name of interviewee Living period Photos of the interviewed house	Depth of debris and water above the ground Date and time of the flood peak Direction of the flood flow Diameter of debris deposited Tree included in the debris Photos in 1999 disaster	Property damaged Reasons of the damage (inundation, debris deposit and destruction by debris/water) Previous activities on Evacuation Previous activities on Recovery

Interview results were analyzed for each stream to see the mechanism of flood and sediment hazard.

Other Information on Damage in Caracas in December 1999

[Evacuation] One interview result reflects that, on January 7, 2000, after the disaster, 50 families among 70 families affected in a sector of Catuche were evacuated for one year to some military bases, such as Fuerte Tiuna and Maracay by the national government. The stay at the military bases was financially supported by the national government.

According to another interview result in Anauco, just after the disaster, the affected people were evacuated to schools in their neighborhood. In January 2000, the national government ordered that the affected people be evacuated to military bases, such as Palo Negro and El Tigre in Anzoategui, for ten to eleven months. The national government offered new houses for the 700 affected families in El Tigre, but quite a few families refused to settle in the houses provided, and thirty families among eighty three families returned to Anauco from El Tigre.

[Damage Cost] In the interview about damage cost, some people answered as follows:

Stream Name	Type of Damage	Damage Cost
Catuche	Furniture and wall of partially destroyed house	1 million to several million Bs. (2000)
Anauco	Totally destroyed house	1 million Bs. (2000)
Anauco	Price of New House	25 million Bs. (2003)

Those houses are all located in non-urban area

(3) Study on Sediment Disaster

1) Study Area and Basic Point

The study area covers the southern slope of El Avila Mountain and its alluvial fan in north-south and the area between the Caurimare Stream and the Caroata Stream catchments in east-west direction. The total area of the southern slope of El Avila Mountain is 60 km^2 as shown in Figure 4.1.1.1.

It is important to identify the location of the fan apex when we study a debris flow phenomenon and its measures, because the fan apex location is an important reference point in terms of the debris flow passing and debris flow deposition. It is generally said that the debris flow passes on the upper side from the fan apex and the debris flow deposits on the lower side of the fan apex; because of the abrupt change of slope gradient.

Here in this study, each fan apex is defined as “the basic point” for the mountain stream, and this definition will be used for the formulation of the disaster prevention plan.

The basic points define the lower end for sediment balance in the mountain stream catchment, and the upper end boundary conditions for urban flooding.

In the cases considered by this study, most of the fan apexes of 47 mountain streams are located at the Boyaca Avenue (called “Cota Mil” in Caracas). Therefore, most of the basic points in this study correspond to the crossing points of the mountain streams with the Boyaca Ave.

2) Stream Order Analysis

Generally, the sediment analysis is conducted based on the unit catchment concept. Figure 4.1.1.14 shows the stream order concept of Strahler. When this concept is applied, it is convenient to compare a lot of mountain stream catchments on a common condition for sediment transport phenomena. In the case of the study area, the 2nd order stream should be treated as a unit catchment to consider the entire catchment size and the drainage density.

Figure 4.1.1.14 shows the sub-catchment boundary for the 2nd order stream unit catchment in the mountain streams. The delineation was conducted based on the scale 1:5,000 Topographic Map of 1984 and 1954.

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

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

3) Rainfall and Discharge Analysis

[Representative Rainfall Stations] MARN-UNDP conducted a comprehensive hydrological study, "ESTUDIO DE CRECIDAS EN LAS CUENCAS DE LA VERTIENTE SUR DEL PARQUE NACIONAL AVILA (2001)." This study has provided the Avila Project with the basic information on rainfall and discharge for the preparation of hazard maps. The important thing to be mentioned here is that this report is authorized by MARN as a benchmark hydrological study for the Caracas Valley, and has been applied for the basic condition of the Avila Project. According to the study, the rainfall in the mountain stream catchment can be represented by five (5) rainfall stations. Table 4.1.1.5 shows the probable rainfall (Intensity-Duration and Frequency) of the five (5) representative stations.

Representative stations for main stream catchments are shown below. The neighboring stations of each stream were selected.

Name of the stream	Representative Stations
Catuche	Maiquetía, San Jose Avila
Anauco	Maiquetía, San Jose Avila
Cotiza	Maiquetía, San Jose Avila
Beatas	San José Avila, Teleférico
Gamboa	San José Avila, Teleférico, Maiquetía
Canoas	Teleférico
Maripérez	Teleferico
Guno	Teleférico, Los Chorros
Chapellin-Avila	Teleférico, Los Chorros
Chacaíto	Teleférico, Los Chorros

Name of the stream	Representative Stations
Quintero	Teleférico, Los Chorros
Pajaritos	Teleférico, Los Chorros
Sebucán	Teleférico, Los Chorros
Torres	Teleférico, Los Chorros
Agua de maíz	Teleférico, Los Chorros
Teneria	Teleférico, Los Chorros
Tócome	Los Chorros
Camburi	Los Chorros
Pasaquire	Los Chorros, Caurimare
Galindo	Caurimare
Caurimare	Caurimare

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

The SCS curve number for each watershed is decided mainly by the aerial photo and the chart made by the U.S. Soil Conservation Service, and calibrated by the SCS curve number of other watershed similar to that of El Avila Mountain, which has been already calibrated by the runoff analysis conducted by previous report.

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

[Runoff Analysis] The kinematics wave method is applied to produce the runoff hydrographs. The kinematics wave method assumes that the weight or gravity force of flowing water is simply balanced with the resistive force of bed friction. All flows are assumed to follow the equations of continuity and momentum as shown below.

$$\frac{\partial y}{\partial t} + \frac{\partial q}{\partial x} = i - f = i_e$$

$$q = \frac{1}{n} S_0^{1/2} y^{5/3}$$

y :depth of overland flow, q :rate of overland flow/unit width, $i - f = i_e$:net rainfall rate, n :effective roughness coefficient, S_0 :average overland flow slope

Effective roughness coefficient is 0.4-0.8 for watershed, and 0.04-0.06 for channel

[Probable Discharge] The computed probable discharge by return period is shown in Table 4.1.1.6. Figure 4.1.1.15 shows the 100 years return period specific discharge distribution for catchment areas upstream of the Cota Mil. The main catchments whose area are larger than 3 km^2 have the specific discharges in the range of 10-20 $m^3/(s*km^2)$.

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

4) Geomorphologic Survey

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

The objectives of the survey are the zoning of hazardous area and the estimation of volume of unstable soil in all of the catchments. For the former objective, from the geomorphologic, geological and biological point of view, the study area should be zoned based on the hazardous condition such as geomorphology – aerial photos, satellite images, topographic map, geology, site reconnaissance and flora condition. For the latter objective, investigating thickness of covered soil and thickness of highly weathered rocks in the collapse area, the volume of soil in the catchments should be estimated. The collapse area can be interpreted by aerial photos and the volume of unstable soil can be evaluated by site reconnaissance.

Geomorphic Anomalies

Upper ends of the Caurimare, Galindo, Quintero and Chacaito basins have flatter areas with small mounds (Pico Naiguata, Topo La Danta to Topo Galindo, Pico Oriental to Asiento de La Sill, Pico Occidental to Lagunazo). According to the geological map (Figure 4.1.1.6), these flatter areas are not geological anomalies.

Trace of Collapse in the basins

Traces of Collapses in the basins were collected on the aerial photos. The traces of collapse that can be seen in El Avila Mountain are shown in Figure 4.1.1.16 as a legend. There are many collapses Type 1 to Type 3 in the Cotiza and Catuche basins. It is hard to find Type 1 in other basins. There were many collapses in slopes in the Cotiza and Catuche basins where debris flows occurred in 1999, and the slopes have not recovered yet (Figure 4.1.1.17).

Sediment and Weathering

The thickness of covered soil and highly weathered rock is important for the estimation of unstable soil in the basins and is subject of site reconnaissance. The Chacaito stream has more sediment along its stream bed than Tocome stream(Figure 4.1.1.18). It may be because of the fault along Chacaito fault.

5) Hydrological Evaluation of Dec. 1999 Flood in Caracas

General

In terms of sediment flood disaster, the event of December 1999 was the worst on record occurred in the Caracas Valley after February 1951. Flood disasters, such as inundation in urban area, have occurred in many places along the Caracas Valley; however, sediment disaster in the southern part of El Avila happened only twice during the last 52 years since 1951.

It is obvious that the sediment flood of Dec. 1999 occurred in Caracas was brought about by the rainfall in El Avila. Unfortunately, rainfall data on El Avila Mountain was not measured at that time. Thus quantitative evaluation of the Caracas Dec. 1999 disaster, in terms of rainfall amount on El Avila and of discharge at the fan apex, has not been clarified so far because of the lack of hydrological information.

Therefore in this Study, to formulate the sediment disaster prevention plan, it is necessary to make hydrological assumptions about the event on El Avila Mountain for the quantitative evaluation of the Caracas Dec. 1999 disaster.

The hydrological considerations described below are based on various kinds of evidence, such as the observed high water marks and sediment deposit volumes, as well as the results of some previous authoritative studies.

Recorded Rainfall Amount

In the December 1999 flood, there were four (4) rainfall stations operating in and around the Caracas Valley as shown in Figure 4.1.1.13. It has been reported that during this event, the main streams affected by the rainfall were Catuche, Anauco, Chacaito and Tocome. Among them, the Catuche and Anauco streams suffered from sediment flow flooding in the urban area below the Cota Mil Ave.

According to the measurements taken by these four (4) stations, shown in Figure 4.1.1.13, the daily rainfall amounts had an increasing tendency from east to west. This tendency corresponds to the fact that the Catuche and Anauco streams were the most seriously affected by the rainfall.

Hourly rainfall data was only available in La Carlota during the event. It recorded 12.2 mm during hours 15:00 – 16:00 on December 15.

For the Caracas Valley, the maximum daily rainfall observed at Cagigal in Dec.1999 was 61.5 mm. The return period for this rainfall amount can be evaluated as less than five (5) years based on Table 3.15 from “ESTUDIO DE CRECIDAS EN LAS CUENCAS DE LA VERTIENTE SUR DEL PARQUE NACIONAL AVILA”. The return periods for the daily rainfall at UCV and La Carlota are also less than five (5) years. These stations are located in the lower area of the Valley and they do not represent the hydrological conditions which occurred on El Avila Mountain during the event of December 1999. Considering the Caracas Valley sediment disaster event, the return period for the rainfall on El Avila Mountain should be much larger than five (5) years.

Catuche Stream

a) Flood Mark

At the fan apex of the Catuche Stream, called Los Mecedores Sector, a flood mark was confirmed based on the interview survey conducted by the JICA Study Team in June 2003. The stream course at the fan apex meanders with s-curve started spreading the floodwater downstream. The water depth at Los Mecedores Sector was approximately 4 meters, which corresponds to the elevation of 1,035 m.

b) Estimation of Peak Discharge

A non-uniform hydraulic simulation was conducted for the reach of Los Mecedores to reproduce the flood mark level and to estimate the peak discharge during December 1999 flood.

The basic conditions of the hydraulic calculation were as follows:

Reach: Los Mecedores Sector upstream (239 m in total)

Cross Section: 6 cross sections based on the year 1984 topographical map (scale 1:5,000)

Manning roughness was set to 0.10. This value is larger than the normal one determined from the bed conditions, because the target flow contains debris whereas the applied continuity equation and momentum equation in the non-uniform calculation is only for water.

As a result of the non-uniform hydraulic calculation, the peak discharge containing sediment was estimated to be 120 m^3/s, approximately.

In order to separate the water discharge from the above calculated value (120 m^3/s), the relation between the water discharge and the discharge containing sediment was used as follows:

$$Q_{sp} = \frac{C_*}{C_* - C_d} Q_p$$

Where, Q_p: water peak discharge (m^3/s), Q_{sp}: peak discharge containing sediment, C_*: volumetric concentration of the deposit, C_d: volumetric concentration of sediment flow.

The volumetric concentration of sediment flow is evaluated as follows:

$$C_d = \frac{\gamma_w \cdot \tan\theta}{(\gamma_s - \gamma_w)(\tan\phi - \tan\theta)}$$

Where γ_w and γ_s are unit weight of water and sediment, respectively. ϕ : repose angle of deposit, θ : stream bed slope. If the calculated C_d is larger than 0.9 C_*, C_d is equal to 0.9 C_*, and if the calculated C_d is smaller than 0.3, C_d is equal to 0.3.[1]

Since the stream bed slope is about 7 degrees, C_d is equal to 0.3. Generally C_* is 0.6, so that

$$Q_{sp}/Q_p = 2$$

The peak water discharge was evaluated to be 60 m^3/s.

The Avila Project conducted the flood simulation for the Catuche stream for 10, 100 and 500 years return periods. This simulation was not intended to reproduce the 1999 event; however, the results at the fan apex of the Catuche (Los Mecedores) are a reference to evaluate the return period of the 1999 event. Comparing the flood condition interview results with the simulated results shown in the Figs.17-13 and 17-16 of the Avila Project Report, it is considered that the Dec. 1999 event is between 100 and 500 years in terms of the inundated area at the fan apex. The water discharges applied for 100 and 500 years cases were 59 m^3/s and 88 m^3/s, respectively (refer to page 396 in the Report).

The resultant 60 m^3/s water discharge in this Study should be acceptable and also supported by the Avila Project based on hydraulic assumptions contained in the Avila Project itself and in the JICA Study.

c) Estimation of Rainfall Intensity

It is necessary to calculate the rainfall intensity from the water discharge in order to evaluate the event in terms of the rainfall. The rainfall intensity can be estimated using the rational formula. The rational formula is one of the widely used rainfall–runoff formulas for small catchment and is suitable to get the reference results under limited information.

The catchment area of the Catuche fan is 3.9 km^2 according to the IMF drawing. The concentration time is:

$$T_c = 1.67 \times 10^{-3} \times (L/\sqrt{S})^{0.7}$$

[1] Lecture Book on Sabo, Vol.6-1,p183

Where, L: length of main stream in m, S: average bed slope. This formula is used in Japan for the mountain area.

$$T_c = 1.67 \times 10^{-3} \times (4{,}087 / \sqrt{0.22})^{0.7} = 0.95 \quad hour$$

To use the rational formula:

$$Q_p = \frac{1}{3.6} f \cdot r \cdot A$$

Where A: Catchment Area in km^2, f: runoff coefficient, r: rainfall intensity (mm/h).

the rainfall intensity during the concentration time is:

$$r = \frac{3.6 \cdot Q_p}{f \cdot A} = \frac{3.6 \cdot 60}{0.7 \cdot 3.9} = 79 \quad mm/h$$

d) Runoff Sediment Volume

Based on the interview survey, the affected area in the Catuche stream for the December 1999 flood was mapped on the topographical map with scale 1:5,000. From the map, the runoff deposit sediment volume was estimated to be approximately 50,000 m^3 within the 500 meters reach of the fan apex downstream.

The above 50,000 m^3 sediment volume is apparent on the site and contains void (Void ratio is 0.4). The net volume is 50,000 * (1-0.4) = 30,000 m^3. This net volume can be checked from the hydraulic viewpoint. If a triangle hydrograph with a peak discharge of 120 m^3/s and half hour duration time shown in the above is assumed, the runoff sediment volume is:

$$V = Q_{w+s} \cdot DR \cdot 60 \cdot \frac{1}{2} \cdot C_d$$
$$= 120(m^3/s) \times 30(\min.) \times 60(\sec.) \times \frac{1}{2} \times 0.3 = 32{,}400 \quad m^3$$

The half an hour duration time (DR) is assumed as the period that the substantial sediment runoff took place to consider the phenomena that was described in the Interview Survey.

Chacaito Stream

e) General

According to the interview survey in June 2003, little sediment arrived at the urban area below the Cota Mil. Hence, it is regarded that the sediment concentration in the flood flow can be neglected for the estimation of peak discharge.

f) Estimation of Peak Water Discharge

According to the interview survey, the flood condition just downstream of the Cota Mil was approximately three (3) meters water depth by 4 meters width. Since it is difficult to generate the cross section data from the 1984 topographical map, uniform flow was assumed in Chacaito for simplicity.

To use the Manning's equation:

$$Q = A \cdot \frac{1}{n} \cdot R^{2/3} \cdot I^{1/2}$$

the peak discharge can be as follows:

$$Q = \frac{1}{0.06} \cdot \left(\frac{3*4}{3 \cdot 2 + 4}\right)^{2/3} \cdot \left(\frac{1}{11}\right)^{1/2} \cdot 3 \cdot 4 = \frac{1.13}{0.06} \cdot 0.30 \cdot 12 = 68 \quad m^3/s$$

Where the bed slope is five (5) degrees.

g) Estimation of Rainfall Intensity

The catchment area of the Chacaito Basin above the Cota Mil is 6.3 km^2 and the length of the main stream and the average slope are 5,550 meters and 0.26, respectively.

The concentration time and the rainfall intensity are as follows:

$$T_c = 1.67 \times 10^{-3} \times (5550 / \sqrt{0.26})^{0.7} = 1.11 \quad hour$$

$$r = \frac{3.6 \cdot Q_p}{f \cdot A} = \frac{3.6 \cdot 68}{0.6 \cdot 6.3} = \quad 65\, mm/h$$

Where A: Catchment Area in km^2, f: runoff coefficient, r: rainfall intensity (mm/h).

Conclusions

h) Peak Water Discharge

The peak water discharges for the Catuche and Chacaito streams were estimated as 60 m^3/s and 68 m^3/s, respectively. According to the probable discharge by CGR report, the return periods are as follows:

Stream	Peak Discharge (m^3/s)	Return Period (year)
Catuche	60	100
Chacaito	68	<25

i) Rainfall

The rainfall intensities during the concentration time for the Catuche and Chacaito streams were estimated as 79 mm/h and 83 mm/h, respectively. From these results, it is expected that higher intensity rainfall occurred in the mountain area than in the lower area of the Caracas Valley. These rainfall amounts are those for the mountain area; however, the comparison with the probable rainfall amounts of neighboring stations is as follows:

Stream	Rainfall Amount for 1 hour (mm)	Return Period (year)
Catuche	79	100 (Maiquetia) <300 (San Jose Avila)
Chacaito	65	5 (Teleferico) 7(Los Chorros)

It is quite difficult to estimate longer duration rainfall, such as daily rainfall, from the peak discharge. Generally the scale of sediment flood is related with the amount of daily or longer rainfall amount. Ideally, it is better to evaluate the daily rainfall on El Avila Mountain on Dec. 1999; however, it can not be done because of lack of sufficient data.

j) Conclusion

In terms of the reliability for the evaluation of the return period among the rainfall and discharge assumed above, the usage of the water discharge is better comparatively because it reflects the flood condition directly. In this context, it can be said that in terms of the water discharge caused by the rainfall on El Avila, the Caracas Valley disaster of December 1999 is at least an event of 25-year return period for the Chacaito Stream and over 100-year return period for the Catuche Stream. The evaluation of the return period for the sediment flood phenomena has many unknown factors, such as the volumetric concentration, however, the concluded return period for the sediment flood should be similar to that of the water discharge as long as the following relation is assumed:

$$Q_{sp} = \frac{C_*}{C_* - C_d} Q_p$$

6) Condition of Cota Mil for Sediment Disaster

At the fan apex of the mountain streams from El Avila there is the Cota Mil expressway that affects the sediment runoff to the downstream alluvial fans; however, the Catuche and Caroata streams are not affected by the Cota Mil because they are out of the route. In the case of the Caurimare stream, at its fan apex there are many new apartment buildings and the Cota Mil is crossing the Caurimare on the way to the Guaire River.

For the stream section under the Cota Mil, there are four (4) types of crossing.

Bridge
Large Box Culvert
Small Box Culvert or Duct
Out of Cota Mil Route

Table 4.1.1.7 shows the crossing condition at the Cota Mil for each mountain streams. The information on the dimension of culvert and bridge were obtained by the field reconnaissance of the Study Team and the IMF Report and the Cota Mil design drawing. However quite a few sites under the Cota Mil are difficult to access because the access routes are within private lands.

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

Also in the Table 4.1.1.7, the storage volume just upstream of the Cota Mil is presented. The volume is calculated based on the contour lines of the scale 1:5,000 topographical map in 1984. The slope of sediment deposit is assumed from the top of the Cota Mil to upstream with the slope of 2/3 of the stream bed slope. The Cotiza, Anauco and Mariperez streams have comparatively big storage capacity because of the deep stream bed to the height of the Cota Mil.

7) Study on Debris Flow Potential

Sediment Balance

For the evaluation of the possibility of debris flow in the mountain streams, it is significant to analyze the mechanism on sediment runoff. For El Avila Mountain, the December 1999 disaster is the only example available for the sufficient analysis.

a) Sediment Balance in December 1999

During the event of December 1999 flood, the significant sediment runoff to the urban area took place in the Catuche, Cotiza and Anauco streams. In other streams the sediment movement might occur within the catchment, however, the runoff to the urban area was quite few. Here taking the phenomenon in the Catuche, Cotiza and Anauco streams in 1999 as a material, the ratio of the runoff sediment volume to the unstable sediment in the catchment is evaluated.

The Figure 4.1.1.19 shows the schematic image of the unstable sediment in a catchment before and after the 1999 event. Before 1999 there was an amount of unstable sediment on the streambed.

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

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

The Figure 4.1.1.19 explains the sediment budget at the event of 1999 for the 3 streams. The left column of each stream is the summation of the sediment runoff in 1999 (=A) and the present unstable sediment on streambed. The right side column of each stream is the summation (=B) of the collapsed sediment in 1999 and the sediment deposit on streambed before 1999. The only unknown factor is the sediment deposit on streambed before 1999. This can be calculated if the left and right column were equal.

The objective sediment and its assumed thickness and runoff ratio are shown below:

Sediment Type	**Thickness (m)**	**Ratio of sediment runoff to connecting stream**
T Unstable sediment on streambed	Varied on order of stream	-
Active Collapse	1.5	1.0
h New collapse covered with grass	2	0.7

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

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

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

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

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

b) Sediment Balance for Future Event

Assuming the rainfall event corresponding to the December 1999 one, for the 47 mountain streams, the runoff sediment volume was estimated as follows, (see Figure4.1.1.20)

The ratio of the area of active slope collapse to the whole catchment area was calculated as 3.7 % for the western part of the Avila, in which significant slope collapses occurred in 1999(see Figure 4.1.1.21). This calculation was done based on the geomorphologic map made in the Study.

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

The sediment volume generated from the assumed slope collapse area was calculated as the product of the above collapsed area, thickness and the ratio of remaining sediment volume.

Thickness (m)	Ratio of remaining sediment volume to collapsed slope volume
2.3	0.3

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

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

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

Where A: Catchment area in km^2, Rt: 24 hours rainfall in mm for the selected return period, λ : void ratio(= 0.4), fr: runoff ratio(= 0.05 (log A – 2.0)^2 + 0.05), Cd: sediment concentration as a function of stream bed slope.

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

The Figure 4.1.1.22 shows the estimated runoff sediment for each major catchment. The catchment No.14 is at the Tocome Stream, which has the largest runoff sediment volume among all. The second largest volume is expected in the Caurimare stream (No. 4). The Catuche (No.44) and Cotiza (No.42) streams have smaller estimated sediment volume compared with the eastern part of El Avila, because the unstable sediment in those two streams already went out of the catchment in 1999.

The Figure 4.1.1.23 indicates the comparison of the estimated runoff sediment in Caracas and that in Vargas and Japan. The specific values per km^2 in Caracas are positioned in lower part compared to that in Vargas. This is because the rainfall amount for the data in Vargas is much larger than in Caracas. The two (2) parallel straight lines indicate the range of specific sediment runoff volume in Japan for the similar geological condition to Caracas. The assumed sediment volume in Caracas is basically also positioned in lower part compared to Japan.

Debris Flow Potential

In terms of the streambed slope there is no significant difference among the 47 mountain streams as well as among the unit catchments. So the amount of unstable sediment volume including new and old collapse area is a major factor to indicate the potential of debris flow.

As the major catchment-wise, the Tocome, Caurimare, Galindo, Chacaito and Cotiza have much sediment in this order to be generated at the future flood as shown in Table 4.1.1.8.

The followings are summary of the study in the Avila Mountains;

1. Although rocks which are relatively less competent such as marble or serpentinite are reported in the western side, there is no major difference of geology / lithology between the east side and the west side. The density of faults and lineaments is not different between the east and the west.

2. New collapses are more in the west because there were a lot of collapses in December 1999, and old collapses are scattered in the whole area. Although there were quite a few collapses in February 1951, their vegetations have already been recovered and at present they are regarded as old collapses.

3. Weathered zone is thicker in the west than in the east. This may be caused by the terrain. The material of weathered zone is rich in gravel and poor in silt/clay.

4. Debris on streams seems more in the east. This may be caused by that the streams in the east have steps in its profile and have trellis / angular pattern of its drainage pattern.

5. Vegetation is classified from lower altitude to upper altitude of the Avila Mountains. Vegetation above 1,700m altitude is thicker than in below. Therefore, Catuche, Cotiza basins which are mostly below 1,700m have weaker vegetation.

From the view of vegetation distribution, weathering thickness, debris on streams and collapses distribution, it can be said that the streams in the west especially Cotiza and Catuche are weaker against debris flow that the streams in the east. The difference of strength of the ground owes mostly the protection by vegetation since the lithologies both in the east and in the west are not much different. However, the distribution of old collapses are scattered even in the east side uniformly shows possibility of debris flow in the east side. If strong rain fall was only in the east side, debris flow would occur only in the east.

4. 1. 2. Development of Sediment Hazard Map

The subjective sediment disasters for the hazard mapping are steep slope failure, landslide and debris flow.

(1) Steep Slope Failure and Landslide

The purpose of this study is identification of the slopes that have possibility to collapse and to develop to disaster, and then to make the slope classification map. The slope classification map that the study team will prepare in this study show unstable slopes which shall effect to inhabitants.

Generally, investigation of slope disaster in Japan is conducted in accordance with the flow chart that is shown in Figure 4.1.1.24. The investigation of slope disaster is consisted of 2 sections that are "Wide Area Study" and "Individual Study (Minute Investigation)". The study team conducted until "Hazard Evaluation" in the sediment study area.

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

The distinctive point of the study is to identify slope as a unit. The maps that INGEOMIN prepares are Hazard Maps, where the basic unit of analysis is the hills, for this reason a map of hills is elaborated, separating each one according to its orientation. The methodology to elaborate the hazard/susceptibility maps is based on the summary of a series of conditioning parameters of stability. The slope is one of the parameters being considered, a map is elaborated where the slope variations are registered, along each one of the considered banks. This information is used as a layer for the analysis of variables.. On the other hand, we identify each unit of slope that have possibility to collapse. Slope unit is divided by change point of slope form (refer to Figure 4.1.1.25). Therefore, slope unit is formed convex slope, concave slope or flat slope. If flat slope is continuous, it shall be divide each 200 m to 250 m width. This criterion is based on the slope investigation standard by the Japanese Ministry of Land, Transportation and Infrastructure. In case of convex or concave slope has "barrio", which is consist of many "Lanchos", it is divided further by a change point of slope form as flat slope.

The number of the interpreted instable steep slope and landslide is 230 and 8, respectively. Among the 230 steep slopes, there are 52 steep slopes above the road. Figure 4.1.1.26 shows the number by Municipality. Most of the steep slopes above house are located in Libertador and Sucre.

(2) Debris Flow

1) Mapping Streams

In the previous chapter, there were totally forty seven (47) principal streams in the Avila. The scope of works of the JICA study specifies twenty (20) streams, which are completely included in the above forty seven (47) principal streams in the Avila. The 20 streams can be grouped into eleven (11) alluvial fans, which are subjective to the hazard and risk mapping in this study. Table 4.1.1.9 shows the relation between the twenty (20) streams and the eleven (11) alluvial fans.

Hazard mapping for the 11 alluvial fans has also been executed by PREVENE, the Avila Project and the Caracas Project in Venezuela. The Table 4.1.1.9 also shows the project names covering these 11 alluvial fans.

Among the above eleven (11) alluvial fans, the Cotiza-Anauco-Gamboa and Tocome-La Julia models were developed by "PREVENE" while the remaining were developed in the "Mapa de Amenaza" by Central University in Venezuela (UCV) except for the Caroata Stream. In addition to the "Mapa de Amenaza", UCV has been conducting an extensive study of drainage system for the eleven (11) alluvial fans including the Caroata stream to improve the simulation models in the Caracas Project.

2) Methodology

This chapter describes the methodology how to delineate the hazardous / risky area by debris flow for the sediment study area.

The methods of the above PREVENE, Avila Project and Caracas Project can be explained as follows (Table 4.1.1.10).

First of all, the rainfall and runoff simulation for the Avila has difference between the PREVENE, and the Avila Project / Caracas Project. The PREVENE applied unit hydrograph method, whereas the Avila Project / Caracas Project is using the kinematic wave method which was conducted by MARN (CGR Engineers).

Regarding the flood simulation for the Caracas Valley, the FLO-2D model was used by these projects.

The rainfall-runoff simulation by MARN (CGR Engineers) is a comprehensive hydrological study for the entire Avila mountain, while the PREVENE was a kind of pilot study for some specific study areas. The Study Team reviewed the results of rainfall-runoff simulation by MARN (CGR Engineers) and compared with the conventional rational formula as described in Supporting Report S13 (Hydrology). Since the hydrological study by MARN (CGR Engineers) has been the basis in the hazard mapping field in Caracas, the Study Team decided to make use of the results as a runoff (water) data from the Avila. For the debris flow hazard mapping, the Study Team took into consideration of sediment volume based on the filed survey.

For the hydraulic modeling, the Study Team merged the 11 alluvial fans into the west and the east modeled area. For each modeled area, the flood simulation model was made using FLO-2D covering the all 11 alluvial fans. The FLO-2D model by the Study Team was designed in order to analyze the effect of sabo dam in the Avila simply taking into consideration of the Master Plan level.

The difference between the model of the Avila Project and the model by JICA Study Team is shown in Table 4.1.1.11.

The hazard map is created by two (2) methods. Method 1 is by Japanese Law Sediment Disaster Prevention. Method 2 is by FLO-2D Model.

3) Method 1: Method by Japanese Law Sediment Disaster Prevention

The Law of Sediment Disaster Prevention, which was issued in 2000 in Japan, and the related guidelines indicate the methodology to delineate the potential area for debris flow.

a. Peak Discharge and Height of Debris Flow

The potential peak discharge by debris flow can be calculated as follows,

$$Q_{sp} = \frac{0.01 \cdot C_*}{Cd} \cdot V$$

$$Cd = \frac{\rho \cdot \tan\theta}{(\sigma - \rho)(\tan\phi - \tan\theta)}$$

where Qsp : potential peak discharge by debris flow, V : transported sediment volume by debris flow, C* : volumetric concentration of the deposit (= 0.6), Cd : concentration of debris flow after Takahashi, σ : specific density of sediment (t/m^3) (= 2.6), ρ : flow density (t/m^3) (= 1.2), ϕ : internal friction angle (degree) (= 35), theta : slope of stream bed (degree).

The unit weight of debris flow and the velocity of debris flow are as follows,

$$\rho_d = \frac{\rho \cdot \tan\theta}{\tan\phi - \tan\theta}$$

$$U = \frac{h^{2/3} \cdot (\sin\theta)^{1/2}}{n}$$

where row-d : unit weight of debris flow (t/m^3), h : depth of debris flow (m), U : average velocity of debris flow (m/s), n: Manning's roughness (= 0.1 for natural channel).

Therefore, the depth (height) of debris flow can be expressed as

$$h = \frac{Q_{sp}}{B \cdot U} = \left(\frac{n \cdot Q_{sp}}{B \cdot (\sin\theta)^{1/2}} \right)^{3/5}$$

b. Flow Width of Debris Flow (B)

The flow width of debris flow can be evaluated by two (2) kinds of approaches, namely Manning method and Regime method.

The Manning method is to calculate the flow width which can satisfy the following equation.

$$Q_{sp} = \frac{1}{n} \left(\frac{A}{S} \right)^{2/3} (\sin\theta)^{1/2} \cdot A$$

where A : flow area (m^2), S : hydraulic radius of the section (m).

In the case of laterally flat alluvial fan, it is difficult to evaluate the flow width from the above formulas. For such case, the regime theory can be applied.

The regime theory is as follows,

$$B = 4\sqrt{Q_{sp}}$$

If both methods can be applicable to evaluate the flow width (B) in a cross section, the smaller width (B) is selected.

c. Longitudinal Change of Debris Flow

The following equations are the relation between the volumetric concentration of debris flow and the peak discharge of debris flow while the debris flow goes downstream.

$$Qsp_i = \frac{C_* - Cd_{i-1}}{C_* - Cd_i} Qsp_{i-1}$$

where suffix (i) and (i-1) indicate downstream and upstream, respectively.

d. Definition of "Red Zone"

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

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

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

The resistance force of house / building is

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

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

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

According to a structure analysis in this study as shown in Figure 4.1.1.27, the yield strength of concrete columns of barrio house in Caracas is almost same as that of ordinal wooden house in Japan assuming that the compressed strength of concrete of barrio house is 80 kgf/cm^2. The concrete column of house in urban (formal) area in Caracas, assuming the compressed strength of concrete of barrio house is 180 kgf/cm^2, has stronger strength than that of ordinal wooden house in Japan. In this sense, the red zone based on the above criteria is conservative (safer) side. In this study, the modified strength equations were derived for the concrete barrio house and the concrete urban area house in order to delineate the red zone.

Figure 4.1.1.28 and Table 4.1.1.12 show an example of calculation. The cross sections on the plane view and the depth and width for each section are shown.

e. Definition of "Yellow Zone"

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

The concept to delineate the yellow zone in the valley shape cross section is illustrated in Figure 4.1.1.29. If the height of red zone is less than 5 m, then the height of the yellow zone will be 5 m. If the height of red zone is more than 5 m, then the height of the yellow zone will be 1 m above the height of the red zone.

"Fan Rule" is applicable when the cross section is flat and the area of 5 m height can not be decided. The fan rule is illustrated in Figure 4.1.1.30. The 40 m length vector (dotted line) is described as the steepest slope direction from each end point of the yellow zone. The vector (non-dotted line) for the yellow zone is described as thirty (30) degrees from the dotted vector. The vector for the yellow zone is repeated until the slope is less than two (2) degrees.

f. Hazard Map by Method -1

Figure 4.1.1.31 is the debris flow hazard map by the method-1. The number of affected house and the total area of the house in Yellow and Red Zones are shown in Table 4.1.1.14 and Table 4.1.1.15. From the 2,700 houses located in the red zone, 1,300 are barrio houses of which about 1,000 are built in the streams. Therefore, it is recommended that these are relocated.

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

a) Hydrological Part

a. Modeled Area

The hydrological study report "Estudio de Crecidas" is focused on the mountainous area above the 1,000 Meter Road (the Cota Mil) of each stream. The report studied the design rainfall hyetograph by return period for the areas. Also the design discharge is calculated by rainfall-runoff analysis.

The output of the hydrological study is configured as the upstream boundary condition for the hydraulic analysis.

b. Rainfall Analysis

"Estudio de Crecidas" states that the distribution of monthly rainfall in Caracas Valley is quite different from that in Vargas State, which means that the metereological characteristics are different among them. While the distributions of monthly rainfall within Caracas Valley are similar among the rainfall stations, the aerial distribution in terms of short duration rainfall has a large variation. Hence, five (5) rainfall stations were selected as representative stations for the southern part of El Avila Mountain.

The report pointed out that the heavy rainfall in Caracas did not continue for several days as it happened in Vargas.

c. Runoff Calculation

For the conversion of the rainfall amount to the runoff discharge, SCS method was used to estimate the effective rainfall amount and the kinematics wave method was applied to produce the runoff hydrographs.

b) Hydraulic Part (FLO-2D)

a. Applicability for the topography of the area to be modeled

The hydraulic study is focused on the urban area below the 1,000 Meter Road (the Cota Mil) of each stream. The area to be modeled is the alluvial fan that was composed of sediment from El Avila. The slope along the streams is very steep and the contour lines of the area are fan-shape, so that the floodwater tends to flow downward very rapidly and to spread. The floodwater passing the fan apex could distribute into two directions depending on the topography. In the above sense, the use of the 2-dimensional hydraulic model "FLO-2D" is quite appropriate.

b. Usability in Venezuela

"FLO-2D" is commercial software. It was developed by Dr. Jim O'Brien in the United States of America and by Dr. Reinaldo Garcia in the Central University of Venezuela (UCV). The UCV is one of the counter parts of the Study.

The methodology for the use of FLO-2D was tested in twenty-three sites in the Caracas and Vargas State region by Venezuelan side. The hazard maps of the Vargas State are being used by planners of the Venezuelan Ministry of Environment and Natural Resources and other agencies to design emergency plans and new land use policies. The methodology is being expanded to other flood hazard regions in Venezuela.

c. Usability in the world

FLO-2D is a hydraulic software officially evaluated as hazard mapping tool by the Federal Emergency Management Agency in the United States. It is widely used for flood hazard mapping in a lot of countries as well as in the USA. This means that there are a lot of users for the software in the world and it has been applied to many practical problems.

d. Hydraulic Solution Concept

FLO-2D is a two-dimensional flood routing model that is a valuable tool for delineating flood hazards, regulating floodplain zoning and designing flood mitigation. FLO-2D routes a flood hydrograph using the full dynamic wave momentum equations and guaranteeing volume conservation to accurately predict the area of inundation. The fluid viscous and yield stress terms are accounted in the model. The channel and floodplain roughness play a role in the turbulent stresses in the full dynamic wave equation. The model is effective for analyzing river overbank flows, but it is also valuable for analyzing unconventional flooding problems such as unconfined flows over complex topography and roughness, spilt flows, mud / debris flows and urban flooding. The key to the model applicability is volume conservation that tracks the flood wave progression over unconfined surfaces. Flood hazard delineation detail can be enhanced with FLO-2D by modeling rainfall and infiltration, applying bridge, culvert and levee components, simulating hyper-concentrated sediment flows or by modeling the effects of buildings or flow obstructions.

e. Mathematical Equations and Solution

The governing equations for hydrodynamic computation are as follows,

$$\frac{\partial h}{\partial t} + \frac{\partial h V_x}{\partial x} + \frac{\partial h V_y}{\partial y} = i$$

$$S_{fx} = S_{ox} - \frac{\partial h}{\partial x} - \frac{V_x}{g}\frac{\partial V_x}{\partial x} - \frac{V_y}{g}\frac{\partial V_y}{\partial y} - \frac{1}{g}\frac{\partial V_x}{\partial t} \quad S_{fy} = S_{oy} - \frac{\partial h}{\partial y} - \frac{V_y}{g}\frac{\partial V_y}{\partial y} - \frac{V_x}{g}\frac{\partial V_y}{\partial x} - \frac{1}{g}\frac{\partial V_y}{\partial t}$$

Where h is the flow depth, Vx and Vy are the depth averaged velocity components along the x- and y- coordinates, and I is excess rainfall intensity.

The differential form of the continuity and momentum equations in the FLO-2D model is solved with a central, finite difference scheme. The solution domain is discretized into uniform, square grid elements.

The friction slope components S_{fx} and S_{fy} are composed of yield slope component, viscous slope component and turbulent-dispersive slope component.

$$S_f = S_y + S_v + S_{td}$$

$$S_f : \textit{friction slope} \quad S_y : \textit{yield slope} \quad S_v : \textit{viscous slope} \quad S_{td} : \textit{turbulent} - \textit{dispersive slope}$$

FLO-2D routes hyper-concentrated sediment flows (mud and debris flow) as a fluid continuum by predicting viscous fluid motion. For mudflows, the motion of the fluid matrix is governed by the sediment concentration. A quadratic rheologic model for predicting viscous and yield stresses as function of sediment concentration is employed and sediment volumes are tracked through the system. As sediment concentration changes for a given grid element, dilution effects, mudflow cessation and the remobilization of deposits are simulated.

f. Criteria of Simulation

The model takes into account the hydraulic structures such as channel, culvert and bridge and existing infrastructure as building density.

The model is the two (2) dimensional and the grid size is 30 m * 30 m except for the Tocome and Anauco models. The hydraulic structure can be modeled within a grid.

The discharge hydrograph for water to be used is based on the study "Estudio de Crecidas". For the return periods of 10, 100 and 500 years, the hazard maps has been prepared.

The hydrograph for sediment material at the upstream boundary is made to consider the ratio of sediment concentration to water discharge.

The reduction factor on building area, which could affect the depth of water and sediment, is taken into account.

c) FLO-2D modeling for Caracas

a. Modeled Area

The 11 alluvial fans were divided into 2 separate modeled areas, namely the east model and the west model. The east model covers the Caurmare, Tocome, Agua de Maiz, Sebucan, Seca and Chacaito alluvial fans. The west model covers the Mariperez, Canoas, Anauco, Catuche and Caroata.

Each model can simulate the floods of all the alluvial fans in one run. So the model can simulate the flood water from two (2) alluvial fans to converge and form the contiguous flooded area.

b. Grid Size and Grid Elevation

The grid size was set to 100 m * 100 m square. It was decided to consider the spatial scale of topography accuracy as well as the modeling work volume. Especially the grid size can affect on the modeling work volume directly because it is necessary to adjust the model data such as elevation, channel section, roughness for each grid cell in the course of repeated simulation runs.

The grid elevation was given by the average elevation of the point elevation data of 5 meter resolution DTM which was generated from the base map (scale 1:5,000) for this study.

c. Channel

The channel within grid was configured for main streams in both models. All the channels are regarded as open channel with rectangular shape.

d. Sediment Concentration

Due to the software requirement, for the simulation of debris flow the sediment concentration must be at least 0.20. For the scenario case, the sediment concentration was decided to input the total sediment volume as the portion exceeding the sediment concentration 0.20, equal to the target sediment volume.

d) FLO-2D model runs

a. Case

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

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

b. Results

Figure 4.1.1.32 and Figure 4.1.1.33 are the depth and velocity for 100 years return period under the existing condition. The values of depth and velocity are the average value for each grid cell.

Figure 4.1.1.34 is the depth for 100 years return period assuming all the Sabo Dam constructed in the future. The peak discharge was reduced because of less sediment concentration, resulting into that the flooded area was also reduced.

4. 2 Development of Sediment Risk Map

The risk map will be prepared based on the physical hazard in relation with the socio-economic information on the urban area. For the preparation of socio-economic data, the following damage survey and property survey were conducted.

4. 2. 1. Steep Slope Failure and Landslide

Figure 4.2.1.1 shows the concept of how to decide the affected area (risk) by steep slope failure. The hazard area below the slope is within the two times of the vertical height of the slope whereas the hazard area above the slope is within the one (1) time of the vertical height of the slope. This concept is based on the Japanese ordinances on sediment disaster prevention.

In the case of landslide (Figure 4.2.1.2), the affected area by a landslide is in the reach of 50 % of the slope length based on another Japanese reference, however, it should noted that the extent of the affected area is varied by the geological, topographical and vegetation.

Based on the above concept, the affected area was delineated for each potential steep slope failure and landslide. The hazard map for landslide and steep slope failure is shown in Figure 4.2.1.3 (1/4-4/4).

The Risk map is shown in Fig 4.2.1.4. This is the map that is classified by the colors according to the density of houses in the hazardous area based on the hazard map.

4. 2. 2. Debris Flow

(1) Physical Damage in "Red Zone"

The Red Zone in Figure 4.1.1.31 is corresponding to the risk in terms of destruction of house / building. The number of affected house and the total area of the house in Yellow and Red Zones are shown in Table 4.1.1.14 and Table 4.1.1.15.

The former table is the principal stream basis, in which the counted property numbers have duplicated counts in alluvial fans. The former table can be referred when individual principal streams are compared in terms of the potential hazard.

The latter table is the alluvial fan basis, in which the counted numbers do not have any duplication in alluvial fans. As a scenario case, if debris flows happen in all the principal streams, the hazard area can be shown in the latter table.

(2) Flood Damage Survey

1) Purpose

This survey is aimed to estimate both in local currency and in US$, the damages occurred in the basins of Anauco, Catuche, Tocome, Caroata, and Chacaito, during the Dec 1999 flood.

2) Methodology

The digital topographic maps will be used to delineate the following information:

- The affected area
- Urban and Non-urban Areas
- Sediment type (big, medium and fine)
- The Non-Urban area is classified into A, B, and C according to the value of their house property
- The area of each Parroquia will be shown
- The Barrios with their name will be shown

The **affected area** for the Catuche, Anauco and Caroata basins, prepared by the Firemen Department, will be used. In the Chacaito and Tocome basins, the survey of the affected area done by the JICA Study Team will be used too.

The study will separate or differentiate the urban area affected by the flood from the so-called non-urban area. **Urban Area** is considered that part of the basin where constructions are built according to the District regulations, where formal documents of property exist in the local Register, and where the Engineering Department of the Municipal Government supervises the construction process and grants the required construction permits. **Non-Urban Area** is considered the part of the basin where the population lives in the so called “ranchos”, where constructions are built without complying with any regulation at all; that is to say, without engineering studies, District permits and/or property documentation.

The study will determine the type of damage suffered in each basin indicating whether it was:

- otally destroyed
- Partially destroyed

- Just flooded with some sediments in the floor

In The Urban Area as well as in Non-Urban Area of each basin, the type of building will be identified as:

- Residential
- Commercial or
- Public

3) Estimation of Damage Price in the Non-Urban Area

In the Non-Urban Area the price of the building depends mainly in its location. People there are willing to pay more for a building that is located in a safer area, and closer to the formal city, than for a building located in other site. Therefore, unit damage price will be established per sectors (A, B, and C) and then it will be used to determine the total damage price.

A survey to estimate the damages to automobiles in each basin will be presented.

The survey in the Urban Area will include the Basement of the different affected buildings.

4) Damage Price Estimation

The damage price estimation for the Non-Urban Area will be based on a survey performed on each basin.

There is no Register information at all about the value of the "ranchos". Their construction style varies significantly from one to another.

5) Results of Flood Damage Survey

a) Affected Houses / Property

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

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

b) Unit Damage Price

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

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

c) Total Damage Price

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

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

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

The damage during the December 1999 event took place mainly in the Catuche and Anauco Streams. Also the damage in those 2 streams concentrated in the non-urban area. The damage in other streams was small, less than 10 % of those of the Catuche and Anauco. The detailed result of the damage survey is shown in Table 4.2.2.1.

(3) Risk Map

The Risk map is shown in Figure 4.2.1.5. This is the map that is classified by the colors according to the density of houses in the hazardous area based on the hazard map.

4. 3 Disaster Prevention Study for Sediment Disasters

4. 3. 1. General

(1) Identification of Target Disasters

Sediment and flood disasters occur at different locations and affect the social and economic activities in the sediment study area in the Metropolitan District of Caracas. The disasters are classified into three (3) according to type and magnitude as follows:

- Disasters due to landslide and steep slope failure that occur at spot sites but affect the social and economic activities as well as human life to a great extent through the house/building damage and the interruption of traffic.
- Disasters due to debris flow or sediment flow that originates from the Avila, resulting into spreading over a wide area over the alluvial fans to affect the social and economic activities as well as human life to a great extent through the house/building damage and the interruption of traffic.
- Disasters due to local inundation caused by heavy storm in the urban area like the disaster which occurred in Agua de Maiz in 2003.

Since damage to assets and human life under the first two (2) categories will have serious influence on the social and economic activities as well as human life in the sediment study area whereas the third one can be regarded as out of the scope of work of this study, the disasters covered by these two (2) categories were selected as the target for the M/P.

(2) Manner of Master Plan Project Formulation

1) Master Plan and Action Plan

The master plan for the disaster prevention measures for the 3 subjective sediment disasters is firstly formulated with its target year set at 2020. Within the framework of the master plan, an action plan for short term is also formulated for the selected urgent projects with the target year at 2012.

2) Basin-wide Project and Local Project

The planning area for the disaster prevention works depends on target assets, as described hereafter.

Disasters due to landslide and steep slope failure occur at spots independent each other. The planning area for each disaster is, therefore, limited to a relatively small area.

In the case of the disasters due to steep slope failure and landslide, the planning area could be specified locally. Accordingly the planning area is limited to the small area of the watershed.

Disasters due to debris flow or sediment flow are basically caused by sediment and flood discharge from the Avila and by inundation in the fan apex downstream.

In the case of the disasters due to debris flow, the assumed affected area and the flood water sediment generation area are distributed within the whole watershed that is from top of the Avila to the confluence of the Guaire river. Accordingly the planning area should cover the whole catchment, namely basin-wide project concept.

4. 3. 2. Concept of Project Formulation

Basin-wide project subject to debris flow and local project subject to steep slope failure and landslide will be the component of the master plan. Figure 4.3.2.1 shows the basic work flow diagram for the master plan study.

The objective of the basin-wide project is to mitigate debris flow and inundation damage in the alluvial fans. To achieve this objective, the runoff sediment should be controlled in the Avila and the flood water should be controlled in the alluvial fan to prevent sediment deposition and the resulting decrease in flow capacity of the water channel in the alluvial fan.

The local project aims at the protection of roads and houses from the steep slope failure and landslide.

The hazard and risk for steep slope failure and landslide have been evaluated preliminary in the previous sections. For the affected property as risk, it will be studied if any structure measure is economically feasible or not at first.

The hazard and risk for debris flow also have been evaluated preliminary in the previous sections. The sediment study area is divided into ten (10) primary watersheds. For each watershed it will be studied if any structure measures are economically feasible or not.

For the formulation of the master plan, the economical feasibility is one of the most prioritized factors, however, other evaluation factors such as technical, financial and social, environmental factors as well as opinions of Venezuelan sides shall be considered comprehensively.

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

(1) Property to be protected

According to the risk map prepared preliminary in the section 4.2, the number of house / building to be protected is as shown in Table 4.2.1.1.

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

(2) Conceivable Measure

One of the features in the sediment study area is that most areas of the potential steep slope failure and landslide are occupied by houses. Those houses should become subject for relocation because of the slope protection works. Also it is necessary to conduct some slope protection works on the slope itself in order to protect the property below and above the slope. In this sense the conceivable measure is composed of the relocation of the houses occupying the slope and the slope protection works for the slope.

The standard protection works are set as shown in Figure 4.3.3.1.

The above unit cost in Figure 4.3.3.1 including labors, machine and engineering indirect cost is at present derived from some examples in southeast asia country, whose price level is similar to Venezuela. The actual unit cost in Caracas was investigated in the 4th field work in Venezuela.

(3) Cost and Property Value Comparison

In order to study the economic feasibility of the protection works and relocation, a typical steep slope is assumed as shown in Figure 4.3.3.2.

In the above case, the affected area below the slope is approximately 1,500 m^2. If one house in barrio occupies 100 m^2, the total property value is US$150,000(=15 houses * US$10,000 per house). This is much cheaper than the cost for the protection works.

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

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

Table 4.3.3.1 shows the list of risk slope, where some slope protection works could be feasible based on the comparison between the cost of protection works and the protected property values.

4. 3. 4. Structure Measures for Debris Flow

(1) Basic Concept

In the section 4.1.1(3) the potential runoff sediment volume from the southern part of the Avila was estimated. Also the flood water discharge from each mountain stream above its basic point was calculated for various return periods.

In the sediment study area, the area below the basic points is already highly urbanized and almost all the mountain streams have been confined and occupied by houses and buildings. Therefore the assumed sediment runoff volume should be controlled in the area upstream of the basic points, which is in the Avila. In order to protect property below the basic points, this is the only way.

Also the urban area in Caracas has been developed historically on the alluvial fans, which was formed by the runoff sediment from the Avila. The natural stream courses on the alluvial fans are not so stable and vulnerable for bank erosion. Those natural stream courses, especially in the upstream section below the basic points should be improved by channel works. Besides, the water channels in the urban area have small flow capacity, resulting into the spreading inundation. The water channel with small flow capacity should be improved to minimize the inundation damage.

(2) Conceivable Structure Measures

Figure 4.3.4.1 shows the work flow diagram for the selection of structure measures for debris flow from the Avila. In the figure, totally 7 types of sediment control measures are mentioned. The seven (7) types of measures are illustrated in Figure 4.3.4.2.The brief explanation for the figure is as follows,

Possibility of occurrence of debris flow can be recognized for all the mountain streams in the sediment study area. Sediment control structure will be studied for all the mountain streams (47 streams).

Each mountain stream can be divided into two (2) segments at its basic point. The segment upstream of the basic point has steep stream bed slope steeper than around three (3) degree, which belongs to the Avila. The other segment downstream of the basic point has comparatively mild stream bed slope milder than around three (3) degree, which belongs to the urban area in Caracas.

In the Avila there are three (3) structure measures possible.

- Measure(1) for sediment generation control (Hillside works/groundsill or Protection works for landslide)
- Measure(2) to mitigate debris flow energy (Sabo dams)
- Measure(3) to trap debris flow (Sabo dams)

The measures (1) and (2) require the basin-wide layout of structure. They are not appropriate in the Avila in terms of the scale of structure. The measure (3) aims at trapping of debris flow by a series of sabo dam at the downstream reach within the Avila. The measure (3) is recommended for the Avila.

In the urban area of Caracas, there are four (4) structure measures possible.

- Measure (4) to trap sediment (Sediment Trap)
- Measure (5) to guide debris flow (Training Channel)
- Measure (6) to stabilize stream course (Channel Works)
- Measure (7) to make flood flow safely (Water Channel Works)

If the runoff sediment can not be controlled in the Avila, the measures (4) and (5) are required in the urban area. In Caracas, it is not practical to construct such large scale structures in terms of the availability of open space. In this context, the runoff sediment must be controlled upstream within the Avila.

The measure (6) aims at the stabilization of stream courses on the alluvial fan. The streams that the Cota Mil is crossing at its basic point do not need the measure (6) because the Cota Mil could fix the stream course already. The measure (6) should be applied to the fan apex of Catuche, Chacaito, Tocome and Caurimare.

The measure (7) could be applied to all the stream courses in the urban area.

(3) Proposed Level

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

The flow capacity of the existing Guaire river has been evaluated 25 to 50 years return period as shown in Figure 4.3.4.3 based on the Caracas Project[2].

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

(4) Sabo Dam in the Avila

1) Function of Sabo Dam

Generally Sabo Dam has the following functions.

	FUNCTIONS	APPLICABILITY in the Avila
1	Avoiding of vertical (longitudinal) erosion to give a fixed elevation by dams	No
2	Avoiding of bank erosion to guide the stream flow toward center by dams	No
3	Avoiding of slope failure to raise the stream bed by dams	No
4	Storage and keeping of runoff sediment	Yes
5	Control of sediment runoff to deposit temporally during floods	No

Among the above five (5) functions, the function no.4 can be applicable in the Avila. Because the Avila is in comparatively stable and low frequency in terms of sediment runoff process, only debris flow generated by extraordinary heavy rainfall is subject to the function of Sabo Dam. The functions No.1, 2, 3 and 5 are applicable for the unstable mountain streams with high frequency of small floods.

2) Preliminary Design

(1) General

Preliminary design of Sabo dam was prepared from the viewpoint of availability of construction materials near the dam site, economy, construction efficiency and construction experiences in Venezuela.

The structure type of sabo dam was studied to take into consideration the construction method, access road and maintenance work, etc.

The location and the height of proposed Sabo Dam was decided based on the objective of the dam and the site conditions. Since the stream bed of the Avila as the base of the Dam is composed of sand and gravel materials, the Dam height was set to be shorter than 15 m.

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[2] UCV-IMF, Impacto y Prevencion de Inundaciones y Aludes Torrenciales en El Valle de Caracas, Informe Tecnico No.1, 2003

The function of the proposed Sabo Dam for the Avila is to storage and keeping of runoff sediment as discussed in section 2.4.1. Generally the methodology to determine the location and the height of Sabo Dam is different among the objectives. Here the methodology only for the Sabo Dam to storage and keep the runoff sediment was explained below.

It is more advantageous that the more sediment trapping capacity and the surface area of the trap for unit concrete volume of a Dam. Therefore it is desirable to locate a Dam at narrow section with V-valley and wider section upstream as well as mild stream bed slope.

(2) Preliminary Design

For the purpose of the estimation of number of Sabo Dam and work quantity in the Avila, the concrete Sabo Dam, the most general structure type, was designed. The basic structure of Sabo Dam is shown in Figure 4.3.4.4.

The basic design principles in the Study are as follows,

- The dam height is lower than 15 m.
- The effective height of the dam is 2 m shorter than the dam height.
- The downstream side slope of a dam is generally 1: 0.2, while the upstream side slope was decided by the stability calculation.

The dimension of the designed Sabo Dam is summarized in Table 4.3.4.1(1/2 and 2/2).

(3) Layout of Sabo Dam

For the target sediment volume decided in the section 4.1.1, the necessary Sabo Dam was designed. The trapped sediment volume by each Sabo Dam was calculated as shown in Figure 4.3.4.5. The size and number of Sabo Dam was designed in a manner that the trapped sediment volume is larger than the target sediment volume.

Q – E–(C+D+B)=0

Q: Target Sediment Volume

E: Design Allowable Sediment Transport(=0)

C: Design Trapped Volume

D: Design Deposit Volume

B: Design Reduction Volume for Debris flow generation (=0)

Design Allowable Sediment Transport(E) is the sediment volume which can be transported not to cause damage at the basic point downstream. In Caracas, since the basic point downstream is urban area, the E is set zero.

Design Trapped Volume (C) is the sediment volume which can be allowed to deposit at Sabo Dam when a debris flow occurs. In Caracas, this volume was considered. The trapped volume capacity can be recovered naturally after small-middle scale floods after the debris flow. However, in the case of small catchment area and small flood discharge, or in the case that the Dam slit is closed by large boulders, the recovery of the trapped capacity can not be expected. In those cased, the excavation is required immediately after the debris flow.

Design Deposit Volume (D) is the sediment volume, which can be deposited in the sediment trap area when debris flow occurs. In Caracas, such sediment trap area can not be proposed because the basic point downstream is highly urbanized, therefore D is set zero.

Design Reduction Volume for Debris flow generation(B) is the sediment volume, which can be reduced by slope protection works or groundsill in the segment of debris flow generation and transport. In Caracas, since the Sabo Dams are proposed in the lower reach of each catchment, B is set to zero.

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

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

Table 4.3.4.1 shows the proposed Sabo Dam features in the Avila and Figure 4.3.4.6 shows the location of each Sabo Dam.

There is an index called “ratio of trapped to runoff sediment” which can indicate the effectiveness of Sabo Dam. The ratio is calculated by the following formula. When all the Sabo Dams are constructed in a catchment, the ratio would be 100 %.

ratio of trapped to runoff sediment (%)＝Summation（Design Trapped Volume）/（Target SedimentVolume）*100

Table 4.3.4.2 shows the proposed ratio of trapped to runoff sediment for each principal mountain stream.

(4) Cost Estimate

The project cost for the Sabo Dam works was estimated based on the concrete volume basis. Table 4.3.4.3 is an actual cost for a dam constructed in Vargas in 2000. The cost is expressed by Bs. in 2000. In this case, the concrete volume for the main dam is 2,095 m^3. The partial cost only for the sabo dam works is 600 million Bs. in 2000 including the overhead cost. The project cost per 1 m^3 concrete is 286,400 Bs. in 2000. For the master plan study, 300,000 Bs. per 1 m^3 Sabo Dam concrete will be used as year 2000 price level.

The cost of proposed Sabo dam was shown in Table 4.3.4.1.

(5) Channel Works and Water Channel Works

1) Channel Works

Channel Works (refer to Figure 4.3.4.7) was proposed to stabilize the stream course on the alluvial fans for the section downstream of the basic point. The stream, whose the basic point is not crossed by the Cota Mil or is going through the bridge opening of the Cota Mil, should have the channel works downstream of its basic point. Among the 47 mountain streams, the Catuche, Chacaito, Tocome streams need the channel works. The streams west of the Catuche do not need the channel works because their fan apex is forming the clear straight V-valley.

The proposed cross section and detailed dimension are shown in Figure 4.3.4.8 and Table 4.3.4.4, respectively.

2) Water Channel Works

Water Channel Works was proposed to make the flood flow safely from the downstream end of channel work section until the Guaire River. Most of the existing water channels downstream of the basic point have insufficient flow capacity against the scenario flood discharge. The Central University of Venezuela has been investigating the flow capacity of the existing channel in Caracas under the Caracas Project funded by the Venezuelan Government[3]. Figure 4.3.4.9 is the flow capacity of the existing channel in the Catuche. For the section whose flow capacity is smaller than the design discharge, the appropriate water channel works should be proposed.

[3] UCV-IMF,Borrador Informe FONACIT

3) Cost Estimate

The project cost for the Channel Works and Water Channel Works was estimated based on the concrete volume basis. The unit price for 1 m^3 concrete (80 kgf / cm^2) is 120,000 Bs. in 2000 according to the Table 4.3.4.3. Considering intangible cost, the unit price is set 240,000 Bs. to estimate the project cost for Channel works and Water Channel Works in Caracas.

The cost of proposed Channel Works was shown in Table 4.3.4.2.

(6) Temporary Yard for Construction

Figure 4.3.4.9 illustrates the procedures to determine the location of temporary yard and temporary route between the yard and the construction site. The minimum requirement of temporary yard and access route are described in the bottom of the figure.

Regarding the temporary yard, the availability of appropriate site should be checked, where the access time is less than one (1) hour. If there is not an appropriate site, a new temporary yard should be constructed. Actually in the sediment study area the open space the Cotiza and the Anauco upstream are the only candidate site for the temporary yard.

Also the road for vehicle as temporary route between the yard and the dam site is available in the Cotiza. In the case of Anauco, other way such as cable way must be constructed.

For other streams, there are no appropriate temporary yards near their dam sites. If new temporary yards and access route are proposed, the construction cost and the environmental impact will be quite higher.

Figure 4.3.4.10 is the proposed temporary works for Sabo dam and channel works.

Table 4.3.4.5 is the work quantity for temporary works.

Table 4.3.4.6 is the proposed construction schedule.

(7) Type of Sabo Dam in the Avila

1) Manner of Sediment Runoff and Countermeasures

The manner of sediment transport can be categorized based on the stream bed slope as shown in Table 4.3.4.7. The type of countermeasures such as construction method and structure type can be decided according to the category.

Figure 4.3.4.12 shows the segment of each mountain stream based on the streambed slope. The segment at the Sabo dam site was shown in Table 4.3.4.1.

2) Layout of Sabo Dam

There are two (2) types of Sabo Dam. They are open type and closed type.

Table 4.3.4.9 explains the sabo dam layout based on the feature of debris flow transport. According to this concept, the type of sabo dam was decided as shown in Table 4.3.4.1.

Figure 4.3.4.13 illustrates typical sabo dam layouts for the Avila as a reference.

3) Type of Dam

Open type is the dam which can allow the water and smaller sediment through the slits considering the continuity of flow between upstream and downstream. The open type can trap and storage the first debris flow after the dam starts its operation. In the case of mountain stream in which quite a few small floods occur frequently, the trapped sediment is easily transported downstream to result into that the dam is emptied before the next debris flow. Consequently the function of the dam is kept for long time. This situation is very common in Japan. However in Caracas, such small floods are not so common that when the second debris flow comes, since the dam is already full, the dam can not be functioning. Therefore, in Caracas the maintenance dredging is required in order to keep the function of open type dam.

Closed type is the conventional dam without deep slit. This type is appropriate to the site whose downstream is urban area whose geological conditions are susceptible to the alteration of the stream bed or channel and bank erosion.

The effectiveness in terms of the controlled sediment volume is quite different between open type and closed type. The open type dam can consider the storage volume and the controlled volume, while the closed type dam can only consider the controlled storage. Therefore open type is more effective in terms of the sediment volume.

Considering the above characteristics, open type sabo dam shall be located from downstream, however, closed type dam shall be located for the stream flowing into the urban area directly without Cota Mil or through bridge.

(8) Open Type Sabo Dam

The open type Sabo dam for the purpose of sediment storage and trapping of debris flow should be located on the stream where debris flow could occur, go downstream and deposit. The open section can be regarded to be blocked after the dam trapped debris flow. If the trapped sediment remains just upstream of the dam the function to storage and trap sediment is lowered, so that the dredging is inevitable.

In terms of the selection of Sabo dam site, the basic principle is same as that of closed type sabo dam. The open type Sabo dam should be avoided to locate just upstream of the property to be protected because the sediment could pass through the open section or the sediment easily flows over the dam due to the remaining sediment upstream.

For the open type dam, the concrete slit type and the steel frame type are conceivable at present. In the case of concrete slit type, sometimes it is difficult to control the sediment during the falling limb of the flood, while it is said that the steel frame type can control even such problems since the frame is dense. Table 4.3.4.10 shows the comparison of structure type of open type Sabo dam. Among the four (4) types in the Table, concrete slit dam and frame type slit dam are more appropriate than the others.

(9) Closed Type Sabo Dam

For the closed type dam, the gravity concrete type, steel frame type and the grouting type are considered as shown in Table 4.3.4.11. As a conclusion, the gravity concrete type is the most appropriate.

(10) Design in selected mountain stream

Figure 4.3.4.13(1/2-2/2) is the typical design of concrete slit sabo dam and steel frame sabo dam, respectively.

4. 3. 5. Non Structure Measures

(1) General

The study on sediment disaster prevention was conducted for structure measures. The subjective sediment disasters in the Study are debris flow disaster and landslide / steep slope failure disaster in the sediment study area. For these disasters, the hazard and risk were studied and identified based on the study on topography, geology, hydrology and meteorology.

The debris flow hazard is caused directly by the sediment runoff associated with heavy rainfall in the Avila Mountain. The sediment from the Avila goes down the alluvial fans of the Caracas Valley, resulting into physical and social damage to people and property in Caracas. The extent and seriousness of the debris flow hazard were identified and shown in the hazard maps.

The hazard by landslide and steep slope failure was also identified as hazard map including the affected area by each risky slope.

The counter measures to mitigate and reduce the hazard / risk by the sediment disasters have a wide variety of types. The general sediment disaster prevention program is shown in Figure 4.3.5.1, which was derived from a Japanese text book edited by Mr. Yasuo Nakano, the former JICA Advisory Committee Chairman for this study. As shown in this figure, there are quite a few items for sediment disaster prevention. There are four (4) phases in disaster cycle. The middle column shows the comprehensive sediment disaster prevention plan in Japan. The mitigation and preparation phases include structure measure such as sabo works and non-structure measures such as the physical system for early warning and evacuation, institutional arrangement for disaster information transfer and relocation, research activities. The emergency response phase includes institutional arrangement for emergency response.

In principal, the sediment disaster prevention should be executed in comprehensive manner. Also in Caracas, the importance of establishment of proper early warning and evacuation system for sediment disaster is indisputable as well as the importance structure measures such as Sabo dam. The establishment of early warning and evacuation could be effective to save people life whereas not effective to reduce substantial damage on property. It is certain that structure measure such as sediment control structure is only measure to protect property from sediment hazard.

(2) Difficulty of System for Early Warning and Evacuation

Early warning and evacuation are a kind of preparedness to be realized by co-working of government and community for the anticipated sediment disaster. This preparedness can be said a fighting with leading time. The leading time varies according to meteorological condition as well as topography of the area (Figure 4.3.5.2).

Caracas is located in sub-tropical low pressure region. As it is written in the Supporting Report S13, there are five (5) meteorological factors which cause heavy rainfall in and around the Caracas Valley. Basically these factors are associated with small spatial scale and short time scale phenomena. Among these factors, the cold front in the Caribbean Sea has so long time scale and large spatial scale that the cumulative rainfall by the meteorological factor can be anticipated, however, threshold rainfall such as short duration rainfall is sometimes caused by local meteorological factors. The weather tendency is difficult to be anticipated. In terms of the precise weather forecast, it can be said that Caracas is comparatively difficult area.

Moreover, the Avila mountain is contiguous to the urban area in the Caracas Valley, so the leading time which means the time from a threshold event such as rainfall to a disaster is very short.

As described in the above, Caracas is comparatively difficult area with respect to the effective implementation of early warning and evacuation from the technical viewpoint. However, it is believed that the significance of the institutional arrangement as a preparedness for early warning and evacuation is indisputable. The study team believes that it is important to start from minimum institutional arrangement as well as necessary hydrological analysis to establish a proper early warning and evacuation system in the future as proposed in this report in order to save peoples life in Caracas.

Basically sediment disasters such as debris flow, steep slope failure are caused by rainfall. Especially the occurrence of debris flow and steep slope failure in hillsides with slopes larger than 30 degrees is quite instant and sudden, so it is significant to forecast the occurrence of heavy rainfall to issue early warning and evacuation order.

Actually the relation between the rainfall amount and the occurrence of debris flow or steep slope failure is quite complicated including many factors. Since it is still very difficult to forecast occurrence of debris flow and steep slope failure, it is important to focus on the required conditions in terms of antecedent rainfall and trigger rainfall, and the facts of the occurrence.

(3) Components of Study on Early Warning and Evacuation

In this study, the following study components were selected,

Institutional Arrangement

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

Critical Rainfall

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

Community Activity

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

(4) Definition

In Venezuela, meteorological warning has been used as national, global and regional warning. At present, the web page of MARN issues a daily meteorological bulletin, forecast, which sometimes contains warning ("alerta" in Spanish) for significant weather conditions. Indeed this warning is applied for region such as the entire of Caracas and Central Coastal area in Vargas.

In this report, when a word "warning" is used, it means local warning which should cover only the Caracas valley or more detailed area such as a western part of the Avila.

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

In terms of the rainfall forecast, the project called VENEHMET has been implemented by the lead of MARN to start the partial operation in 2005. VENEHMET has radar system over the Metropolitan District of Caracas which can be used for the rainfall forecast. The VENEHMET project will finish in 2005 and an institution called INAMEH will be created to operate and maintenance the installed equipment by the project. The provisional law of INAMEH has been discussed in MARN and the actual implementation program is not clear. In the proposal of this study, some duplicated projects were proposed with the responsibility of the INAMEH.

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

In the 4th and 5th field study period in Venezuela, the Study Team held periodical discussion meetings with C/P and the related organizations with early warning system. Based on the findings in the discussion, evaluation of present system, limitation and recommendation for early warning and evacuation were summarized in Table 4.3.5.1.

Based on the above evaluation on the existing situation on early warning system in Caracas, the study team proposed a draft agreement on early warning and evacuation system among the related organizations. The entire text of the agreement is shown in Table 4.3.5.2.

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

The main features in the draft agreement are as follows,

- to designate MARN as a primary function to monitor, analyze and distribute hydrological information and to create the Caracas Regional Office (CRO) in MARN –INAMEH.
- to designate ADMC (Operation Control Center) as a primary function to receive and manipulate the hydrological information from MARN and distribute it to the municipalities. ADMC is in charge of issuing of local warning in accordance with the MARN and issuing of recommendation of evacuation.
- to designate municipalities as a local body closest to communities to transfer the information from ADMC to communities and to support the activities of communities.
- It should be certain that the Operation Control Center (OCC) shall be activated when the necessity of issuing of local warning is anticipated. The schematic image of the timing for the activation and issuing of local warning is illustrated in Figure 4.3.5.3. The practical timing of the activation of Operation Control Center and the issuing of local warning is discussed in next section.
- The physical system for the above early warning system can be illustrated as shown in Figure 4.3.5.4. In this system, MARN shall be primary organization of hydro-meteorology information system. MARN shall assemble all information on hydro-meteorology collected by other institutions such as UCV, FAV and ARMADA, etc.
- Based on the collected and observed hydro-meteorological data, MARN shall analyze those data and send them to ADMC to decide if the warning and evacuation order are issued to the Caracas.
- MARN shall supply appropriate information regarding the order as well as some observed information via Computer network and facsimile and telephone on warning and evacuation to the Metropolitan District of Caracas.
- The Operation Control Center is activated by AMDC in Emergency Command Center based on the information from MARN. The activation means that the operation level 1 as shown in Figure 4.3.5.3. It is proposed that when regional warning is issued for Caracas or Central

Coastal Area the OCC should be activated. At this moment, the OCC will receive necessary resources from Municipalities in order to make the entire operation smoothly. The official commands are issued by the top of ADMC and municipalities, and are supported by Civil Protections and fire fighters on site.

- While the center is receiving the hydro-meteorological information from MARN, the center shall provide some information with communities without regards to warning or evacuation.
- The center shall decide if the warning or evacuation order is issued or not based on the hydrological information from MARN to refer to the Warning Level (WL), Evacuation Level (EL) and Critical Level (CL). At the same time the center should decide which municipality and community should be given the recommendation because the provided information from MARN generally has aerial distribution.
- Also it is widely said that local people should protect their own communities by themselves. It is recommended that local people should organize their own self disaster prevention group to work with the administrative level both at normal time and emergency.
- Within each community, the water level of staff gauge should be observed in normal time as well as after the warning is issued. The reading water level shall be reported to the community leaders as well as to the operation control center to consider for the decision of issue of evacuation.
- In order to conduct the above operation between institutions and communities, in normal time disaster education is necessary in school class and community meetings. Also hazard and risk map for each community should be familiarized to let the people know their own risk. It is recommended to put the hazard and risk maps in stores and shops such as kiosk and local bakery.
- In the case of the post-disaster phase, the required institutional arrangement for emergency response is a little different from the mitigation and preparation phase. In this phase they need additional resource input for rescue and emergency service as well as prevention of secondary disaster.

(6) Study on Critical Rainfall

1) General

Early warning system can play a significant role in debris flow hazard mitigation by alerting the public when rainfall conditions reach critical levels for hazardous debris flow activity. Such warning systems depend on comparing forecasts and real-time rainfall observations to threshold values required to initiate debris flow. Empirically derived from historical data on rainfall and debris flow occurrence, thresholds are combined values of rainfall intensity and duration that predict debris flow initiation at susceptible sites within a specified area.

Rainfall/debris flow thresholds depend on the thickness, character, and mechanical properties of the hillslope materials, which depend, in turn, on the geology, topography, vegetation, and climate of the area.

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

2) Methodology

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

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

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

The Guideline Method called Method A was presented in the “Guidelines (tentative) for setting of rainfalls for warning issuance and evacuation instruction against debris flow disasters” which was prepared by the former Ministry of Construction in 1984. This method is intended to forecast the occurrence of a debris flow using rainfall indexes which are obtained by combining a rainfall intensity and a total rainfall. This type of index was derived because it is known from the actual state of debris flow disasters that a debris flow tends to occur even when the total rainfall is small if the rainfall intensity is large, and that it tends to occur even when the rainfall intensity is small if the total rainfall is large. This method was originally developed for debris flows, but it is also applicable to steep slope failures because the occurrence process of a debris flow is similar to that of a slope failure.

Figure 4.3.5.6 is a schematic image of the critical line. The rainfall index is expressed by a combination of the rainfall intensity and the total rainfall (cumulative rainfall). As shown in the figure, the rainfall intensity is shown in the ordinate (Y-axis) and the total rainfall in the abscissa (X-axis). Debris flow causing rainfall and non-causing rainfall are plotted in the figure by the different symbols. Then, those two rainfall groups are separated with a linear line or a curved line descending to the right. This boundary line is called the Critical Line (CL) which distinguishes the occurrence and non-occurrence of a debris flow. The lower left side of this line is the safe zone where a debris flow may not be caused. The upper right side of this line is the unsafe zone where a debris flow may be caused. The definitions of plotted rainfall values are explained in Table 4.3.5.3

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

Before setting the WL and the EL, it is necessary to determine the timing to give a warning issuance or an evacuation recommendation. It means that how many hours before the forecasted occurrence time a warning issuance or an evacuation recommendation should be given, so that people as well as the related organizations can take necessary actions for safety. After that the WL and EL are set in consideration of an estimated rainfall during the leading time. Table 4.3.5.4 shows the conditions used in the “Method A” in Japan. In this study the conditions in Japan was used because of few historical debris flow events in Caracas. However, the timing of warning issuance and evacuation recommendation should be determined based on the conditions in Caracas.

3) Proposed Warning Level and Evacuation Level for Caracas

Figure 4.3.5.10 shows the proposed Warning Level and Evacuation Level for Caracas. For the detail, it was described in Supporting Report S18.

(7) Dissemination of Hazard / Risk Maps for Land use Regulation and Relocation.

The hazard and risk maps for steep slope failure, landslide and debris flow in this Study have cleared dangerous areas in Caracas. Needless to say, those dangerous areas are quite local and anticipated to greater extents according to the historical facts as well as the maps. It is clear that the less property occupies those areas, the less disaster damage is generated in the future.

Relocation is recommended on condition that the people deeply recognize their own risk in the dangerous area.

As to relocation, a process suggested in the Japanese Sediment Disaster Prevention Law is presented in Figure 4.3.5.11, showing the responsibility of national level, prefecture level, local level and citizen level. The prefecture level and local level are corresponding to the ADMC and municipalities level, respectively. The basic study in the figure is corresponding to the sediment disaster study in this JICA study to prepare the hazard / risk map. Prior to recommendation of relocation to the people, prefecture governments conduct the basic study and prepare hazard map in order to specify Yellow and Red Zones. Based on the zoning, prefecture governments recommend the relocation or necessary mitigation measures to the owner of the house / building. If the owner accepts the recommendation, the owner can request financial program to the prefecture government. The financial program by prefecture level is supported by national level.

Hazard / risk map for sediment disaster shall include information on evacuation. According to the social survey in this study, communities and municipalities feel necessity to share the information on available evacuation route and refuge. According as the process in the Figure 4.3.5.11, municipalities should assemble the information on evacuation route and refuge based on the hazard / risk map in their area, and specify practical data in the map, working with communities.

(8) Others

[Inspection of Potential Steep Slope Failure and Landslide] In this JICA Study, the hazard and risk map for steep slope failure and landslide within the sediment study area. For the remaining hazardous area within the three (3) municipalities, the slope classification map has been prepared as the results of screening. In order to complete the hazard and risk map for steep slope failure and landslide, the site inspection works should be done for each interpreted slope.

[Academic research collaboration on sediment disaster] should be promoted in order to enhance further development of technology in Venezuela. Central University of Venezuela has been working with Universities in Japan in the field of sediment disaster on the fund of Japanese Ministry of Science and Education. They are exchanging research information on sediment flow simulation and physical model tests, etc. This kind of collaboration is quite beneficial for both sides for their application to the disaster prevention planning. The desired specific research items to be conducted in the future shall be discussed in the 5th field work in Venezuela to take into consideration in the recommendation of this study.

4. 3. 6. Operation and Maintenance

(1) Sediment Control Works

The maintenance dredging for the proposed Sabo Dam, channel works and water channel works should be proposed in order to keep the function of those structures. It is proposed to conduct the dredging the dam upstream for the anticipated debris flow and to remove debris and garbage in channel before every rainy season.

(2) Physical System for Early Warning and Evacuation

The proposed physical system is composed of several sectors such as VENEMET of MARN, UCV, MDC and Municipalities, communities, etc. Each sector will need operation and maintenance plan to keep its individual function for allocation of personnel, replacement and repair of equipment, human resource training.

4. 3. 7. Implementation Schedule

Figure 4.3.6.1 shows the proposed implementation schedule of the sediment related projects in this study.

4. 4 Installation of Hydro-Meteorological Equipments

4. 4. 1. General

To prepare the future establishment of early warning system for the Metropolitan District of Caracas, installation of hydro-meteorological equipments is quite significant. In the Study, one (1) self-recording rainfall gauge and twenty (20) water level staff gauges were installed in the study area to know the hydrological characteristics of the study area, as well as to enhance the early warning and evacuation system.

4. 4. 2. Installation of Rainfall Gauge

(1) Site Selection

The candidate sites are selected from the following viewpoints.

- Considering the existing rain gauge stations, the site should keep distance from any existing rainfall stations and clarify the regional distribution of rainfall in El Avila.
- The site should be within a catchment of high potential for debris flow
- The site desired to contribute to the past rainfall data around.
- The site should be located with easy access for maintenance.

As to the potential of debris flow occurring, almost all the mountain streams in El Avila have not significant difference.

The existing stations around study area are shown in Table 4.4.2.1.

There are four (4) stations along El Avila Mountain at present such as Los Venados in the Anauco Stream, Hotel Humbolt at the top of El Avila, Chacaito in the Chacaito Stream and Caurimare in the Caurimare Stream. Among them the Hotel Humbolt Station has telemeter system to transfer the data to UCV.

From the viewpoint of data continuity, it is desirable to restart the observation from the stations San Jose de Avila, Teleferico and Los Chorros, which had been operated for many years until the 1980’s.

As can be seen, the upstream of the streams Catuche / Caroata and Tocome and Caurimare have no existing stations.

Considering the above situation, the five (5) sites shown below can be proposed.

Next, from the viewpoint of security and accessibility, five candidate sites shown below are selected.

Campo Alegre (Catuche),San Jose Avila, Teleferico, Los Chorros (Tocome), Topo Santa Rosa (Caurimare)

The characteristics of each proposed site are described in Table 4.4.2.2.

(2) Equipment

The rainfall gauge to be installed is a self-recording type with tipping bucket. A data logger and battery will be equipped.

(3) Operation and Maintenance

The operation and maintenance was conducted by the Study Team in cooperation with the Counterpart during the field work in Venezuela.

4. 4. 3. Installation of Water Level Staff Gauge

(1) Site Selection

The sites for water level staff gauges were selected, with the help of Counterpart, according to the points listed below

・ Visibility by the local people

・ Upstream as much as possible

・ Easy access for maintenance

The selected sites are listed in Table 4.4.3.1.

(2) Equipment

The staff gauge is made of acrylic and the dimension of 1 piece is 1 m * 8 cm * 8 mm. The maximum length is 5 meter and the average length is 3 m. The staff gauges, to be placed on concrete wall on the site, are attached in a H-type steel bar for protection against the flow.

The readings of the staff gauge are painted in red and white alternately in 10 cm space intervals to make the observation easy.

(3) Operation and Maintenance

The operation and maintenance shall be conducted by the Counterpart and related communities.

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Table 4.1.1.1 General Climate in and Around Caracas Valley

Station	Item	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Total
Maiquetia Airport	Temp. Media	24.5	24.5	24.9	25.7	26.6	26.7	26.4	27.1	27.5	27.3	26.6	25.4	26.1	
0503	Temp. Max	28.4	28.3	28.4	29.1	30.1	30.2	30.1	30.9	31.5	31.2	30.5	29.3	29.8	
	Temp. Min.	21.7	21.7	22.0	22.6	23.9	23.9	23.6	24.2	24.4	24.3	23.7	22.4	23.2	
	Evaporation	133.0	134.5	172.0	152.4	156.9	154.7	157.7	181.0	175.9	160.4	146.1	135.9	155.0	1860.5
	Rainfall	40.1	26.5	20.2	24.1	35.8	53.4	54.8	51.2	54.9	50.7	58.8	59.9	44.2	530.4
Los Caracas	Temp. Media	23.7	24.3	24.7	25.5	26.7	26.8	25.6	25.8	26.1	26.2	25.6	24.2	25.4	
5011	Temp. Max	27.7	28.3	28.1	27.4	30.3	30.6	30.1	30.5	31.3	30.9	29.8	28.4	29.5	
	Temp. Min.	16.8	17.5	17.8	19.4	20.5	20.6	20.0	20.3	20.1	19.7	19.1	17.4	19.1	
	Evaporation	135.0	134.7	165.9	162.2	174.8	172.2	177.7	172.6	169.9	152.5	133.0	128.7	156.6	1879.2
	Rainfall	104.0	68.0	55.1	55.6	46.4	88.1	106.3	80.1	57.2	80.3	158.1	192.0	90.9	1091.2
Cagigal	Temp. Media	19.2	19.6	20.4	21.3	21.9	21.6	21.2	21.5	21.7	21.4	20.7	19.8	20.9	
0531	Temp. Max	25.4	26.4	27.6	28.3	28.1	27.4	27.1	27.5	27.9	27.4	26.4	25.6	27.1	
	Temp. Min.	15.1	15.3	15.9	17.2	18.2	18.1	17.6	17.6	17.7	17.6	16.9	16.0	16.9	
	Evaporation	117.5	123.5	162.9	158.8	143.8	139.2	141.0	137.1	132.9	122.1	112.6	114.8	133.9	1606.2
	Rainfall	19.4	11.7	12.3	35.2	81.1	106.7	105.8	115.3	106.4	115.2	84.9	40.8	69.6	834.8
La Mariposa	Temp. Media	19.1	20.0	20.7	21.6	22.1	21.4	21.0	21.4	21.4	21.4	20.9	19.7	20.9	
0563	Temp. Max	24.8	26.7	27.7	28.0	27.2	26.2	25.7	26.3	27.0	27.8	26.4	25.2	26.6	
	Temp. Min.	12.7	14.3	13.2	15.6	15.5	16.6	15.2	14.9	15.8	14.6	14.1	13.1	14.6	
	Evaporation	115.7	127.1	157.7	144.3	140.9	119.3	127.6	134.6	131.6	127.1	107.7	105.9	128.3	1539.5
	Rainfall	20.1	12.5	13.6	42.2	93.8	131.2	118.6	124.4	97.7	112.3	82.4	42.4	74.3	891.2

Source: MARN, Aspectos Sinopticos y Climatologicos del Desastre Natural Ocurrido en la Region Norte Costera de Venezuela en diciembre de 1999, Table N-3 and N-66

Table 4.1.1.2 Maximum Daily Rainfall

	Maiquetía*				Cagigal				San José Avila				Hotel Humboldt			
	(1948-2002)				(1891-1987)				(1967-1983)				(1959-1974)			
	Y	M	D	(mm/day)	Y	M	D	(mm/day)	Y	M	D	(mm/day)	Y	M	D	(mm/day)
1	1999	12	16	410.4	1892	10	7	98.0	1981	7	6	86.9	1970	3	1	97.0
2	1951	2	16	193.0	1972	3	28	93.9	1981	4	23	76.5	1960	8	24	91.7
3	1949	12	26	150.8	1943	9	1	86.3	1976	10	11	74.7	1969	11	16	85.7
4	1970	3	3	142.3	1920	9	4	83.2	1974	9	1	69.0	1971	8	26	73.5
5	1978	6	17	132.5	1980	9	18	83.1	1980	9	19	66.5	1974	5	24	73.0

	Teleférico				La Carlota				Los Chorros				Caurimare			
	(1968-1980)				(1964-2003)				(1967-1983)				(1949-2003)			
	Y	M	D	(mm/day)	Y	M	D	(mm/day)	Y	M	D	(mm/day)	Y	M	D	(mm/day)
1	1971	4	28	141.6	1981	2	22	96.7	1981	9	10	93.0	1988	8	2	112.6
2	1975	9	23	126.7	1993	8	7	94.7	1975	10	14	90.3	1976	10	10	92.2
3	1976	10	11	103.4	1968	6	7	79.3	1971	4	28	85.9	1953	5	20	87.2
4	1979	9	4	92.6	1987	5	18	78.9	1980	9	3	85.4	1993	8	7	87.2
5	1980	9	19	79.1	1981	4	20	74.8	1981	2	22	81.1	1985	12	4	84.4

*Maiquetía(MARN)1948-1960, Maiquetía(FAV)1961-2002

Table 4.1.1.3 Features of Principal Streams in the Avila

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

Table 4.1.1.4 Historical Event of Debris/Sediment Flow Damage in Caracas

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

Source: PREVENE Informe Final pp.128

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

Table 4.1.1.5 Probable Rainfall at 5 Representative Stations

Station : Caurimare

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

Station : Los Chorros

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

Station : Teleferico

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

Station : San Jose de Avila

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

Station : Maiquetía 0502

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

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

Table 4.1.1.6 Hydrological Characteristics of the Mountain Streams

Alluvial Fan Number	Alluvial Fan Name	Alluvial Fan Area(km2)	No. of Catchment	20	IMF	Catchment name	Catchment Area(km2)		Length of Principal Stream(km)	Slope(m/m)	Rainfall Stations	Rainfall (mm) for 100 years	Probable Peak Discharge (m3/s)			
													25 years	50 years	100 years	500 years
69	Caroata	12.45	-	*		Agua Salad					San Jose Avila, Teleferico	155				
			47	*		Agua Salud	0.48		1.20	0.37	San Jose Avila, Teleferico	155	10.0	12.2	14.7	20.5
			46				0.08		0.37	0.60	San Jose Avila, Teleferico	155	1.9	2.3	2.7	3.8
			45	*		St. Isabel	0.09	0.65	0.36	0.56	San Jose Avila, Teleferico	155	2.1	2.5	3.0	4.2
67	Catuche	2.21	44	*	*	Catuche	4.50		4.09	0.22	San Jose Avila, Maiquetia	212	34.0	47.0	59.0	88.0
			43				0.27	4.77	0.79	0.32	San Jose Avila, Teleferico	155	7.5	8.9	10.4	14.0
66	Anauco	3.00	42	*		Cotiza	3.80		4.17	0.21	San Jose Avila, Maiquetia	212	33.0	45.0	56.0	83.0
			41	*		Anauco	3.69		3.90	0.24	San Jose Avila, Maiquetia	212	30.0	40.0	50.0	74.0
			40				0.19		0.79	0.49	San Jose Avila, Teleferico	155	4.4	5.3	6.4	8.8
			39			Beatas	0.43		1.47	0.37	San Jose Avila, Teleferico	155	7.0	9.0	10.0	15.0
			38				0.19		0.73	0.45	San Jose Avila, Teleferico	155	4.4	5.4	6.4	8.9
			37	*		Gamboa	3.07		4.25	0.33	San Jose Avila, Teleferico	155	31.8	40.9	52.8	83.3
			36				0.27	11.64	0.69	0.30	San Jose Avila, Teleferico	155	6.1	7.4	8.9	12.3
63	Canoas	1.23	35	*		Canoas(Sarria)	0.57		1.58	0.39	Teleferico	189	20.0	24.0	28.0	39.0
			34				0.09	0.66	0.28	0.25	Teleferico	189	3.0	3.6	4.3	5.7
62	Mariperez	0.60	33	*	*	Mariperez	0.70		1.69	0.37	Teleferico	189	23.0	28.0	34.0	47.0
			32				0.06	0.75	0.30	0.50	Teleferico	189	1.8	2.3	2.7	3.5
58	Chacaito	2.86	31				0.24		0.73	0.40	Teleferico	189	7.6	9.3	10.9	14.5
			30			Cuno	0.60		1.90	0.42	Teleferico, Los Chorros	204	15.6	19.7	24.5	35.5
			29				0.07		0.40	0.55	Los Chorros	220	2.4	2.8	3.3	4.3
			28	*	*	Chapellin	1.19		2.68	0.28	Teleferico, Los Chorros	204	26.0	32.0	40.0	58.0
			27				0.25		0.97	0.35	Los Chorros	220	7.1	8.7	10.3	13.9
			26				0.16		0.40	0.52	Los Chorros	220	4.6	5.7	6.7	9.0
			25	*	*	Chacaito	6.33	8.84	5.55	0.26	Teleferico, Los Chorros	204	70.0	92.0	117.0	180.0
56	Seca	2.07	24				0.21		0.56	0.52	Los Chorros	220	6.1	7.4	8.8	11.8
			23			Seca	0.78		1.49	0.40	Teleferico, Los Chorros	204	17.1	20.7	25.9	38.0
			22	*	*	Quintero	1.97	2.96	3.80	0.40	Teleferico, Los Chorros	204	24.1	31.5	41.2	64.8
54	Sebucan	2.82	21				0.27		0.97	0.50	Teleferico, Los Chorros	204	7.9	9.6	11.5	15.4
			20				0.11		0.47	0.45	Los Chorros	220	3.3	4.0	4.8	6.4
			19	*	*	Pajarito	1.37		3.03	0.53	Teleferico, Los Chorros	204	27.0	33.0	42.0	59.0
			18				0.17		0.54	0.44	Los Chorros	220	4.9	6.0	7.1	9.5
			17	*	*	Sebucan	1.57	3.49	2.66	0.57	Teleferico, Los Chorros	204	32.0	41.0	53.0	78.0
52	Agua de maiz	2.32	16		*	Agua de maiz	0.38	0.38	0.70	0.42	Teleferico, Los Chorros	204	8.5	10.0	12.0	16.0
50	Tocome	4.14	15	*		Tenerias	1.40		2.40	0.47	Teleferico, Los Chorros	204	31.0	37.0	47.0	66.0
			14	*		Tocome	9.45		6.60	0.24	Los Chorros	220	105.0	139.0	182.0	284.0
			13				0.33		0.70	0.41	Los Chorros	220	9.6	11.7	13.9	18.7
			12	*		La Julia	2.10		3.18	0.37	Los Chorros	220	49.0	60.0	74.0	103.0
			11			Gamburi	0.25	13.53	1.16	0.29	Los Chorros	220	7.5	9.0	10.6	13.9
48	Caurimare	4.75	10				0.06		0.42	0.41	Caurimare, Los Chorros	182	1.7	2.0	2.4	3.4
			9				0.12		0.45	0.42	Caurimare, Los Chorros	182	3.6	4.3	5.1	7.3
			8	*	*	Pasaquire	1.14		2.21	0.47	Caurimare, Los Chorros	182	22.0	28.0	34.0	48.0
			7				0.36		1.12	0.38	Caurimare, Los Chorros	182	10.1	12.2	14.4	20.5
			6				0.09		0.53	0.19	Caurimare	143	2.2	2.7	3.2	5.0
			5	*	*	Galindo	3.85		4.51	0.34	Caurimare	143	50.0	58.0	68.0	111.0
			4	*	*	Caurimare	6.35		5.40	0.29	Caurimare	143	48.0	58.0	75.0	118.0
			3				0.08		0.39	0.12	Caurimare	143	2.8	3.3	3.7	5.5
			2				0.99		2.12	0.34	Caurimare	143	17.0	20.8	24.8	35.8
			1				0.16	13.18	0.42	0.10	Caurimare	143	6.0	7.0	8.0	11.9
	Total	38.45					60.84	60.84								

Source: UCV-IMF, Impacto y prevencion de inundaciones y aludes torrenciales en el valle de caracas, informe tecnico no.1, 2003

Table 4.1.1.7 Crossing Condition of the Mountain Streams at Cota Mil

No. of Catchment	Catchment name	Catchment Area	Storage Volume at Cota Mil upstream	Crossing Condition at Cota Mil				
		(km2)	(m3)	Bridge	Large Culvert	Small Culvert	No Info.	Remark
–	Agua Salad							
47	Agua Salud	0.48						
46		0.08						
45	St. Isabel	0.09						
44	Catuche	4.50						
43		0.27						
42	Cotiza	3.80	444,852		*			3.5m*2.3m 2 Box
41	Anauco	3.69	116,246		*			5.5m*9m 1 Box
40		0.19	176				*	
39	Beatas	0.43	680				*	
38		0.19	14,941				*	
37	Gamboa	3.07	–	*				Bridge with pier (Open)
36		0.27					*	
35	Canoas(Sarria)	0.57	21,338			*		1300mm 1nos.
34		0.09					*	
33	Mariperez	0.70	72,161				*	
32		0.06					*	
31		0.24	3,270		*			2.0m*2.0m 1 Box
30	Cuno	0.60	9,462		*			2.0m*2.0m 1 Box
29		0.07				*		Dia.1070mm 1 nos.
28	Chapellin	1.19	7,353		*			Dia.2440mm 1 nos.
27		0.25				*		Dia.1520mm 1 nos.
26		0.16				*		Dia.1520mm 1 nos.
25	Chacaito	6.33	–	*				Bridge (Culvert 6m*10m)
24		0.21				*		Dia.1520mm 1 nos.
23	Seca	0.78			*			2.2m*2.2m 1 Box
22	Quintero	1.97			*			
21		0.27			*			2.5m*2.5m*1 Box
20		0.11				*		Dia.1520mm 1 nos.
19	Pajarito	1.37					*	
18		0.17					*	
17	Sebucan	1.57			*			2.0m*2.7m 1 Box
16	Agua de maiz	0.38				*		1500mm 1 nos.
15	Tenerias	1.40	10,835		*			4m*3m 1Box
14	Tocome	9.45	–	*				Bridge with pier (Open)
13		0.33					*	
12	La Julia	2.10				*		1 Box
11	Gamburi	0.25					*	
10		0.06					*	
9		0.12					*	
8	Pasaquire	1.14					*	
7		0.36					*	
6		0.09					*	
5	Galindo	3.85			*			Water Supply Dam H=15m
4	Caurimare	6.35			*			5m*3m 2 Box
3		0.08						
2		0.99						
1		0.16						
TOTAL		60.84		3	12	8	16	

Table 4.1.1.8 Sediment Runoff Volume

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

Table 4.1.1.9 Subjective Mountain Stream for Debris Flow Hazard Mapping

	20 streams by JICA S/W	Name of Alluvial Fan	Venezuelan Study
1	Caroata, Agua Salud, Agua Salada	Caroata	"Project Caracas"
2	Catuche	Catuche	"Mapa de Amenaza"
3	Cotiza, Anauco, Gamboa	Cotiza-Anauco-Gamboa	"PREVENE"
4	Sarria (Canoas)	Canoas	"Project Caracas"
5	Mariperez	Mariperez	"Mapa de Amenaza"
6	Chapellin, Chacaito	Chacaito-Chapellin	"Mapa de Amenaza"
7	Quintero	Quebrada Seca	"Mapa de Amenaza"
8	Pajaritos, Sebucan	Pajaritos-Sebucan	"Mapa de Amenaza"
9	Tenería	Agua de Maíz	"Mapa de Amenaza"
10	Tocome, La Julia	Tócome-La Julia	"PREVENE"
11	Pasaquire, Galindo, Caurimare	Caurimare-Galindo-Pasaquire	"Mapa de Amenaza"

Table 4.1.1.10 Model Structure

	PREVENE	Avila / Caracas Project	JICA Study
Rainfall Runoff Model	Unit Hydrograph	Kinematic wave(MARN-CGR report)	Kinematic wave(MARN-CGR report)
Hydraulic Model	FLO-2D (Tocome, Anauco)	FLO-2D (11 alluvial fans, each alluvial fan has a separated model)	FLO-2D (11 alluvial fans, combined as 2 models)
	25 m grid	30 m grid	100m grid

Table 4.1.1.11 Difference Between the FLO-2D Model by the Avila Project and by the Study Team

	Avila / Caracas Project	Study Team
Inflow Hydrograph	Water Hydrograph (CGR report)+ standard sediment concentration value	Water Hydrograph (CGR report)+ proposed sediment volume
Grid size	30 m	100 m
Channel within grid	considered	considered
Culver, Street		

Table 4.1.1.12 Sediment Runoff Volume for Method-1 and Method-2

No of Catchment		Catchment name		Area		Sediment Runoff Volume	adjustment	Cota Mil upstream pocket capacity	Sediment Runoff Volume for Method-1 and 2			Qp for Method-1
				(km2)		(m3)	(m3)	(m3)	(m3)	(m3/km2)		(m3/s)
1	48		Caurimare	0.161		9,300				58,000	Vec	8.0
2-0	48		Caurimare	0.987	0.107	21,100	2,400			21,000	Ve	24.8
2-1				0.955	0.155		3,400		3,400			
2-2					0.071		1,600		1,600			
2-3					0.622		13,700		13,700			
3	48		Caurimare	0.075		3,800				51,000	Vec	3.7
4	48	Caurimare	Caurimare	6.354		101,400			101,400	16,000	Vec	75.0
5	48	Galindo	Caurimare	3.845		59,000			59,000	15,000	Vec	68.0
6	48		Caurimare	0.087		6,800			6,800	78,000	Ve	3.2
7	48		Caurimare	0.36		16,300			16,300	45,000	Vec	14.4
8	48	Pasaquire	Caurimare	1.143		34,200		13,400	20,800	30,000	Ve	34.0
9	48		Caurimare	0.117		7,000			7,000	60,000	Ve	5.1
10	48		Caurimare	0.055		3,300			3,300	60,000	Ve	2.4
11	50	Gamburi	Tocome	0.247		15,100			15,100	61,000	Vec	10.6
12	50	La Julia	Tocome	2.1		62,900			62,900	30,000	Vec	74.0
13	50		Tocome	0.327	0.142	39,700	17,240		17,240	121,000	Ve	13.9
14	50	Tocome	Tocome	9.448		152,200			152,200	16,000	Vec	182.0
15	50	Tenerias	Tocome	1.403		45,200			45,200	32,000	Ve	47.0
16	52	Agua de maiz	Agua de maiz	0.38	0.142	32,100	12,000		12,000	84,000	Ve	12.0
17	54	Sebucan	Sebucan	1.57		48,700		10,700	38,000	31,000	Vec	53.0
18	54		Sebucan	0.167	0.1	18,300	10,960		10,960	110,000	Ve	7.1
19	54	Pajarito	Sebucan	1.374		44,700			44,700	33,000	Vec	42.0
20	54		Sebucan	0.112		7,800		2,400	5,400	70,000	Ve	4.8
21	54		Sebucan	0.27	0.223	24,900	20,570	4,900	15,670	92,000	Vec	11.5
22	56	Quintero	Seca	1.973		56,200			56,200	28,000	Vec	41.2
23	56	Seca	Seca	0.775		30,800			30,800	40,000	Vec	25.9
24	56		Seca	0.207	0.84	15,100	6,130		6,130	73,000	Ve	8.8
25	58	Chacaito	Chacaito	6.332		112,400			112,400	18,000	Vec	117.0
26	58		Chacaito	0.158		10,100				64,000	Ve	6.7
27	58		Chacaito	0.253	0.18	19,100	13,590		13,590	75,000	Ve	10.3
28	58	Chapellin	Chacaito	1.192		50,000		1,000	49,000	42,000	Ve	40.0
29	58		Chacaito	0.069		4,100				59,000	Ve	3.3
30	58	Cuno	Chacaito	0.598		57,100		3,800	53,300	95,000	Ve	24.5
31	58		Chacaito	0.235	0.136	14,000	8,100		8,100	60,000	Ve	10.9
32	62		Mariperez	0.057		3,400				60,000	Ve	2.7
33	62	Mariperez	Mariperez	0.696		26,600			26,600	38,000	Vec	34.0
34	63		Canoas	0.092	0.034	5,500	2,030		2,030	60,000	Ve	4.3
35	63	Canoas	Canoas	0.569		23,200			23,200	41,000	Vec	28.0
36	66		Anauco	0.266	0.107	17,100	6,880		6,880	64,000	Ve	8.9
37	66	Gamboa	Anauco	3.071		82,300			82,300	27,000	Ve	52.8
38	66		Anauco	0.192		11,400			11,400	59,000	Ve	6.4
39	66	Beatas	Anauco	0.427		15,600			15,600	37,000	Vec	10.0
40	66		Anauco	0.191		11,400			11,400	60,000	Ve	6.4
41	66	Anauco	Anauco	3.69		106,900		68,500	38,400	29,000	Ve	50.0
42	66	Cotiza	Anauco	3.798		144,500		93,000	51,500	38,000	Vec	56.0
43	67		Catuche	0.269		11,300				42,000	Vec	10.4
44	67	Catuche	Catuche	4.499		95,900			95,900	21,000	Vec	59.0
45	69	St.Isabel	Catroata	0.091		5,400			5,400	59,000	Ve	3.0
46	69		Catroata	0.082		4,900			4,900	60,000	Ve	2.7
47	69	Agua Salud	Catroata	0.478		21,700			21,700	45,000	Vec	14.7

Table 4.1.1.13 Example of Calculation Result (Catuche)

Cross Section No.	h: Heigh of Debris Flow (m)	B: Flow Width of Debris Flow (m)	U: Velocity of Debris Flow (m/s)	Fd: Hydraulic Force (kN/m2)	P2: Resistance Force (kN/m2)
1	5.16	34.24	8.04	101.52	4.50
2	4.52	38.92	6.92	69.62	4.50
3	4.71	36.34	6.45	58.85	4.50
4	5.04	32.87	6.38	57.41	4.50
5	4.27	48.40	5.04	33.55	4.50
6	4.22	49.42	5.88	45.62	4.50
7	4.18	50.13	5.74	43.61	4.50
8	4.17	50.31	5.36	37.98	4.50
9	2.18	148.54	4.72	29.48	4.74
10	2.28	145.71	3.99	20.66	4.66
11	2.82	102.61	5.18	34.87	4.50
12	2.44	129.97	4.34	24.48	4.58
13	2.58	118.53	5.16	34.59	4.53
14	2.28	145.71	4.79	29.76	4.66
15	2.48	127.10	5.08	33.54	4.56
16	2.86	100.30	5.95	45.94	4.50
17	2.53	122.46	4.55	26.83	4.54
18	2.28	145.71	4.65	28.12	4.66
19	2.28	145.71	4.65	28.03	4.66
20	2.32	145.71	3.93	19.99	4.64
21	2.36	141.52	4.10	21.77	4.62
22	2.32	145.71	4.64	27.88	4.64
23	2.33	144.35	3.87	19.30	4.63
24	3.34	79.43	4.68	28.26	4.50
25	3.30	80.85	5.13	33.92	4.50
26	3.44	89.45	3.55	15.89	4.50
27	2.69	134.57	4.39	24.25	4.51
28	2.61	141.75	3.46	15.03	4.52
29	2.61	141.75	4.17	21.91	4.52
30	2.78	127.37	5.20	33.95	4.50
31	2.61	141.75	3.87	18.84	4.52
32	2.61	141.75	4.59	26.49	4.52
33	2.61	141.75	5.03	31.84	4.52
34	5.30	43.57	5.16	33.43	4.50
35	3.58	83.89	5.72	41.20	4.50
36	2.81	125.48	5.33	35.78	4.50
37	2.61	141.75	3.87	18.80	4.52
38	3.84	77.86	3.40	14.47	4.50
39	3.23	139.29	2.44	7.33	4.50
40	3.23	139.29	5.24	33.74	4.50
41	4.12	93.14	5.19	33.01	4.50
42	4.34	85.45	5.50	37.10	4.50
43	4.27	87.82	4.89	29.29	4.50
44	3.36	130.88	3.69	16.66	4.50
45	3.62	115.41	3.70	16.79	4.50
46	3.66	113.20	3.20	12.56	4.50
47	3.23	139.29	4.41	23.81	4.50
48	3.23	139.29	2.97	10.83	4.50
49	3.23	139.29	3.16	12.23	4.50
50	3.64	114.59	4.45	24.34	4.50
51	3.23	139.29	3.97	19.36	4.50
52	3.23	139.29	4.30	22.69	4.50
53	3.23	139.29	3.79	17.63	4.50
54	3.23	139.29	3.14	12.10	4.50
55	3.23	139.29	3.98	19.44	4.50
56	3.23	139.29	4.29	22.58	4.50
57	3.23	139.29	5.21	33.28	4.50
58	3.23	139.29	5.43	36.20	4.50
59	3.23	139.29	4.90	29.45	4.50
60	3.23	139.29	4.35	23.24	4.50
61	3.23	139.29	3.25	12.98	4.50
62	3.70	138.10	1.94	4.58	4.50
63	3.70	138.10	3.12	11.85	4.50
64	3.70	138.10	3.73	16.90	4.50
65	3.70	138.10	4.16	21.02	4.50
66	3.70	138.10	4.84	28.53	4.50
67	3.70	138.10	4.37	23.18	4.50
68	3.70	138.10	3.64	16.15	4.50
69	3.70	138.10	3.58	15.60	4.50
70	3.70	138.10	3.13	11.95	4.50
71	3.70	138.10	1.94	4.60	4.50
72	3.70	138.10	2.46	7.34	4.50

Table 4.1.1.14 Property in Yellow and Red Zones (Principal Stream Basis)

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

Note: The count and area of building/house were calculated based on basemap (scale 1:5,000).

Table 4.1.1.15 Property in Yellow and Red Zones (Alluvial Fan Basis)

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

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

Table 4.2.1.1 Affected Number of Houses by Steep Slope Failure and Landslide

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

Table 4.2.2.1 Results of Damage Survey

Unit Damage Price

Non-Urban Area Unit:Bs./1 house

Stream Name	Totally Destroyed			Partially Destroyed			Inundation		
	Sec. A	Sec. B	Sec. C	Sec. A	Sec. B	Sec. C	Sec. A	Sec. B	Sec. C
Catuche	15,500,000	8,000,000	5,000,000	3,000,000			1,000,000		
Anauco	15,500,000	8,000,000	5,000,000	3,000,000			1,000,000		
Chacaito	9,500,000			3,500,000			1,000,000		
Tocome	9,500,000			3,500,000			1,000,000		
Caroata	9,500,000			3,500,000			1,000,000		

Urban Area Unit:Bs./m2

Stream Name	Totally Destroyed			Partially Destroyed			Inundation		
	Residential	Commercial	Public	Residential	Commercial	Public	Residential	Commercial	Public
Catuche	277,000	388,000	388,000	50,000			10,000		
Anauco	530,000	742,000	742,000	50,000			10,000		
Chacaito	547,000	766,000	766,000	50,000			10,000		
Tocome	520,000	728,000	728,000	50,000			10,000		
Caroata	213,000	298,000	298,000	50,000			10,000		

Number of Affected House

Non-Urban Area Unit: nos.

Stream Name	Totally Destroyed			Partially Destroyed			Inundation			Total
	Sec. A	Sec. B	Sec. C	Sec. A	Sec. B	Sec. C	Sec. A	Sec. B	Sec. C	
Catuche	4	214	0	12	154	44	36	481	32	977
Anauco	3	29	289	10	68	74	37	2	481	993

Urban and Non-Urban Area Unit: nos.

Stream	Totally Destroyed	Partially Destroyed	Inundation	Total
Chacaito	3	1	6	10
Tocome	12	2	78	92
Caroata	13	24	0	37

Affected Area in Urban Area Unit: m2

Stream	Totally Destroyed	Partially Destroyed	Inundation	Total
Catuche	675	4,052	27,441	32,168
Anauco	140	23,781	35,497	59,418

Damage Cost

Non-Urban Area Unit: Bs.

Stream Name	Totally Destroyed			Partially Destroyed			Inundation			Total
	Sec. A	Sec. B	Sec. C	Sec. A	Sec. B	Sec. C	Sec. A	Sec. B	Sec. C	
Catuche	62,000,000	1,712,000,000	0	36,000,000	462,000,000	132,000,000	36,000,000	481,000,000	32,000,000	2,953,000,000
Anauco	46,500,000	232,000,000	1,445,000,000	30,000,000	204,000,000	222,000,000	37,000,000	2,000,000	481,000,000	2,699,500,000
Chacaito										
Tocome										
Caroata										

Urban Area Unit: Bs.

Stream	Totally Destroyed			Partially Destroyed			Inundation			Total
Catuche	186,975,000			202,600,000			274,410,000			663,985,000
Anauco	74,200,000			1,189,050,000			354,970,000			1,618,220,000
Chacaito	28,500,000			3,500,000			6,000,000			38,000,000
Tocome	114,000,000			7,000,000			78,000,000			199,000,000
Caroata	123,500,000			84,000,000			0			207,500,000

Grand Total	8,379,205,000

Table 4.3.3.1 List of Risky Slope in Urban Area

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

Table 4.3.4.1 (1/2) Sabo Dam Dimension for 100 years Return Period

No.	Principal Catchment	Catchment name	No. of Structures	Structure Code	Dam Height H (m)	Effective Dam Height (m)	Dam Width (m)	Bottom Width of Overflow section (m)	Slope downstream side 1:n	Slope upstream side 1:n	Concrete Volume (m3)	Water Discharge Q (m3/s)	Overflow Depth h (m)	Original Bed Slope 1:n	Design Bed Slope 1:n
1	2		1	2-1	12.0	10.0	40.0	10.0	0.20	0.45	2,280	24.8	1.6	4.4	5.5
2	4	Caurimare	1	4-1	7.0	5.0	35.0	15.0	0.20	0.40	1,040	72.0	2.6	4.5	8.0
3	4	Caurimare	2	4-2	14.0	12.0	60.0	17.0	0.20	0.55	5,250	72.0	2.7	5.0	10.0
4	4	Caurimare	3	4-3	14.0	12.0	50.0	17.0	0.20	0.55	7,070	72.0	2.7	7.0	14.0
5	4	Caurimare	4	4-4	14.0	12.0	55.0	17.0	0.20	0.55	7,660	72.0	2.7	3.0	6.0
6	4	Caurimare	5	4-5	14.0	12.0	45.0	17.0	0.20	0.55	8,710	72.0	2.7	3.0	6.0
7	4	Caurimare	6	4-6	14.0	12.0	40.0	15.0	0.20	0.55	2,830	72.0	2.6	2.5	5.0
8	5	Galindo	1	5-1	9.0	7.0	55.0	15.0	0.20	0.45	2,600	65.0	2.4	8.2	16.4
9	5	Galindo	2	5-2	14.0	12.0	65.0	15.0	0.20	0.55	5,860	65.0	2.4	6.0	12.0
10	6		1	6-1	6.0	5.0	60.0	10.0	0.20	0.20	2,070	2.2	0.5	5.0	10.0
11	7		1	7-1	10.0	8.0	60.0	10.0	0.20	0.40	3,130	14.4	1.2	6.2	12.4
12	8	Pasaquire	1	8-1	7.0	5.0	35.0	10.0	0.20	0.35	1,060	34.0	2.0	5.0	10.0
13	8	Pasaquire	2	8-2	14.0	12.0	52.0	13.0	0.20	0.50	4,080	34.0	1.7	6.0	12.0
14	9		1	9-1	10.0	8.0	45.0	10.0	0.20	0.35	2,050	5.1	0.6	4.0	8.0
15	10		1	10-1	10.0	8.0	40.0	10.0	0.20	0.30	1,700	2.4	0.4	2.2	4.4
16	11	Camburi	1	11-1	14.0	12.0	45.0	13.0	0.20	0.45	3,120	10.8	0.8	3.3	6.6
17	12	La Julia	1	12-1	12.0	10.0	60.0	15.0	0.20	0.50	4,220	74.0	2.5	7.5	15.0
18	12	La Julia	2	12-2	12.0	10.0	40.0	15.0	0.20	0.50	2,360	74.0	2.5	10.0	20.0
19	13		1	13-1	12.0	10.0	35.0	10.0	0.20	0.45	1,810	10.9	1.1	7.7	15.4
20	14	Tocome	1	14-1	12.0	10.0	50.0	15.0	0.20	0.60	3,650	102.0	4.4	4.0	8.0
21	14	Tocome	2	14-2	14.0	12.0	50.0	15.0	0.20	0.65	4,440	102.0	4.4	6.0	12.0
22	14	Tocome	3	14-3	14.0	12.0	45.0	15.0	0.20	0.65	3,770	102.0	4.4	4.7	9.4
23	14	Tocome	4	14-4	14.0	12.0	40.0	15.0	0.20	0.70	3,200	102.0	4.4	3.5	7.0
24	14	Tocome	5	14-5	14.0	12.0	50.0	15.0	0.20	0.65	4,420	102.0	4.4	12.7	25.4
25	15	Teneria	1	15-1	7.0	5.0	35.0	10.0	0.20	0.35	1,050	47.0	2.4	5.0	10.0
26	15	Teneria	2	15-2	14.0	12.0	50.0	15.0	0.20	0.50	3,830	47.0	1.8	8.0	16.0
27	16	Agua de Maiz	1	16-1	12.0	10.0	60.0	10.0	0.20	0.45	4,080	13.0	1.0	3.1	6.2
28	17	Sebucan	1	17-1	7.0	5.0	40.0	20.0	0.20	0.30	1,150	56.0	1.7	4.0	8.0
29	17	Sebucan	2	17-2	14.0	12.0	50.0	20.0	0.20	0.50	3,810	56.0	1.7	4.7	9.4
30	17	Sebucan	3	17-3	14.0	12.0	50.0	15.0	0.20	0.55	4,080	56.0	2.1	3.9	7.8
31	18		1	18-1	14.0	12.0	40.0	10.0	0.20	0.45	2,570	21	0.7	3.0	6.0
32	19	Pajarito	1	19-1	6.0	5.0	60.0	27.0	0.20	0.30	2,190	42.0	1.2	4.0	8.0
33	19	Pajarito	2	19-2	14.0	12.0	50.0	15.0	0.20	0.50	3,850	42.0	1.8	4.5	9.0
34	19	Pajarito	3	19-3	14.0	12.0	45.0	15.0	0.20	0.50	3,200	42.0	1.8	2.8	5.6
35	20		1	20-1	14.0	12.0	40.0	10.0	0.20	0.45	2,590	4.8	0.6	2.2	4.4
36	21		1	21-1	14.0	12.0	40.0	10.0	0.20	0.45	2,590	11.5	1.0	2.8	5.6
37	21		2	21-2	14.0	12.0	35.0	10.0	0.20	0.45	2,030	11.5	1.0	3.0	6.0
38	22	Quintero	1	22-1	14.0	12.0	55.0	15.0	0.20	0.50	4,420	41.2	1.8	7.5	15.0
39	22	Quintero	2	22-2	12.0	10.0	45.0	10.0	0.20	0.50	2,870	41.2	2.2	4.0	8.0
40	23	Seca	1	23-1	14.0	12.0	50.0	10.0	0.20	0.50	3,860	25.0	1.7	6.5	13.0
41	24		1	24-1	10.0	8.0	40.0	10.0	0.20	0.35	1,750	5.8	0.9	4.0	8.0
42	25	Chacaito	1	25-1	7.0	5.0	35.0	10.0	0.20	0.50	1,230	117.0	4.2	12.0	24.0
43	25	Chacaito	2	25-2	7.0	5.0	30.0	15.0	0.20	0.45	910	117.0	3.4	14.0	28.0
44	25	Chacaito	3	25-3	14.0	12.0	45.0	15.0	0.20	0.60	3,580	117.0	3.4	10.5	21.0
45	25	Chacaito	4	25-4	14.0	12.0	45.0	15.0	0.20	0.60	3,580	117.0	3.4	10.3	20.6
46	27		1	27-1	14.0	12.0	40.0	10.0	0.20	0.45	2,610	10.0	0.9	2.1	4.2
47	27		2	27-2	14.0	12.0	40.0	10.0	0.20	0.45	2,650	10.0	0.9	1.4	2.8
48	28	Chapellin	1	28-1	12.0	10.0	35.0	15.0	0.20	0.45	1,600	40.0	1.7	2.5	5.0
49	28	Chapellin	2	28-2	14.0	12.0	40.0	15.0	0.20	0.50	2,710	40.0	1.7	2.0	4.0
50	28	Chapellin	3	28-3	14.0	12.0	35.0	15.0	0.20	0.50	2,110	40.0	1.7	2.0	4.0
51	28	Chapellin	4	28-4	14.0	12.0	50.0	15.0	0.20	0.50	3,840	40.0	1.7	5.0	10.0
52	29		1	29-1	12.0	10.0	50.0	10.0	0.20	0.40	3,120	7.3	0.5	1.5	3.0
53	30	[illegible]	1	30-1	14.0	12.0	40.0	15.0	0.20	0.50	2,880	21.5	1.3	2.5	5.0
54	30	[illegible]	2	30-2	14.0	12.0	40.0	15.0	0.20	0.50	2,880	21.5	1.3	2.4	4.8
55	30	[illegible]	3	30-3	14.0	12.0	55.0	15.0	0.20	0.50	4,720	21.5	1.3	4.4	8.8
56	30	[illegible]	4	30-4	14.0	12.0	50.0	15.0	0.20	0.50	3,900	21.5	1.3	1.8	3.6
57	31		1	31-1	12.0	10.0	45.0	10.0	0.20	0.45	2,720	10.9	1.0	3.0	6.0
58	33	Mariperez	1	33-1	14.0	12.0	50.0	20.0	0.20	0.50	3,790	54.0	1.3	4.5	9.0
59	34		1	34-1	10.0	8.0	30.0	10.0	0.20	0.35	1,140	4.3	0.6	1.6	2.9
60	35	Canoas	1	35-1	12.0	10.0	35.0	10.0	0.20	0.50	1,900	26.0	1.8	11.0	22.0
61	36		1	36-1	12.0	10.0	40.0	10.0	0.20	0.40	2,190	5.3	0.9	2.8	5.6
62	37	Gamboa	1	37-1	7.0	5.0	40.0	15.0	0.20	0.35	1,250	52.3	2.1	4.0	8.0
63	37	Gamboa	2	37-2	14.0	12.0	45.0	15.0	0.20	0.55	3,400	52.3	2.1	4.5	9.0
64	37	Gamboa	3	37-3	14.0	12.0	35.0	10.0	0.20	0.55	2,230	52.3	2.6	4.5	9.0
65	37	Gamboa	4	37-4	14.0	12.0	35.0	10.0	0.20	0.55	2,230	52.3	2.6	6.3	12.6
66	37	Gamboa	5	37-5	14.0	12.0	35.0	10.0	0.20	0.55	2,240	52.3	2.6	4.0	8.0
67	37	Gamboa	6	37-6	10.0	8.0	40.0	10.0	0.20	0.50	2,010	52.3	2.6	6.7	13.4
68	38		1	38-1	14.0	12.0	40.0	10.0	0.20	0.45	2,570	5.4	0.7	3.0	6.0
69	39	Dantas	1	39-1	12.0	10.0	45.0	10.0	0.20	0.40	2,570	10.0	0.9	5.5	11.0
70	40		1	40-1	14.0	12.0	40.0	10.0	0.20	0.45	2,600	5.4	0.7	2.1	4.2
71	40		2	40-2	12.0	10.0	30.0	10.0	0.20	0.40	1,340	5.4	0.7	2.0	4.0
72	41	Anauco	1	41-1	6.0	4.0	35.0	15.0	0.20	0.25	630	50.0	2.0	9.0	18.0
73	41	Anauco	2	41-2	14.0	12.0	35.0	15.0	0.20	0.50	2,100	50.0	2.0	5.0	10.0
74	41	Anauco	3	41-3	14.0	12.0	45.0	20.0	0.20	0.50	3,290	50.0	1.7	7.5	14.4
75	41	Anauco	4	41-4	14.0	12.0	45.0	20.0	0.20	0.50	3,220	50.0	1.7	8.4	16.8
76	42	Cotiza	1	42-1	6.0	4.0	35.0	10.0	0.20	0.30	900	53.0	2.7	10.0	20.0
77	42	Cotiza	2	42-2	14.0	12.0	40.0	15.0	0.20	0.55	2,800	53.0	2.1	4.0	8.0
78	42	Cotiza	3	42-3	14.0	12.0	45.0	15.0	0.20	0.55	3,890	53.0	2.1	5.6	11.2
79	42	Cotiza	4	42-4	14.0	12.0	55.0	15.0	0.20	0.55	4,980	53.0	2.1	12.2	24.4
80	42	Cotiza	5	42-5	12.0	10.0	60.0	15.0	0.20	0.50	4,220	53.0	2.1	5.0	10.0
81	44	Catuche	1	44-1	6.0	4.0	38.0	15.0	0.20	0.30	860	63.0	2.2	12.0	24.0
82	44	Catuche	2	44-2	14.0	12.0	40.0	15.0	0.20	0.55	2,780	63.0	2.2	10.0	20.0
83	44	Catuche	3	44-3	14.0	12.0	50.0	17.0	0.20	0.50	3,820	63.0	2.0	8.4	16.8
84	45	[illegible]	1	45-1	12.0	10.0	40.0	10.0	0.20	0.40	2,190	5.0	0.4	2.0	4.0
85	46		1	46-1	10.0	8.0	40.0	10.0	0.20	0.30	1,680	2.7	0.4	3.2	6.4
86	47	Agua Salud	1	47-1	14.0	12.0	35.0	10.0	0.20	0.50	2,100	14.7	1.2	4.2	8.4
87	47	Agua Salud	2	47-2	12.0	10.0	35.0	10.0	0.20	0.45	1,830	14.7	1.2	3.6	7.2
Total											240,650				

No.	Sedimentation Top Width B (m)	Sedimentation Bottom Width b (m)	Average Sedimentation Width B (m)	Sedimentation Length l (m)	Sedimentation Length l' (m)	Area of Sediment Storage A1 (m2)	Area of Sediment Storage A1' (m2)	Sediment Storage Volume Vs (m3)	Sediment Storage Volume Vs' (m3)	cost m3 (×10³ DG)	cost (×10³ DG)	Streambed Slope 200m Return Average (degree)	Segment	Dam Type	Structure	remarks
1	30.0	5.0	17.5	85.0	132.0	440	660	7,700	11,550	300	684,000	10.5	T-D	open type	(1) or(2) or(3)	
2	25.0	10.0	17.5	45.0	67.5	113	169	1,898	2,844	300	524,000	11.1	T-D	closed type	(4)	
3	50.0	12.0	31.0	120.0	180.0	720	1,080	22,320	33,480	300	1,574,000	9.8	D	open type	(1) or(2) or(3)	
4	40.0	12.0	26.0	96.0	144.0	576	864	14,976	22,464	300	1,206,000	15.5	G-T	open type	(1) or(2) or(3)	
5	45.0	12.0	28.5	72.0	108.0	432	648	12,312	18,468	300	1,284,000	20.8	G	open type	(1)or(2)	
6	35.0	12.0	23.5	72.0	108.0	432	648	10,152	15,228	300	1,025,000	18.7	G-T	open type	(1)or(2)	
7	30.0	10.0	20.0	60.0	90.0	360	540	7,200	10,800	300	849,000	23.0	G	open type	(1)or(2)	
8	45.0	10.0	27.5	114.8	172.2	402	603	11,050	16,574	300	780,000	5.1	D	open type	(1)or(2)or(3)	
9	55.0	10.0	32.5	144.0	216.0	864	1,296	28,080	42,120	300	1,758,000	11.1	T-D	open type	(1)or(2)or(3)	
10	50.0	5.0	27.5	60.0	90.0	180	270	4,950	7,425	300	621,000	14.9	T-D	open type	(1)or(4)	
11	50.0	5.0	27.5	99.2	148.8	397	595	10,912	16,368	300	939,000	3.5	D	open type	(1)or(2)or(3)	
12	25.0	5.0	15.0	50.0	75.0	125	188	1,875	2,813	300	318,000	3.7	D	open type	(1)or(2)or(3)	
13	42.0	8.0	25.0	144.0	216.0	864	1,296	21,600	32,400	300	1,224,000	3.9	D	open type	(1)or(2)or(3)	
14	35.0	5.0	20.0	64.0	96.0	256	384	5,120	7,680	300	615,000	18.8	G-T	open type	(1)or(2)	
15	30.0	5.0	17.5	35.2	52.8	141	211	2,464	3,696	300	510,000	22.1	G	open type	(1)or(2)	
16	35.0	8.0	21.5	79.2	118.8	475	713	10,217	15,325	300	936,000	13.0	T-D	open type	(1)or(2)or(3)	
17	50.0	10.0	30.0	150.0	225.0	750	1,125	22,500	33,750	300	1,266,000	7.6	D	open type	(1)or(2)or(3)	
18	30.0	10.0	20.0	200.0	300.0	1,000	1,500	20,000	30,000	300	708,000	4.3	D	open type	(1)or(2)or(3)	
19	25.0	5.0	15.0	154.0	231.0	770	1,155	11,550	17,325	300	543,000	15.4	G-T	open type	(1)or(2)	
20	40.0	10.0	25.0	80.0	120.0	400	600	10,000	15,000	300	1,095,000	15.5	G-T	open type	(1)or(2)	
21	40.0	10.0	25.0	144.0	216.0	864	1,296	21,600	32,400	300	1,332,000	12.0	T-D	open type	(1)or(2)or(3)	
22	35.0	10.0	22.5	112.8	169.2	677	1,015	15,228	22,842	300	1,131,000	11.5	T-D	open type	(1)or(2)or(3)	
23	30.0	10.0	20.0	84.0	126.0	504	756	10,080	15,120	300	960,000	20.7	G	open type	(1)or(2)	
24	40.0	10.0	25.0	304.8	457.2	1,829	2,743	45,720	[illegible]	300	1,326,000	1.7	D	open type	(1)or(2)or(3)	
25	25.0	5.0	15.0	50.0	75.0	125	188	1,875	2,813	300	321,000	7.9	D	open type	(1)or(4)	
26	40.0	10.0	25.0	192.0	288.0	1,152	1,728	28,800	43,200	300	1,149,000	13.8	G-T	open type	(1)or(2)	
27	50.0	5.0	27.5	62.0	93.0	310	465	8,525	12,788	300	1,224,000	19.7	G-T	open type	(1)or(2)	
28	30.0	15.0	22.5	40.0	60.0	100	150	2,250	3,375	300	345,000	15.2	G-T	open type	(1)or(4)	
29	40.0	15.0	27.5	112.8	169.2	677	1,015	18,612	27,918	300	1,144,000	11.6	T-D	open type	(1)or(2)or(3)	
30	40.0	10.0	25.0	78.2	118.8	475	713	11,880	17,820	300	1,208,000	21.1	G	open type	(1)or(2)	
31	30.0	5.0	17.5	72.0	108.0	432	648	7,560	11,340	300	771,000	23.7	G	open type	(1)or(2)	
32	50.0	22.0	36.0	48.0	72.0	144	216	5,184	7,776	300	657,000	15.9	G-T	open type	(1)or(4)	
33	40.0	10.0	25.0	103.2	154.8	619	929	15,480	23,220	300	1,155,000	13.7	T-D	open type	(1)or(2)or(3)	
34	35.0	10.0	22.5	67.2	100.8	403	605	9,072	13,608	300	960,000	20.4	G	open type	(1)or(2)	
35	30.0	5.0	17.5	52.8	79.2	317	475	5,544	8,316	300	777,000	23.6	G	open type	(1)or(2)	
36	30.0	5.0	17.5	67.2	100.8	403	605	7,056	10,584	300	777,000	20.3	G	open type	(1)or(2)	
37	25.0	5.0	15.0	72.0	108.0	432	648	6,480	9,720	300	609,000	25.3	G	open type	(1)or(2)	
38	45.0	10.0	27.5	180.0	270.0	1,080	1,620	29,700	44,550	300	1,326,000	11.9	T-D	open type	(1)or(2)or(3)	
39	35.0	5.0	20.0	80.0	120.0	400	600	8,000	12,000	300	861,000	11.9	T-D	open type	(1)or(2)or(3)	
40	40.0	5.0	22.5	156.0	234.0	936	1,404	21,060	31,590	300	1,158,000	10.7	T-D	open type	(1)or(2)or(3)	
41	30.0	5.0	17.5	64.0	96.0	256	384	4,480	6,720	300	525,000	9.0	D	open type	(1)or(2)or(3)	
42	25.0	5.0	15.0	120.0	180.0	300	450	4,500	6,750	300	369,000	11.0	T-D	closed type	(4)	
43	20.0	10.0	15.0	140.0	210.0	350	525	5,250	7,875	300	273,000	7.6	D	open type	(1)or(4)	
44	35.0	10.0	22.5	252.0	378.0	1,512	2,268	34,020	51,030	300	1,074,000	4.4	D	open type	(1)or(2)or(3)	
45	35.0	10.0	22.5	247.2	370.8	1,483	2,225	33,372	50,058	300	1,074,000	4.2	D	open type	(1)or(2)or(3)	
46	30.0	5.0	17.5	50.4	75.6	302	454	5,292	7,938	300	783,000	21.1	G	open type	(1)or(2)	
47	30.0	5.0	17.5	33.6	50.4	202	302	3,528	5,292	300	795,000	31.5	G	open type	(1)or(2)	
48	25.0	10.0	17.5	50.0	75.0	250	375	4,375	6,563	300	545,000	14.4	G	open type	(1)or(2)	
49	30.0	10.0	20.0	48.0	72.0	288	432	5,760	8,640	300	813,000	22.0	G	open type	(1)or(2)	
50	25.0	10.0	17.5	48.0	72.0	288	432	5,040	7,560	300	633,000	27.8	G	open type	(1)or(2)	
51	40.0	10.0	25.0	120.0	180.0	720	1,080	18,000	27,000	300	1,152,000	4.7	D	open type	(1)or(2)or(3)	
52	40.0	5.0	22.5	30.0	45.0	90	135	[illegible]	[illegible]	300	936,000	30.4	G	open type	(1)or(2)	
53	30.0	10.0	20.0	60.0	90.0	360	540	7,200	10,800	300	864,000	23.7	G	open type	(1)or(2)	
54	30.0	10.0	20.0	57.6	86.4	346	518	6,912	10,368	300	864,000	18.9	G-T	open type	(1)or(2)	
55	45.0	10.0	27.5	105.6	158.4	634	950	17,424	26,136	300	1,326,000	14.1	G-T	open type	(1)or(2)	
56	40.0	10.0	25.0	43.2	64.8	259	389	6,480	9,720	300	1,170,000	13.5	G	open type	(1)or(2)	
57	35.0	5.0	20.0	60.0	90.0	300	450	6,000	9,000	300	816,000	17.9	G-T	open type	(1)or(2)	
58	40.0	15.0	27.5	108.0	162.0	648	972	17,820	26,730	300	1,137,000	14.0	T-D	open type	(1)or(2)or(3)	
59	20.0	5.0	12.5	28.8	43.2	115	173	1,440	2,160	300	342,000	32.8	G	open type	(1)or(2)	
60	25.0	5.0	15.0	220.0	330.0	1,100	1,650	16,500	24,750	300	570,000	3.0	D	open type	(1)or(2)or(3)	
61	30.0	5.0	17.5	56.0	84.0	280	420	4,900	7,350	300	657,000	18.1	G-T	open type	(1)or(2)	
62	30.0	10.0	20.0	40.0	60.0	100	150	2,000	3,000	300	375,000	15.2	G-T	open type	(1)or(2)	
63	35.0	10.0	22.5	108.0	162.0	648	972	14,580	21,870	300	1,020,000	13.8	T-D	open type	(1)or(2)or(3)	
64	25.0	5.0	15.0	108.0	162.0	648	972	9,720	14,580	300	669,000	11.9	T-D	open type	(1)or(2)or(3)	
65	25.0	5.0	15.0	151.2	226.8	907	1,361	13,608	20,412	300	669,000	12.7	T-D	open type	(1)or(2)or(3)	
66	25.0	5.0	15.0	96.0	144.0	576	864	8,640	12,960	300	672,000	13.4	T-D	open type	(1)or(2)or(3)	
67	30.0	5.0	17.5	107.2	160.8	429	643	7,504	11,256	300	603,000	13.4	T-D	open type	(1)or(2)or(3)	
68	30.0	5.0	17.5	72.0	108.0	432	640	7,560	11,340	300	771,000	23.3	G	open type	(1)or(2)	
69	35.0	5.0	20.0	110.0	165.0	550	825	11,000	16,500	300	771,000	14.7	T-D	open type	(1)or(2)or(3)	
70	30.0	5.0	17.5	50.4	75.6	302	454	5,292	7,930	300	780,000	22.2	G	open type	(1)or(2)	
71	20.0	5.0	12.5	40.0	60.0	200	300	2,500	3,750	300	402,000	19.0	G-T	open type	(1)or(2)	
72	25.0	10.0	17.5	72.0	108.0	144	216	2,520	3,700	300	189,000	10.9	T-D	open type	(1)	Martinez
73	25.0	10.0	17.5	120.0	180.0	720	1,080	12,600	18,900	300	630,000	14.7	T-D	open type	(1)or(2)or(3)	
74	35.0	15.0	25.0	172.8	259.2	1,037	1,555	25,920	38,880	300	966,000	11.2	T-D	open type	(1)or(2)or(3)	
75	35.0	15.0	25.0	201.6	302.4	1,210	1,814	30,240	45,360	300	966,000	7.9	D	open type	(1)or(2)or(3)	
76	25.0	10.0	17.5	80.0	120.0	160	240	2,800	4,200	300	270,000	1.5	T	open type	(1)	Martinez
77	30.0	10.0	20.0	96.0	144.0	576	864	11,520	17,280	300	840,000	11.2	T-D	open type	(1)or(2)or(3)	
78	35.0	10.0	22.5	134.4	201.6	806	1,210	18,144	27,216	300	1,077,000	7.8	D	open type	(1)or(2)or(3)	
79	45.0	10.0	27.5	292.8	439.2	1,757	2,635	48,312	72,468	300	1,494,000	3.4	D	open type	(1)or(2)or(3)	
80	50.0	10.0	30.0	100.0	150.0	500	750	15,000	22,500	300	1,266,000	9.6	D	open type	(1)or(2)or(3)	
81	25.0	15.0	20.0	96.0	144.0	192	288	3,840	5,760	300	258,000	7.7	D	open type	(1)	Martinez
82	30.0	10.0	20.0	240.0	360.0	1,440	2,160	28,800	43,200	300	837,000	8.7	D	open type	(1)or(2)or(3)	
83	40.0	12.0	26.0	201.6	302.4	1,210	1,814	31,450	47,174	300	1,146,000	5.2	D	open type	(1)or(2)or(3)	
84	30.0	5.0	17.5	40.0	60.0	200	300	3,500	5,250	300	657,000	31.8	G	open type	(1)or(2)	
85	30.0	5.0	17.5	51.2	76.8	205	307	3,584	5,376	300	504,000	29.0	G	open type	(1)or(2)	
86	25.0	5.0	15.0	100.8	151.2	605	907	9,072	13,608	300	630,000	15.5	G-T	open type	(1)or(2)	
87	25.0	5.0	15.0	72.0	108.0	360	540	5,400	8,100	300	549,000	18.7	G-T	open type	(1)or(2)	
Total								1,060,425	1,595,130		73,095,000				see Table16.2.7.C	

Table 4.3.4.1 (2/2) Sabo Dam Dimension for 25 years Return Period

No	Principal Catchment	Catchment name	No of Structure	Structure Code	Dam Height H (m)	Effective Dam Height h (m)	Dam Width L (m)	Bottom Width of Overflow section B (m)	Slope downstream side 1:n	Slope upstream side 1:m	Dam Volume	Water Discharge Q (m3/s)	Overflow Depth h (m)	Original Bed Slope 1/-	Design Bed Slope 1/n	Sedimentation Toe Width b' (m)	Sedimentation Bottom Width b (m)	Average Sedimentation Width E (m)	Sedimentation Length L (m)	L' (m)	Area of sediment storage Al (m2)	Al' (m2)	Sediment Storage Volume Vs (m3)	Vs' (m3)	cost/m3 (US$)	cost (US$)	Streambed Slope 200m Reach Average (degree)	Segment	Dam Type	Structure	remarks
1	2		1	2-1	12.0	10.0	70.0	10.0	0.20	0.45	2,270	17.0	1.3	4.7	8.3	50.0	5.0	27.5	88.0	132.0	770	1,155	7,700	11,550	300	681,000	10.5	T-D	open type	(1)or(2)or(3)	
2	4	Caurimare	1	4-1	7.0	5.0	35.0	15.0	0.20	0.30	1,000	17.0	1.9	4.5	9.0	25.0	10.0	17.5	45.0	67.5	106	159	1,900	2,850	300	300,000	11.1	T-D	close type	C	
3	4	Caurimare	2	4-2	14.0	12.0	60.0	15.0	0.20	0.50	5,010	40.0	1.0	5.0	10.0	50.0	12.0	31.0	120.0	180.0	720	1,080	22,260	33,400	300	1,503,000	9.3	D	open type	(1)or(2)or(3)	
4	4	Caurimare	3	4-3	14.0	12.0	50.0	15.0	0.20	0.50	3,840	45.0	1.8	4.0	8.0	40.0	12.0	26.0	96.0	144.0	576	864	14,976	22,464	300	1,152,000	16.5	G-T	open type	(1)or(2)or(3)	
5	4	Caurimare	4	4-4	14.0	12.0	55.0	15.0	0.20	0.50	4,400	45.0	1.8	5.0	6.0	45.0	12.0	28.5	72.0	108.0	732	1,098	12,512	18,768	300	1,320,000	20.3	G	open type	(1)or(2)	
6	4	Caurimare	5	4-5	12.0	10.0	40.0	10.0	0.20	0.50	2,340	17.0	1.0	3.0	6.0	30.0	10.0	20.0	60.0	90.0	300	450	5,700	8,550	300	702,000	19.7	G-T	open type	(1)or(2)	
7	5	Gallinco	1	5-1	9.0	7.0	55.0	15.0	0.20	0.40	2,500	50.0	2.0	3.2	16.4	45.0	10.0	27.5	114.0	171.0	402	603	11,050	16,574	300	750,000	5.1	D	open type	(1)or(2)or(3)	
8	5	Gallinco	2	5-2	13.0	11.0	60.0	15.0	0.20	0.50	4,610	50.0	2.0	6.0	12.0	50.0	10.0	30.0	132.0	198.0	726	1,089	21,780	32,670	300	1,383,000	11.1	T-D	open type	(1)or(2)or(3)	
9	6		1	6-1	8.0	6.0	60.0	10.0	0.20	0.30	2,050	2.2	0.4	5.0	10.0	50.0	5.0	27.5	60.0	90.0	180	270	4,950	7,425	300	615,000	14.8	T-D	open type	(1)or(4)	
10	7		1	7-1	10.0	7.0	60.0	10.0	0.20	0.35	2,890	10.1	0.9	6.2	12.1	50.0	5.0	27.5	88.0	132.0	397	595	10,812	16,060	300	867,000	9.5	D	open type	(1)or(2)or(3)	
11	8	Pasquale	1	8-1	7.0	5.0	35.0	10.0	0.20	0.30	1,010	27.0	1.5	5.0	10.0	25.0	5.0	15.0	50.0	75.0	125	170	1,075	2,010	300	303,000	9.7	D	open type	(1)or(4)	
12	8	Pasquale	2	8-2	13.0	11.0	50.0	13.0	0.20	0.45	3,390	33.0	1.3	6.0	12.0	40.0	8.0	24.0	132.0	198.0	726	1,089	17,424	26,136	300	1,017,000	8.3	D	open type	(1)or(2)or(3)	
13	9		1	9-1	10.0	8.0	45.0	10.0	0.20	0.35	1,980	2.6	0.5	4.0	8.0	35.0	5.0	20.0	64.0	96.0	256	384	5,120	7,680	300	594,000	16.8	G-T	open type	(1)or(2)	
14	10		1	10-1	10.0	8.0	70.0	10.0	0.20	0.30	1,700	1.7	0.3	2.2	4.4	30.0	5.0	17.5	85.2	127.8	141	211	2,464	3,696	300	510,000	22.1	G	open type	(1)or(2)	
15	11	Guaribi	1	11-1	13.0	11.0	42.0	17.0	0.20	0.40	2,500	7.5	0.7	3.3	6.5	30.0	10.0	20.0	72.6	108.9	399	599	7,986	11,979	300	750,000	10.0	T-D	open type	(1)or(2)or(3)	
16	12	La Julia	1	12-1	12.0	10.0	60.0	15.0	0.20	0.50	4,190	43.0	2.0	7.5	15.0	50.0	10.0	30.0	150.0	225.0	750	1,125	22,500	33,750	300	1,257,000	7.8	D	open type	(1)or(2)or(3)	
17	12	La Julia	2	12-2	10.0	8.0	35.0	15.0	0.20	0.45	1,550	43.0	2.0	10.0	20.0	25.0	10.0	17.5	160.0	240.0	640	960	11,200	16,800	300	465,000	4.3	D	open type	(1)or(2)or(3)	
18	13		1	13-1	12.0	10.0	35.0	10.0	0.20	0.40	1,780	3.6	0.9	7.7	15.4	25.0	5.0	15.0	154.0	231.0	770	1,155	11,550	17,325	300	534,000	15.4	G-T	open type	(1)or(2)	
19	14	Tocoma	1	14-1	12.0	10.0	50.0	15.0	0.20	0.55	3,470	105.0	3.2	4.0	8.0	40.0	10.0	25.0	80.0	120.0	400	600	10,000	15,000	300	1,041,000	16.5	G-T	open type	(1)or(2)	
20	14	Tocoma	2	14-2	14.0	12.0	50.0	15.0	0.20	0.60	4,220	105.0	3.2	6.0	12.0	40.0	10.0	25.0	144.0	216.0	864	1,296	21,600	32,400	300	1,266,000	12.0	T-D	open type	(1)or(2)or(3)	
21	14	Tocoma	3	14-3	14.0	12.0	45.0	15.0	0.20	0.60	3,590	105.0	3.2	4.7	9.4	35.0	10.0	22.5	112.8	169.2	677	1,015	15,228	22,842	300	1,077,000	11.5	T-D	open type	(1)or(2)or(3)	
22	14	Tocoma	4	14-4	14.0	12.0	70.0	15.0	0.20	0.60	2,940	105.0	3.2	3.5	7.0	30.0	10.0	20.0	84.0	126.0	504	756	10,080	15,120	300	882,000	20.7	G	open type	(1)or(2)	
23	14	Tocoma	5	14-5	12.0	10.0	40.0	15.0	0.20	0.55	2,460	105.0	3.2	12.7	25.4	30.0	10.0	20.0	254.0	381.0	1,270	1,905	25,400	38,100	300	738,000	4.7	D	open type	(1)or(2)or(3)	
24	15	Tanarise	1	15-1	7.0	5.0	35.0	10.0	0.20	0.30	1,030	31.0	1.9	5.0	10.0	25.0	5.0	15.0	50.0	75.0	125	133	1,875	2,813	300	309,000	7.2	D	open type	(1)or(4)	
25	15	Tanarise	2	15-2	13.0	11.0	45.0	15.0	0.20	0.50	3,010	31.0	1.5	8.0	16.0	35.0	10.0	22.5	176.0	264.0	968	1,452	21,780	32,670	300	903,000	15.3	G-T	open type	(1)or(2)	
26	16	Agua de Maiz	1	16-1	12.0	10.0	60.0	10.0	0.20	0.40	3,900	35	0.8	3.1	6.2	50.0	5.0	27.5	62.0	93.0	310	465	8,525	12,788	300	1,170,000	18.7	G-T	open type	(1)or(2)	
27	17	Sebucan	1	17-1	7.0	5.0	70.0	20.0	0.20	0.25	1,110	72.0	1.0	4.0	8.0	30.0	15.0	22.5	40.0	60.0	100	150	2,250	3,375	300	333,000	15.2	G-T	open type	(1)or(4)	
28	17	Sebucan	2	17-2	14.0	12.0	50.0	20.0	0.20	0.50	3,790	72.0	1.0	4.7	9.4	40.0	15.0	27.5	112.0	168.0	677	1,015	18,612	27,910	300	1,137,000	11.8	T-D	open type	(1)or(2)or(3)	
29	17	Sebucan	3	17-3	11.0	9.0	40.0	15.0	0.20	0.45	2,070	72.0	1.5	3.3	6.6	30.0	10.0	20.0	59.4	89.1	267	401	5,346	8,019	300	621,000	21.1	G	open type	(1)or(2)	
30	18		1	18-1	14.0	12.0	70.0	10.0	0.20	0.45	2,590	4.9	0.6	3.0	6.0	50.0	5.0	27.5	72.0	108.0	732	1,098	7,920	11,880	300	777,000	23.7	G	open type	(1)or(2)	
31	19	Pajarito	1	19-1	8.0	5.0	60.0	20.0	0.20	0.25	2,100	27.0	0.9	4.0	8.0	50.0	20.0	35.0	70.0	105.0	344	516	5,184	7,776	300	630,000	16.9	G-T	open type	(1)or(4)	
32	19	Pajarito	2	19-2	14.0	12.0	50.0	15.0	0.20	0.50	3,830	27.0	1.0	4.3	8.6	40.0	10.0	25.0	103.2	154.8	619	929	15,480	23,220	300	1,149,000	13.7	T-D	open type	(1)or(2)or(3)	
33	19	Pajarito	3	19-3	10.0	8.0	35.0	15.0	0.20	0.40	1,490	27.0	1.3	2.8	5.6	25.0	10.0	17.5	44.8	67.2	179	269	3,136	4,704	300	447,000	30.4	G	open type	(1)or(2)	
34	20		1	20-1	14.0	12.0	70.0	10.0	0.20	0.45	2,590	2.5	0.5	2.2	4.4	50.0	5.0	27.5	52.8	79.2	317	475	5,544	8,316	300	777,000	28.5	G	open type	(1)or(2)	
35	21		1	21-1	14.0	12.0	70.0	10.0	0.20	0.45	2,570	7.6	0.6	2.8	5.5	30.0	5.0	17.5	67.2	100.8	403	605	7,056	10,584	300	771,000	20.7	G	open type	(1)or(2)	
36	21		2	21-2	12.0	10.0	30.0	10.0	0.20	0.40	1,130	7.6	0.6	3.0	6.0	20.0	5.0	12.5	60.0	90.0	300	450	3,750	5,625	300	339,000	25.0	G	open type	(1)or(2)	
37	22	Quintero	1	22-1	14.0	12.0	55.0	15.0	0.20	0.50	4,390	24.1	1.3	7.5	15.0	45.0	10.0	27.5	180.0	270.0	1,080	1,620	29,700	44,550	300	1,317,000	11.3	T-D	open type	(1)or(2)or(3)	
38	23	Sosa	1	23-1	13.0	11.0	70.0	10.0	0.20	0.45	3,110	17.4	1.3	6.5	13.0	57.0	5.0	31.0	178.0	267.0	787	1,130	19,247	27,775	300	933,000	10.7	T-D	open type	(1)or(2)or(3)	
39	24		1	24-1	10.0	7.0	70.0	10.0	0.20	0.35	1,740	3.1	0.7	4.0	8.0	30.0	5.0	17.5	64.0	96.0	256	384	4,480	6,720	300	522,000	9.0	D	open type	(1)or(2)or(3)	
40	25	Chacaito	1	25-1	7.0	5.0	35.0	10.0	0.20	0.40	1,100	70.0	3.1	12.0	24.0	25.0	5.0	15.0	120.0	180.0	300	450	4,500	6,750	300	330,000	11.0	T-D	close type	C	
41	25	Chacaito	2	25-2	7.0	5.0	30.0	15.0	0.20	0.35	840	70.0	2.4	14.0	28.0	20.0	10.0	15.0	140.0	210.0	350	525	5,250	7,875	300	252,000	7.8	D	open type	(1)or(4)	
42	25	Chacaito	3	25-3	14.0	12.0	45.0	15.0	0.20	0.55	3,590	70.0	2.4	10.5	21.0	35.0	10.0	22.5	252.0	378.0	1,512	2,268	34,020	51,030	300	1,077,000	4.4	D	open type	(1)or(2)or(3)	
43	25	Chacaito	4	25-4	12.0	10.0	70.0	15.0	0.20	0.50	2,350	70.0	2.4	10.3	20.5	30.0	10.0	20.0	206.0	309.0	1,030	1,545	20,600	30,900	300	705,000	4.2	D	open type	(1)or(2)or(3)	
44	27		1	27-1	14.0	12.0	40.0	10.0	0.20	0.45	2,600	7.1	0.7	2.1	4.2	30.0	5.0	17.5	50.4	75.6	302	454	5,292	7,938	300	780,000	31.1	G	open type	(1)or(2)	
45	27		2	27-2	14.0	12.0	40.0	10.0	0.20	0.45	2,640	7.1	0.7	1.4	2.3	30.0	5.0	17.5	33.6	50.4	202	302	3,528	5,292	300	792,000	31.5	G	open type	(1)or(2)	
46	28	Chapellin	1	28-1	12.0	10.0	35.0	15.0	0.20	0.45	1,810	25.0	1.3	2.5	5.0	25.0	10.0	17.5	50.0	75.0	250	375	4,375	6,563	300	543,000	24.4	G	open type	(1)or(2)	
47	28	Chapellin	2	28-2	14.0	12.0	70.0	15.0	0.20	0.50	2,700	27.0	1.3	2.0	4.0	30.0	10.0	20.0	48.0	72.0	288	432	5,760	8,640	300	810,000	22.3	G	open type	(1)or(2)	
48	28	Chapellin	3	28-3	14.0	12.0	35.0	15.0	0.20	0.50	2,100	27.0	1.3	2.0	4.0	25.0	10.0	17.5	40.0	60.0	280	420	5,040	7,560	300	630,000	20.9	G	open type	(1)or(2)	
49	28	Chapellin	4	28-4	14.0	12.0	50.0	15.0	0.20	0.50	3,820	28.0	1.3	5.0	10.0	40.0	10.0	25.0	120.0	180.0	720	1,080	18,000	27,000	300	1,146,000	4.7	D	open type	(1)or(2)or(3)	
50	29		1	29-1	12.0	10.0	50.0	10.0	0.20	0.40	3,110	2.4	0.4	1.5	3.0	40.0	5.0	22.5	30.0	45.0	150	225	3,375	5,063	300	933,000	36.4	G	open type	(1)or(2)	
51	30	Cuno	1	30-1	14.0	12.0	70.0	15.0	0.20	0.45	2,500	13.6	1.0	2.5	5.0	30.0	10.0	20.0	60.0	90.0	360	540	7,200	10,800	300	750,000	28.2	G	open type	(1)or(2)	
52	30	Cuno	2	30-2	14.0	12.0	40.0	15.0	0.20	0.45	2,570	15.6	1.0	2.4	4.7	30.0	10.0	20.0	57.6	86.4	346	518	6,912	10,368	300	771,000	19.9	G-T	open type	(1)or(2)	
53	30	Cuno	3	30-3	14.0	12.0	55.0	15.0	0.20	0.45	4,210	15.6	1.0	4.4	8.8	45.0	10.0	27.5	105.6	158.4	634	950	17,424	26,136	300	1,263,000	19.1	G-T	open type	(1)or(2)	
54	30	Cuno	4	30-4	14.0	12.0	50.0	15.0	0.20	0.45	3,790	12.6	1.0	1.8	3.5	40.0	10.0	25.0	43.2	64.8	259	389	6,480	9,720	300	1,137,000	33.5	G	open type	(1)or(2)	
55	31		1	31-1	12.0	10.0	45.0	10.0	0.20	0.40	2,500	7.6	0.8	3.0	6.0	35.0	5.0	20.0	60.0	90.0	300	450	6,000	9,000	300	750,000	17.9	G-T	open type	(1)or(2)	
56	33	Maripérez	1	33-1	13.0	11.0	47.0	20.0	0.20	0.45	3,050	77.0	1.6	4.5	9.0	37.0	15.0	26.0	99.0	148.5	545	817	14,157	21,226	300	915,000	14.0	T-D	open type	(1)or(2)or(3)	
57	34		1	34-1	10.0	8.0	30.0	10.0	0.20	0.30	1,100	3.0	0.4	1.0	3.3	20.0	5.0	12.5	20.0	30.0	115	173	1,440	2,160	300	330,000	32.0	G	open type	(1)or(2)	
58	35	Canoas	1	35-1	11.0	9.0	35.0	10.0	0.20	0.45	1,680	20.0	1.4	11.0	22.0	25.0	5.0	15.0	198.0	297.0	891	1,337	13,365	20,048	300	504,000	8.0	D	open type	(1)or(2)or(3)	
59	36		1	36-1	12.0	10.0	70.0	10.0	0.20	0.40	2,180	3.4	0.7	2.8	5.6	50.0	5.0	27.5	56.0	84.0	280	420	4,800	7,950	300	654,000	16.1	G-T	open type	(1)or(2)	
60	37	Gamboa	1	37-1	7.0	5.0	70.0	15.0	0.20	0.30	1,100	71.0	1.5	4.0	8.0	30.0	10.0	20.0	40.0	60.0	100	150	2,000	3,000	300	330,000	15.2	G-T	open type	(1)or(2)	
61	37	Gamboa	2	37-2	14.0	12.0	45.0	15.0	0.20	0.50	3,250	71.0	1.5	4.5	9.0	35.0	10.0	22.5	108.0	162.0	648	972	14,580	21,870	300	975,000	10.0	T-D	open type	(1)or(2)or(3)	
62	37	Gamboa	3	37-3	14.0	12.0	35.0	15.0	0.20	0.50	2,130	71.6	1.9	4.5	9.0	25.0	5.0	15.0	108.0	162.0	648	972	9,720	14,580	300	639,000	11.3	T-D	open type	(1)or(2)or(3)	
63	37	Gamboa	4	37-4	14.0	12.0	35.0	15.0	0.20	0.50	2,120	71.6	1.9	6.3	12.6	25.0	5.0	15.0	151.2	226.8	907	1,361	13,608	20,412	300	636,000	12.7	T-D	open type	(1)or(2)or(3)	
64	37	Gamboa	5	37-5	14.0	12.0	35.0	10.0	0.20	0.50	2,100	71.0	1.9	4.0	8.0	25.0	5.0	15.0	96.0	144.0	576	864	8,640	12,960	300	630,000	10.1	T-D	open type	(1)or(2)or(3)	
65	38		1	38-1	14.0	12.0	40.0	10.0	0.20	0.45	2,570	4.4	0.6	3.0	6.0	30.0	5.0	17.5	72.0	108.0	432	648	7,560	11,340	300	771,000	26.0	G	open type	(1)or(2)	
66	39	Beatas	1	39-1	11.0	9.0	42.0	10.0	0.20	0.35	2,050	7.0	0.7	5.5	11.0	32.0	5.0	18.5	99.0	148.5	446	669	8,242	12,363	300	615,000	14.7	T-D	open type	(1)or(2)or(3)	
67	40		1	40-1	14.0	12.0	70.0	10.0	0.20	0.45	2,590	4.4	0.6	2.1	4.2	50.0	5.0	27.5	50.4	75.6	302	454	5,292	7,938	300	777,000	22.2	G	open type	(1)or(2)	
68	40		2	40-2	12.0	10.0	30.0	10.0	0.20	0.40	1,040	1.4	0.6	2.0	4.0	20.0	5.0	12.5	40.0	60.0	200	300	2,500	3,750	300	312,000	19.0	G-T	open type	(1)or(2)	
69	41	Anauco	1	41-1	6.0	4.0	35.0	15.0	0.20	0.30	800	30.0	1.4	5.0	10.0	25.0	10.0	17.5	72.0	108.0	144	213	2,520	3,700	300	240,000	13.9	T-D	open type	(1)	Martínez
70	41	Anauco	2	41-2	14.0	12.0	35.0	15.0	0.20	0.50	2,080	30.0	1.4	5.0	10.0	25.0	10.0	17.5	120.0	180.0	720	1,080	12,600	18,900	300	624,000	14.7	T-D	open type	(1)or(2)or(3)	
71	41	Anauco	3	41-3	14.0	12.0	45.0	20.0	0.20	0.50	3,200	30.0	1.2	7.2	14.4	35.0	15.0	25.0	172.8	259.2	1,037	1,555	25,920	38,880	300	960,000	11.2	T-D	open type	(1)or(2)or(3)	
72	41	Anauco	4	41-4	14.0	12.0	45.0	20.0	0.20	0.50	3,200	30.0	1.2	8.4	16.8	35.0	15.0	25.0	201.6	302.4	1,210	1,814	30,240	45,360	300	960,000	8.8	D	open type	(1)or(2)or(3)	
73	42	Cotiza	1	42-1	6.0	4.0	35.0	10.0	0.20	0.25	850	77.0	1.9	10.0	20.0	25.0	10.0	17.5	80.0	120.0	160	240	2,800	4,200	300	255,000	1.5	T	open type	(1)	Martínez
74	42	Cotiza	2	42-2	14.0	12.0	40.0	15.0	0.20	0.50	2,680	33.0	1.5	4.0	8.0	30.0	10.0	20.0	96.0	144.0	576	864	11,520	17,280	300	804,000	11.2	T-D	open type	(1)or(2)or(3)	
75	42	Cotiza	3	42-3	14.0	12.0	45.0	15.0	0.20	0.50	3,250	33.0	1.5	5.6	11.2	35.0	10.0	22.5	134.4	201.6	806	1,210	18,144	27,216	300	975,000	7.3	D	open type	(1)or(2)or(3)	
76	42	Cotiza	4	42-4	14.0	12.0	55.0	13.0	0.20	0.50	4,390	33.0	1.5	12.2	24.4	45.0	10.0	27.5	282.8	423.2	1,357	2,033	48,312	72,468	300	1,317,000	6.1	D	open type	(1)or(2)or(3)	
77	44	Catuche	1	44-1	6.0	4.0	35.0	15.0	0.20	0.30	800	74.0	1.6	12.0	24.0	25.0	15.0	20.0	96.0	144.0	192	288	3,840	5,760	300	240,000	7.7	D	open type	(1)	Martínez
78	44	Catuche	2	44-2	14.0	12.0	40.0	15.0	0.20	0.50	2,660	34.0	1.6	10.0	20.0	30.0	10.0	20.0	240.0	360.0	1,440	2,160	28,800	43,200	300	798,000	6.7	D	open type	(1)or(2)or(3)	
79	44	Catuche	3	44-3	12.0	10.0	45.0	15.0	0.20	0.45	2,600	34.0	1.4	8.4	16.8	35.0	12.0	23.5	108.0	162.0	840	1,260	19,740	29,610	300	780,000	5.2	D	open type	(1)or(2)or(3)	
80	45	San Julián	1	45-1	12.0	10.0	70.0	10.0	0.20	0.40	2,190	2.1	0.4	2.0	4.0	30.0	5.0	17.5	40.0	60.0	200	300	3,500	5,250	300	657,000	31.3	G	open type	(1)or(2)	
81	46		1	46-1	10.0	7.0	40.0	10.0	0.20	0.30	1,670	1.5	0.3	3.2	6.4	30.0	5.0	17.5	51.2	76.8	205	307	3,584	5,376	300	501,000	26.5	G	open type	(1)or(2)	
82	47	Agua Salud	1	47-1	14.0	12.0	35.0	10.0	0.20	0.45	2,010	10.0	0.9	4.2	8.4	25.0	5.0	15.0	100.8	151.2	605	907	9,072	13,608	300	603,000	15.5	G-T	open type	(1)or(2)	
83	47	Agua Salud	2	47-2	10.0	8.0	30.0	10.0	0.20	0.35	1,190	10.0	0.9	3.6	7.2	20.0	5.0	12.5	57.6	86.4	230	346	2,880	4,320	300	357,000	18.7	G-T	open type	(1)or(2)	
Total											208,550												917,722	1,375,582		62,565,000			see Table 5.10.2.7.8		

Note: In the "Segment" column, "G" means debris flow generation, "T" means debris flow transport and "D" means debris flow deposit.

Table 4.3.4.2 (1/2) Summary of Sabo Dam for Principal Stream (100 years Return Period)

No of Catchment		Catchment name		Area		Sediment Runoff Volume				Qp	No. of Dam	Concrete Volume	Trapped Sediment Volume	Ratio of Trapped to Runoff Volume	Dam_cost	channel works Cost	Total Cost	Construction Duration
				(km2)		(m3)		(m3/km2)		(m3/s)		(m3)	(m3)	(%)	$\times 10^3$(BS)	$\times 10^3$(BS)	$\times 10^3$(BS)	(year)
1	48		Caurimare	0.161		9,300		58,000	Vec	8.0	0	0	0	0	0		0	
2	48		Caurimare	0.987	0.321	21,100	11,396	21,000	Ve	24.8	1	2,280	11,880	104	684,000		684,000	1.5
3	48		Caurimare	0.075		3,800		51,000	Vec	3.7	0	0	0	0	0		0	
4	48	Caurimare	Caurimare	6.354		101,400		16,000	Vec	75.0	6	21,260	102,130	101	6,378,000		6,378,000	7.5
5	48	Galindo	Caurimare	3.845		59,000		15,000	Vec	68.0	2	8,460	59,650	101	2,538,000		2,538,000	3.0
6	48		Caurimare	0.087		6,800		78,000	Ve	3.2	1	2,070	7,560	111	621,000		621,000	1.0
7	48		Caurimare	0.360		16,300		45,000	Vec	14.4	1	3,130	16,670	102	939,000		939,000	1.5
8	48	Pasaquire	Caurimare	1.143		34,200		30,000	Ve	34.0	2	5,140	35,220	103	1,542,000		1,542,000	2.0
9	48		Caurimare	0.117		7,000		60,000	Ve	5.1	1	2,050	7,680	110	615,000		615,000	1.0
10	48		Caurimare	0.055		3,300		60,000	Ve	2.4	1	1,700	3,800	115	510,000		510,000	1.0
11	50	Gamburi	Tocome	0.247		15,100		61,000	Vec	10.6	1	3,120	15,680	104	936,000		936,000	1.5
12	50	La Julia	Tocome	2.100		62,900		30,000	Vec	74.0	2	6,580	63,750	101	1,974,000		1,974,000	2.5
13	50		Tocome	0.327	0.142	39,700	17,240	121,000	Ve	13.9	1	1,810	17,330	101	543,000		543,000	1.0
14	50	Tocome	Tocome	9.448		152,200		16,000	Vec	182.0	5	19,480	154,460	101	5,844,000	313,200	6,157,200	6.5
15	50	Tenerias	Tocome	1.403		45,200		32,000	Ve	47.0	2	4,900	46,020	102	1,470,000		1,470,000	2.0
16	52	Agua de maiz	Agua de maiz	0.380	0.142	32,100	12,000	84,000	Ve	12.0	1	4,080	13,020	109	1,224,000		1,224,000	1.5
17	54	Sebucan	Sebucan	1.570		48,700		31,000	Vec	53.0	3	8,990	49,700	102	2,697,000		2,697,000	3.5
18	54		Sebucan	0.167	0.100	18,300	10,960	110,000	Ve	7.1	1	2,570	11,670	106	771,000		771,000	1.0
19	54	Pajarito	Sebucan	1.374		44,700		33,000	Vec	42.0	3	9,330	44,900	100	2,799,000		2,799,000	3.5
20	54		Sebucan	0.112		7,800		70,000	Ve	4.8	1	2,590	8,550	110	777,000		777,000	1.0
21	54		Sebucan	0.270	0.223	24,900	20,570	92,000	Vec	11.5	2	4,620	20,610	100	1,386,000		1,386,000	2.0
22	56	Quintero	Seca	1.973		56,200		28,000	Vec	41.2	2	7,290	57,360	102	2,187,000		2,187,000	2.5
23	56	Seca	Seca	0.775		30,800		40,000	Vec	25.9	1	3,860	32,300	105	1,158,000		1,158,000	1.5
24	56		Seca	0.207	0.840	15,100	6,130	73,000	Ve	8.8	1	1,750	6,920	113	525,000		525,000	1.0
25	58	Chacaito	Chacaito	6.332		112,400		18,000	Vec	117.0	4	9,300	113,470	101	2,790,000	771,600	3,561,600	4.0
26	58		Chacaito	0.158		10,100		64,000	Ve	6.7	0	0	0	0	0		0	
27	58		Chacaito	0.253	0.180	19,100	13,590	75,000	Ve	10.3	2	5,260	13,610	100	1,578,000		1,578,000	2.0
28	58	Chapellin	Chacaito	1.192		50,000		42,000	Ve	40.0	4	10,490	50,160	100	3,147,000		3,147,000	4.0
29	58		Chacaito	0.069		4,100		59,000	Ve	3.3	1	3,120	5,180	126	936,000		936,000	1.5
30	58	Cuno	Chacaito	0.598		57,100		95,000	Ve	24.5	4	13,700	57,500	101	4,110,000		4,110,000	5.0
31	58		Chacaito	0.235	0.136	14,000	8,100	60,000	Ve	10.9	1	2,720	9,000	111	816,000		816,000	1.5
32	62		Mariperez	0.057		3,400		60,000	Ve	2.7	0	0	0	0	0		0	
33	62	Mariperez	Mariperez	0.696		26,600		38,000	Vec	34.0	1	3,790	27,210	102	1,137,000		1,137,000	1.5
34	63		Canoas	0.092	0.034	5,500	2,030	60,000	Ve	4.3	1	1,140	2,250	111	342,000		342,000	1.0
35	63	Canoas	Canoas	0.569		23,200		41,000	Vec	28.0	1	1,900	24,750	107	570,000		570,000	1.0
36	66		Anauco	0.266	0.107	17,100	6,880	64,000	Ve	8.9	1	2,190	7,560	110	657,000		657,000	1.0
37	66	Gamboa	Anauco	3.071		82,300		26,800	Ve	52.8	6	13,360	84,890	103	4,008,000		4,008,000	5.5
38	66		Anauco	0.192		11,400		59,000	Ve	6.4	1	2,570	11,670	102	771,000		771,000	1.0
39	66	Beatas	Anauco	0.427		15,600		37,000	Vec	10.0	1	2,570	16,500	106	771,000		771,000	1.0
40	66		Anauco	0.191		11,400		60,000	Ve	6.4	2	3,940	12,060	106	1,182,000		1,182,000	2.0
41	66	Anauco	Anauco	3.690		106,900		29,000	Ve	50.0	4	9,370	107,570	101	2,811,000		2,811,000	4.0
42	66	Cotiza	Anauco	3.798		144,500		38,000	Vec	56.0	5	15,900	145,720	101	4,770,000		4,770,000	6.0
43	67		Catuche	0.269		11,300		42,000	Vec	10.4	0	0	0	0	0		0	
44	67	Catuche	Catuche	4.499		95,900		21,000	Vec	59.0	3	7,470	96,140	100	2,241,000	1,010,400	3,251,400	3.0
45	69	St.Isabel	Catroata	0.091		5,400		59,000	Ve	3.0	1	2,190	5,400	100	657,000		657,000	1.0
46	69		Catroata	0.082		4,900		60,000	Ve	2.7	1	1,680	5,540	113	504,000		504,000	1.0
47	69	Agua Salud	Catroata	0.478		21,700		45,000	Vec	14.7	2	3,930	21,710	100	1,179,000		1,179,000	2.0
											87	243,650	1,604,750		73,095,000	2,095,200	75,190,200	99

Table 4.3.4.2 (2/2) Summary of Sabo Dam for Principal Stream (25 years Return Period)

No of Catchment		Catchment name		Area		Sediment Runoff Volume			Qp	No. of Dam	Concrete Volume	Trapped Sediment Volume	Ratio of Trapped to Runoff Volume	Dam_cost	channel works Cost	Total Cost	Construction Duration
				(km2)		(m3)		(m3/km2)	(m3/s)		(m3)	(m3)	(%)	$\times 10^3$(BS)	$\times 10^3$(BS)	$\times 10^3$(BS)	(year)
1	48		Caurimare	0.161		7,751		48,000	6.0	0	0	0		0		0	
2	48		Caurimare	0.987	0.630	21,105	11,399	21,000	17.0	1	2,270	11,880	1726	681,000		681,000	1.5
3	48		Caurimare	0.075		3,193		43,000	2.8	0	0	0		0		0	
4	48	Caurimare	Caurimare	6.354		84,548		13,000	48.0	5	16,650	85,220	755	4,995,000		4,995,000	6.0
5	48	Galindo	Caurimare	3.845		49,147		13,000	50.0	2	7,110	49,550	1300	2,133,000		2,133,000	2.5
6	48		Caurimare	0.087		6,796		78,000	2.2	1	2,060	7,560	2575	618,000		618,000	1.0
7	48		Caurimare	0.36		13,029		36,000	10.1	1	2,990	16,670	2811	897,000		897,000	1.5
8	48	Pasaquire	Caurimare	1.143		28,309		25,000	22.0	2	4,400	28,950	1925	1,320,000		1,320,000	2.0
9	48		Caurimare	0.117		6,970		60,000	3.6	1	1,980	7,680	3051	594,000		594,000	1.0
10	48		Caurimare	0.055		3,276		60,000	1.7	1	1,700	3,800	3055	510,000		510,000	1.0
11	50	Gamburi	Tocome	0.247		11,797		48,000	7.5	1	2,500	11,990	3020	750,000		750,000	1.0
12	50	La Julia	Tocome	2.1		49,070		23,000	49.0	2	5,740	51,030	2333	1,722,000		1,722,000	2.5
13	50		Tocome	0.327	0.142	39,377	17,099	120,000	9.6	1	1,730	17,330	2920	519,000		519,000	1.0
14	50	Tocome	Tocome	9.448		118,627		13,000	105.0	5	16,680	123,980	1111	5,004,000	313,200	5,317,200	6.0
15	50	Tenerias	Tocome	1.403		35,465		25,000	31.0	2	4,040	36,210	2210	1,212,000		1,212,000	2.0
16	52	Agua de maiz	Agua de maiz	0.38	0.142	32,100	11,995	84,000	8.5	1	3,900	13,020	2237	1,170,000		1,170,000	1.5
17	54	Sebucan	Sebucan	1.57		38,088		24,000	32.0	3	6,970	39,910	2038	2,091,000		2,091,000	3.0
18	54		Sebucan	0.167	0.100	18,294	10,954	110,000	4.9	1	2,570	11,670	2922	771,000		771,000	1.0
19	54	Pajarito	Sebucan	1.374		34,996		25,000	27.0	3	7,420	35,840	1965	2,226,000		2,226,000	3.0
20	54		Sebucan	0.112		7,757		69,000	3.3	1	2,590	8,550	2920	777,000		777,000	1.0
21	54		Sebucan	0.27	0.223	19,479	16,088	72,000	7.9	2	3,910	16,740	2907	1,173,000		1,173,000	2.0
22	56	Quintero	Seca	1.973		43,948		22,000	24.1	1	4,390	45,360	1221	1,317,000		1,317,000	2.0
23	56	Seca	Seca	0.775		24,105		31,000	17.1	1	3,110	24,780	2200	933,000		933,000	1.5
24	56		Seca	0.207	0.084	15,090	6,124	73,000	6.1	1	1,740	6,920	2923	522,000		522,000	1.0
25	58	Chacaito	Chacaito	6.332		87,960		14,000	70.0	4	7,710	93,200	1105	2,313,000	771,600	3,084,600	3.5
26	58		Chacaito	0.158		10,059		64,000	4.6	0	0	0	2924	0		0	
27	58		Chacaito	0.253	0.180	19,118	13,601	76,000	7.1	2	5,240	13,610	2787	1,572,000		1,572,000	2.0
28	58	Chapellin	Chacaito	1.192		49,994		42,000	26.0	4	10,430	50,160	2181	3,129,000		3,129,000	4.0
29	58		Chacaito	0.069		4,110		60,000	2.4	1	3,110	5,180	3435	933,000		933,000	1.5
30	58	Cuno	Chacaito	0.598		55,505		93,000	15.6	4	13,070	57,500	2609	3,921,000		3,921,000	5.0
31	58		Chacaito	0.235	0.136	13,999	8,102	60,000	7.6	1	2,600	9,000	3234	780,000		780,000	1.0
32	62		Mariperez	0.057		3,395		60,000	1.8	0	0	0	3228	0		0	
33	62	Mariperez	Mariperez	0.696		20,773		30,000	23.0	1	3,050	21,240	3305	915,000		915,000	1.5
34	63		Canoas	0.092	0.034	5,480	2,025	60,000	3.0	1	1,100	2,250	3239	330,000		330,000	1.0
35	63	Canoas	Canoas	0.569		18,140		32,000	20.0	1	1,680	20,060	3515	504,000		504,000	1.0
36	66		Anauco	0.266	0.107	17,079	6,870	64,000	6.1	1	2,180	7,560	2305	654,000		654,000	1.0
37	66	Gamboa	Anauco	3.071		73,030		24,000	31.8	5	10,810	73,310	1034	3,243,000		3,243,000	4.5
38	66		Anauco	0.192		11,437		60,000	4.4	1	2,570	11,670	2307	771,000		771,000	1.0
39	66	Beatas	Anauco	0.427		12,499		29,000	7.0	1	2,050	12,690	1639	615,000		615,000	1.0
40	66		Anauco	0.191		11,378		60,000	4.4	2	3,930	12,060	2304	1,179,000		1,179,000	2.0
41	66	Anauco	Anauco	3.69		106,898		29,000	30.0	4	9,280	107,570	813	2,784,000		2,784,000	4.0
42	66	Cotiza	Anauco	3.798		110,771		29,000	33.0	4	11,170	123,220	869	3,351,000		3,351,000	4.5
43	67		Catuche	0.269		9,054		34,000	7.5	0	0	0	2803	0		0	
44	67	Catuche	Catuche	4.499		73,477		16,000	34.0	3	6,120	79,200	756	1,836,000	1,010,400	2,846,400	2.5
45	69	St.Isabel	Catroata	0.091		5,421		60,000	2.1	1	2,190	5,400	2308	657,000		657,000	1.0
46	69		Catroata	0.082		4,885		60,000	1.9	1	1,670	5,540	2305	501,000		501,000	1.0
47	69	Agua Salud	Catroata	0.478		17,352		36,000	10.0	2	3,140	18,110	2094	942,000		942,000	1.5
										83	209,550	1,383,170		62,865,000	2,095,200	64,960,200	86

Table 4.3.4.3 Actual Cost for Sabo Dam Constructed in Vargas in 2000

FONTUR Prpject: Qda. Guanape (Vargas State)

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

Table 4.3.4.4 Channel Works

Table S16-2.5.1 Channel Works

14.Tocome

No	Name	section	Coordinate X (m)	Coordinate Y (m)	Distance Cumulative (m)	Distance Interval (m)	Existing Channel Bed Elevation (m)	Existing Channel Bed Slope (1/n)	Existing Channel Bed Slope (degree)	Proposed bed elevation (m)	Proposed Channel Proposed Drop Height (m)	Proposed Channel Original Bed slope (1/n)	Proposed Bed Slope (1/n)	Proposed Bed Slope (degree)
14	tocome	1	738223	1162484	0.00		903.0			903.00		49.14		
14	tocome	2	738202	1162580	98.27	98.27	905.0	49.14	1.17	905.00	0.00		50.00	1.15
14	tocome	3	738197	1162622	140.57	42.30	907.5	16.92	3.38	907.50	1.65	23.64	50.00	1.15
14	tocome	4	738221	1162694	216.46	75.89	910.0	30.36	1.89	910.00	0.98		50.00	1.15
14	tocome	5	738249	1162754	282.67	66.21	915.0	13.24	4.32	912.99	1.67	22.11	50.00	1.15
14	tocome	6	738347	1162874	437.60	154.93	920.0	30.99	1.85	920.00	3.91		50.00	1.15

25.Chacaito

No	Name	section	Coordinate X (m)	Coordinate Y (m)	Distance Cumulative (m)	Distance Interval (m)	Existing Channel Bed Elevation (m)	Existing Channel Bed Slope (1/n)	Existing Channel Bed Slope (degree)	Proposed bed elevation (m)	Proposed Channel Proposed Drop Height (m)	Proposed Channel Original Bed slope (1/n)	Proposed Bed Slope (1/n)	Proposed Bed Slope (degree)
25	chacaito	1	733786	1162298	0.00		910.0			910.00		26.41		
25	chacaito	2	733801	1162364	67.68	67.68	912.5	27.07	2.12	912.50	0.00		26.00	2.20
25	chacaito	3	733836	1162418	132.03	64.35	915.0	25.74	2.22	915.00	0.02		26.00	2.20
25	chacaito	4	733883	1162472	203.62	71.59	920.0	14.32	3.99	918.79	1.04	18.89	26.00	2.20
25	chacaito	5	733938	1162526	280.70	77.08	925.0	15.42	3.71	922.87	1.12		26.00	2.20
25	chacaito	6	733962	1162592	350.93	70.23	930.0	14.05	4.07	926.59	1.02		26.00	2.20
25	chacaito	7	733989	1162664	427.83	76.90	932.5	30.76	1.86	930.66	1.11		26.00	2.20
25	chacaito	8	734046	1162724	510.59	82.76	935.0	33.10	1.73	935.04	1.20		26.00	2.20
25	chacaito	9	734098	1162802	604.33	93.74	940.0	18.75	3.05	940.00	1.35		26.00	2.20
25	chacaito	10	734130	1162838	652.50	48.17	945.0	9.63	5.93	943.73	1.88	12.90	26.00	2.20
25	chacaito	11	734169	1162898	724.06	71.56	950.0	14.31	4.00	949.28	2.79		26.00	2.20
25	chacaito	12	734191	1162940	771.47	47.41	955.0	9.48	6.02	952.96	1.86		26.00	2.20
25	chacaito	13	734201	1162994	826.39	54.92	960.0	10.98	5.20	957.21	2.14		26.00	2.20
25	chacaito	14	734212	1163018	852.79	26.40	962.5	10.56	5.41	959.26	1.03		26.00	2.20
25	chacaito	15	734219	1163054	889.46	36.67	965.0	14.67	3.90	962.10	1.43		26.00	2.20
25	chacaito	16	734224	1163090	925.81	36.35	967.5	14.54	3.93	964.92	1.42		26.00	2.20
25	chacaito	17	734240	1163138	976.41	50.60	970.0	20.24	2.83	968.84	1.97		26.00	2.20
25	chacaito	18	734248	1163174	1013.29	36.88	972.5	14.75	3.88	971.70	1.44		26.00	2.20
25	chacaito	19	734254	1163216	1055.72	42.43	975.0	16.97	3.37	975.00	1.67		26.00	2.20
25	chacaito	20	734268	1163264	1105.72	50.00	980.0	10.00	5.71	980.00	3.08	10.00	26.00	2.20

↑ See attached figures

Table 4.3.4.5 Work Quantity for Temporary Works

No of Catchment		Temporary Yard		Cable Crane		Road	Monorail	Construction Period(1/100)									Construction Period(1/25)								
								Period for Temporary Works		Month for Earth Works		Period for Concrete Works			Total		Period for Temporary Works		Month for Earth Works		Period for Concrete Works			Total	
		Availability	Area	nos.	length	length	length	Total length	L<500m:1M L<1000m:2M L<3000m:3M	nos. of dam	3M /1 dam	Concrete Volume	$55m^3$/(1day+4day)				Total length	L<500m:1M L<1000m:2M L<3000m:3M	nos. of dam	3M /1 dam	Concrete Volume	$55m^3$/(1day+4day)			
		Area>$600m^2$	(m^2)	(-)	(m)	(m)	(m)	(m)	(month)	(-)	(month)	(m3)	(day)	(month)	(month)	(year)	(m)	(month)	(-)	(month)	(m3)	(day)	(month)	(month)	(year)
2		○	18,238	1	50	1,198	0	1,248	3	1	3	2,280	207	7	13	1.5	1,248	3	1	3	2,270	206	7	13	1.5
4	Caurimare	○	1,478	0	0	977	491	1,468	3	6	18	21,260	1,933	65	86	7.5	2,084	3	5	15	16,650	1,514	51	69	6.0
5	Galindo	○	2,796	0	0	309	0	309	1	2	6	8,460	769	26	33	3.0	828	2	2	6	7,110	646	22	30	2.5
6		○	share with No.7	1	242	0	0	242	1	1	3	2,070	188	7	11	1.0	206	1	1	3	2,060	187	7	11	1.0
7		○	1,048	1	247	0	0	247	1	1	3	3,130	285	10	14	1.5	309	1	1	3	2,990	272	10	14	1.5
8	Pasaquire	○	1,689	0	0	401	0	401	1	2	6	5,140	467	16	23	2.0	506	2	2	6	4,400	400	14	22	2.0
9		○	1,036	0	0	0	0	0	1	1	3	2,050	186	7	11	1.0	204	1	1	3	1,980	180	6	10	1.0
10		○	579	0	0	0	0	0	1	1	3	1,700	155	6	10	1.0	171	1	1	3	1,700	155	6	10	1.0
11	Gamburi	○	1,114	0	0	0	0	0	1	1	3	3,120	284	10	14	1.5	308	1	1	3	2,500	227	8	12	1.0
12	La Julia	○	1,277	0	0	312	0	312	1	2	6	6,580	598	20	27	2.5	645	2	2	6	5,740	522	18	26	2.5
13		○	859	0	0	0	0	0	1	1	3	1,810	165	6	10	1.0	181	1	1	3	1,730	157	6	10	1.0
14	Tocome	○	2,341	7	1,524	531	656	2,711	3	5	15	19,480	1,771	60	78	6.5	1,909	3	5	15	16,680	1,516	51	69	6.0
15	Tenerias	○	share with No.14	0	0	239	0	239	1	2	6	4,900	445	15	22	2.0	482	1	2	6	4,040	367	13	20	2.0
16	Agua de maiz	○	1,134	0	0	0	0	0	1	1	3	4,080	371	13	17	1.5	401	1	1	3	3,900	355	12	16	1.5
17	Sebucan	○	2,115	0	0	0	0	0	1	3	9	8,990	817	28	38	3.5	883	2	3	9	6,970	634	22	33	3.0
18		○	1,195	0	0	0	0	0	1	1	3	2,570	234	8	12	1.0	254	1	1	3	2,570	234	8	12	1.0
19	Pajarito	○	2,802	1	210	244	257	711	2	3	9	9,330	848	29	40	3.5	917	2	3	9	7,420	675	23	34	3.0
20		○	2,276	1	126	0	0	126	1	1	3	2,590	235	8	12	1.0	255	1	1	3	2,590	235	8	12	1.0
21		○	2,101	1	84	99	0	183	1	2	6	4,620	420	14	21	2.0	455	1	2	6	3,910	355	12	19	2.0
22	Quintero	○	2,552	0	0	224	0	224	1	2	6	7,290	663	23	30	2.5	716	2	1	3	4,390	399	14	19	2.0
23	Seca	○	share with No.22	1	181	337	0	518	2	1	3	3,860	351	12	17	1.5	380	1	1	3	3,110	283	10	14	1.5
24		○	826	2	295	0	0	295	1	1	3	1,750	159	6	10	1.0	175	1	1	3	1,740	158	6	10	1.0
25	Chacaito	○	1,945	0	0	1,041	0	1,041	3	4	12	9,300	845	29	44	4.0	918	2	4	12	7,710	701	24	38	3.5
27		○	1,245	1	140	0	0	140	1	2	6	5,260	478	16	23	2.0	517	2	2	6	5,240	476	16	24	2.0
28	Chapellin	○	1,422	1	300	504	0	804	2	4	12	10,490	954	32	46	4.0	1,032	3	4	12	10,430	948	32	47	4.0
29		○	1,281	0	0	0	0	0	1	1	3	3,120	284	10	14	1.5	308	1	1	3	3,110	283	10	14	1.5
30	Cuno	○	2,628	4	698	369	0	1,067	3	4	12	13,700	1,245	42	57	5.0	1,344	3	4	12	13,070	1,188	40	55	5.0
31		○	1,262	1	71	0	0	71	1	1	3	2,720	247	9	13	1.5	269	1	1	3	2,600	236	8	12	1.0
33	Mariperez	○	1,409	0	0	169	0	169	1	1	3	3,790	345	12	16	1.5	373	1	1	3	3,050	277	10	14	1.5
34		○	758	0	0	0	0	0	1	1	3	1,140	104	4	8	1.0	116	1	1	3	1,100	100	4	8	1.0
35	Canoas	○	1,399	0	0	0	163	163	1	1	3	1,900	173	6	10	1.0	189	1	1	3	1,680	153	6	10	1.0
36		○	861	0	0	0	151	151	1	1	3	2,190	199	7	11	1.0	217	1	1	3	2,180	198	7	11	1.0
37	Gamboa	○	2,013	0	0	871	0	871	2	6	18	13,360	1,215	41	61	5.5	1,317	3	5	15	10,810	983	33	51	4.5
38		○	1,077	0	0	0	0	0	1	1	3	2,570	234	8	12	1.0	254	1	1	3	2,570	234	8	12	1.0
39	Beatas	○	1,077	0	0	0	0	0	1	1	3	2,570	234	8	12	1.0	254	1	1	3	2,050	186	7	11	1.0
40		○	1,865	1	119	0	0	119	1	2	6	3,940	358	12	19	2.0	389	1	2	6	3,930	357	12	19	2.0
41	Anauco	○	1,724	2	688	1,483	0	2,171	3	4	12	9,370	852	29	44	4.0	925	2	4	12	9,280	844	29	43	4.0
42	Cotiza	○	6,909	0	0	1,218	0	1,218	3	5	15	15,900	1,445	49	67	6.0	1,561	3	4	12	11,170	1,015	34	49	4.5
44	Catuche	○	1,390	0	0	923	0	923	2	3	9	7,470	679	23	34	3.0	736	2	3	9	6,120	556	19	30	2.5
45	St.Isabel	no	construction using small machine or man power	0	0	243	0	243	1	1	3	2,190	199	7	11	1.0	217	1	1	3	2,190	199	7	11	1.0
46		no		1	136	0	0	136	1	1	3	1,680	153	6	10	1.0	169	1	1	3	1,670	152	6	10	1.0
47	Agua Salud	no		0	0	313	0	313	1	2	6	3,930	357	12	19	2.0	388	1	2	6	3,140	285	10	17	1.5
sum			77,721	27	5,111	12,005	1,718	18,834		87		243,650				98.5	25,010		83		209,550				89.5

Table 4.3.4.6 Proposed Implementation Schedule

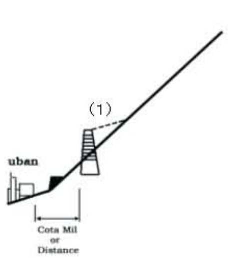
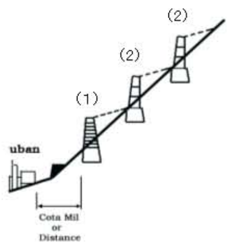
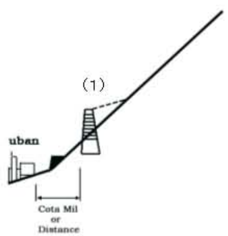
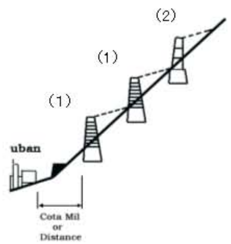
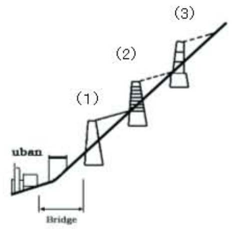
No of Catchment		Sabo Dam Works				Channel Works				BS/year	Annual Construction Cost															
		Nos.	Concrete Volume	Construction Cost	Construction Period	Length	Concrete Volume	Construction Cost	Construction Period		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	sum
		(-)	(m3)	$\times10^3$(BS)	(year)	(m)	(m3)	$\times10^3$(BS)	(year)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)	$\times10^3$(BS)
14	Tocome	5	19,480	5,844,000	6.5					899,077	899,077	899,077	899,077	899,077	899,077	899,077	449,538									5,844,000
						450	2,610	3,132	8.0	392								392	392	392	392	392	392	392	392	3,132
25	Chacaito	4	9,300	2,790,000	4.0					697,500	697,500	697,500	697,500	697,500												2,790,000
						1,100	6,430	7,716	11.0	701					701	701	701	701	701	701	701	701	701	701	701	7,716
44	Catuche	3	7,470	2,241,000	3.0					747,000	747,000	747,000	747,000													2,241,000
						1,600	8,420	1,010,400	12.0	84,200				84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	84,200	1,010,400
4	Caurimare	6	21,260	6,378,000	7.5					850,400	850,400	850,400	850,400	850,400	850,400	850,400	850,400	425,200								6,378,000
42	Cotiza	5	15,900	4,770,000	6.0					795,000	795,000	795,000	795,000	795,000	795,000	795,000										4,770,000
30	Cuno	4	13,700	4,110,000	5.0					822,000	822,000	822,000	822,000	822,000	822,000											4,110,000
37	Gamboa	6	13,360	4,008,000	5.5					728,727		728,727	728,727	728,727	728,727	728,727	364,364									4,008,000
28	Chapellin	4	10,490	3,147,000	4.0					786,750					786,750	786,750	786,750	786,750								3,147,000
41	Anauco	4	9,370	2,811,000	4.0					702,750						702,750	702,750	702,750	702,750							2,811,000
17	Sebucan	3	8,990	2,697,000	3.5					770,571							770,571	770,571	770,571	385,286						2,697,000
19	Pajarito	3	9,330	2,799,000	3.5					799,714							799,714	799,714	799,714	399,857						2,799,000
5	Galindo	2	8,460	2,538,000	3.0					846,000								846,000	846,000	846,000						2,538,000
12	La Julia	2	6,580	1,974,000	2.5					789,600								789,600	789,600	394,800						1,974,000
22	Quintero	2	7,290	2,187,000	2.5					874,800									874,800	874,800	437,400					2,187,000
8	Pasaquire	2	5,140	1,542,000	2.0					771,000										771,000	771,000					1,542,000
15	Tenerias	2	4,900	1,470,000	2.0					735,000										735,000	735,000					1,470,000
21		2	4,620	1,386,000	2.0					693,000										693,000	693,000					1,386,000
27		2	5,260	1,578,000	2.0					789,000											789,000	789,000				1,578,000
40		2	3,940	1,182,000	2.0					591,000											591,000	591,000				1,182,000
47	Agua Salud	2	3,930	1,179,000	2.0					589,500											589,500	589,500				1,179,000
2		1	2,280	684,000	1.5					456,000											456,000	228,000				684,000
7		1	3,130	939,000	1.5					626,000												626,000	313,000			939,000
11	Gamburi	1	3,120	936,000	1.5					624,000												624,000	312,000			936,000
16	Agua de maiz	1	4,080	1,224,000	1.5					816,000												816,000	408,000			1,224,000
23	Seca	1	3,860	1,158,000	1.5					772,000												772,000	386,000			1,158,000
29		1	3,120	936,000	1.5					624,000													624,000	312,000		936,000
31		1	2,720	816,000	1.5					544,000													544,000	272,000		816,000
33	Mariperez	1	3,790	1,137,000	1.5					758,000													758,000	379,000		1,137,000
6		1	2,070	621,000	1.0					621,000													621,000			621,000
9		1	2,050	615,000	1.0					615,000													615,000			615,000
10		1	1,700	510,000	1.0					510,000													510,000			510,000
13		1	1,810	543,000	1.0					543,000														543,000		543,000
18		1	2,570	771,000	1.0					771,000														771,000		771,000
20		1	2,590	777,000	1.0					777,000														777,000		777,000
24		1	1,750	525,000	1.0					525,000														525,000		525,000
34		1	1,140	342,000	1.0					342,000														342,000		342,000
35	Canoas	1	1,900	570,000	1.0					570,000														570,000		570,000
36		1	2,190	657,000	1.0					657,000															657,000	657,000
38		1	2,570	771,000	1.0					771,000															771,000	771,000
39	Beatas	1	2,570	771,000	1.0					771,000															771,000	771,000
45	St.Isabel	1	2,190	657,000	1.0					657,000															657,000	657,000
46		1	1,680	504,000	1.0					504,000															504,000	504,000
sum		87	243,650	73,095,000	98.5	3,150	17,460	1,021,248	31.0	4,941,083	4,810,977	5,539,704	5,539,704	4,876,904	4,966,856	4,847,606	4,808,989	5,205,879	4,868,729	5,185,036	5,147,193	5,120,793	5,176,293	4,576,293	3,445,293	74,116,248
										Nos. of stream	6	7	7	7	8	8	9	10	9	11	11	11	13	12	8	

Note: BS is the Bolivar Currency in 2000

Table 4.3.4.7 Feature of Transported Sediment

Main Segement	Manner of Sediment Transport	Detailed Segment	Slope	Phenomena	Effectiveness of sabo dam for debris flow transport		Applicable Sabo Dam Type
Debris Flow Segment	Mass Transport	Generation	steeper than 20 degree	Initial Generation of debris Flow Steep slope failure Erosion of streambed deposit	C	(1)Trap of debris flow(reduction of sediment runoff)	A: Open Type (wide slit Type) B: Open Type (narrow slit Type)
		Generation–Transport	15～20	Development of debris flow Erosion of streambed deposit Production and breach of natural dam Concentration of boulders at the debris flow front Surge wave of debris flow	C	(1)Trap of debris flow(reduction of sediment runoff) (2)Trap of boulders and drift woods at the debris flow front	A: Open Type (wide slit Type) B: Open Type (narrow slit Type)
		Transport–Deposit	10～15	Transport of boulders Production and breach of natural dam	B	(1)Trap of debris flow(reduction of sediment runoff) (2)Trap of boulders and drift woods at the debris flow front (3)Reduction of peak discharge of debris flow (4)Retarding of concentration time to alluvial fan (5)Trap of debris flow	A: Open Type (wide slit Type) B: Open Type (narrow slit Type)
		Deposit	3～10	Development of Allivial fans	A	(1)Trap of debris flow(reduction of sediment runoff) (2)Trap of boulders and drift woods at the debris flow front (3)Reduction of peak discharge of debris flow (4)Retarding of concentration time to alluvial fan (5)Trap of debris flow (6)Transition of debris flow to bedload transport	A: Open Type (narrow opening Type) A: Close Type (close to target property)
Bedload Transport Segment	Individual Transport	–	milder than 3 degree	Deposit and clog in channel resulting to overflow	–	(7)Control of bedload (8)Trap of floating wood (9)Elimination of debris flow	B:Close Type B:Drift wood trapping B:Channel Works

Table 4.3.4.8 Comparison of Sabo Dam Layout

Segment	A. Generation − Generation・Transport − Transport・Deposition		B. Generation − Generation・Transport − Transport・Deposition − Deposition (partially bedload)		
Streambed Slope	steeper than 10 degree		steeper than 3 degree or 2 degree		
Function	Single	Combination	Single	Combination	Combination
Principal Steam No.	2,6,7,9,10,13,16,18,20,24,29,31 33,34,36,38,39,45,46	17,21,27,30,40,47	11,23,35	5,8,12,(14),15,19,22,28,37,41,42,44	4,25
General Layout					
Dam Type	OpenType (narrow slit) or OpenType (wide slit) in the case of far from urban area	downstream: OpenType (narrow slit) upstream: OpenType (wide slit)	OpenType (narrow slit)	downstream: OpenType (narrow slit) upstream: OpenType (narrow slit) or OpenType (wide slit)	downstream: CloseType upstream: OpenType (narrow slit) or OpenType (wide slit)

Structure Type

A. Single:

Type	No	Applicability	Structure		
Open	(1)	○	L1	Large	Concrete Slit
	(1)	※	L2		Frame/CF/I-type
	(1)	※	L3		L-type
	(1)	※	S4	Small	B-type
	(1)	※	S5		A-type
Close			C1		Concrete
			C2		Doublewall
			C3		Steel Frame

※in the case of far from urban area

A. Combination:

Type	No	Applicability	Structure		
Open	(1)	○	L1	Large	Concrete Slit
	(2)	○	L2		Frame/CF/I-type
			L3		L-type
	(2)	○	S4	Small	B-type
			S5		A-type
Close			C1		Concrete
			C2		Doublewall
			C3		Steel Frame

B. Single:

Type	No	Applicability	Structure		
Open	(1)	○	L1	Large	Concrete Slit
	(1)	○	L2		~~Frame/CF~~/I-type
			L3		L-type
			S4	Small	B-type
			S5		A-type
Close			C1		Concrete
			C2		Doublewall
			C3		Steel Frame

B. Combination (5,8,12,(14),15,19,22,28,37,41,42,44):

Type	No	Applicability	Structure		
Open	(1)	○	L1		Concrete Slit
	(1)	○	L2	Large	~~Frame/CF~~/I-type
	(2)	○	L2		Frame/CF/I-type
	(2)	○	L3		L-type
	(2)	○	L4	Small	B-type
	(2)	○	L5		A-type
Close			C1		Concrete
			C2		Doublewall
			C3		Steel Frame

B. Combination (4,25):

Type	No	Applicability	Structure		
Open	(2)(3)	○	L1	Large	Concrete Slit
	(2)(3)	○	L2		Frame/CF/I-type
	(2)		L3		L-type
	(2)(3)		S4	Small	B-type
	(2)		S5		A-type
Close	(1)	○	C1		Concrete
	(1)	○	C2		Doublewall
	(1)	○	C3		Steel Frame

Table 4.3.4.9 Comparison of Open Type Dam

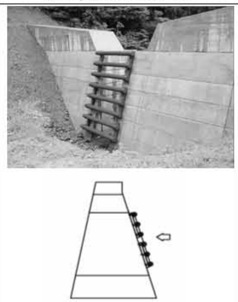
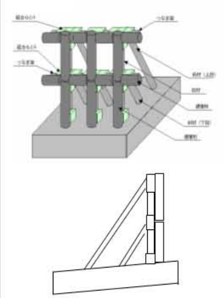
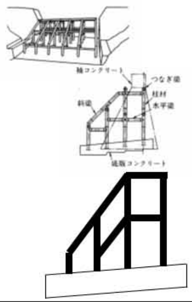
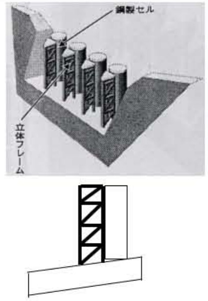
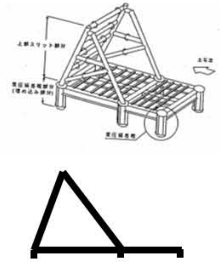
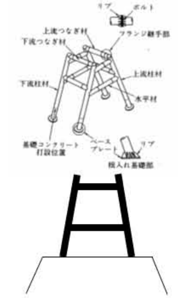
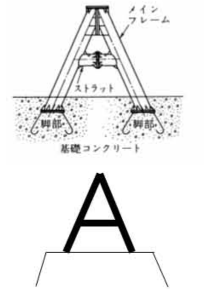
Type	Gravity Concrete Slit Dam	Steel Open Type					
Scale	small-large	large				small	
No	L1	L2			L3	S4	S5
slit opening	narrow	narrow-medium	medium-wide	medium-wide	narrow-medium	medium	medium-narrow
Name	Gravity Concrete Slit Dam	I-type Slit Dam	Frame-type Slit Dam	CF-type Slit Dam	Slit Dam Type L	Slit Dam Type B	Slit Dam Type A
General Layout							
Structure Type	Gravity Concrete	Solid Steel Pipe for shock absorber	Grid Steel Frame	Combination of Steel cells and Solid Steel Frame	Steel Pipe	Steel Pipe Frame	Steel Pipe Frame filled with concrete
General	This is a new type of the conventional concrete gravity type dam (closed). They have been constructed for Sabo and River Project in Japan and they are reliable and popular. They are rigid, so that strong for deflection. Also the structure can be flexible to the site conditions.	The steel frame as shock absorber is installed upstream and the truss members are installed downstream in order to resist the debris flow energy. The selection of structure type and steel pipe can be flexible to respond to various design conditions and site conditions. The steel frame as shock absorber does not have any joint, so that the hit of boulder is absorbed by the deflection of the beam, not resulting into the break of the beam.	The grid steel frame type is composed of the steel pipe (diameter 600 mm), which is the rigid-jointed structure. The horizonral beams are installed to avoid the trapped debris from passing by the following flow. Also a lot of colums are connected to the foundation, so that the energy of the debris flow is dispersed to those colums.	The CF (Cell Frame) type slit dam is composed of the steel cells upstream and the solid steel frame downstream. The steel cells absorbes the energy of debris flow and resist it with the steel frame.	Steel L-type slit dam was developed for the site where rigid concrete foundation is not available. The upper structure can trap debris flow. The lower structure (foundation) is composed of piles resisting for debris flow hit and drainboard supporting sediment weight. It should be located in debris flow section in order to trap the debris flow. Steel pipes can absorb the debris flow energy by its deformation.	Steel B-type slit dam is a kind of solid frame type, stable structure even when debris flow hits the structure with different direction from the flow direction. Inside the steel pipe, concrete is not filled. It should be located in debris flow section in order to trap the debris flow. Steel pipes can absorb the debris flow energy by its deformation.	Steel A-type slit dam is a frame type of "A" shape with concrete foundation, stable structure even when debris flow hits the structure with different direction from the flow direction. Inside the steel pipe, concrete is filled. It should be located in bedload flow section. It is sometimes used as drift wood trap at sub dam.
Height	No limit	No limit(～14.5m)	Steel Frame H=8.0m～14.5m	No limit(～14.5m)	No limit(～14.5m)	Steel Frame H=3.0m～6.0m	Steel Frame H=3.0m～5.0m
	The stream continuity shall be kept to set the top of the foundation concrete being same as the existing stream bed.	The stream continuity shall be kept to set the top of the foundation concrete being same as the existing stream bed.	The stream continuity shall be kept to set the top of the foundation concrete being same as the existing stream bed.	The stream continuity shall be kept to set the top of the foundation concrete being same as the existing stream bed.	The stream continuity can be kept because the concrete foundation is not necessary.	The stream continuity can not be kept because of the concrete foundation.	The stream continuity can not be kept because of the concrete foundation.
Resistance to Debris Hit	Medium	Large	Large	Large	Small	medium	Small
Environmental Consideration	Decorated form can be used.	The steel frame part does not shut down the background. The wing part can be glazed.	The steel frame part does not shut down the background. The wing part can be glazed.	The steel frame part does not shut down the background. The wing part can be glazed.	The steel frame part does not hide the background.	The steel frame part does not hide the background. The wing part and waterway can be glazed.	The steel frame part does not hide the background. The wing part and waterway can be glazed.
Material	Concrete	Carbon steel pipe	Carbon steel pipe	Rolled steel bar	Carbon steel pipe	Carbon steel pipe	Carbon steel pipe
Foundation	Direct Foundation	Concrete foundation	Concrete foundation	Concrete foundation	Direct foundation	Concrete foundation	Concrete foundation

Table 4.3.4.10 Comparison of Closed Type Dam

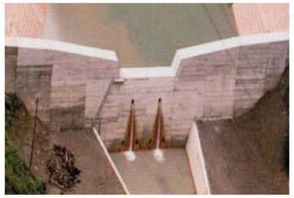
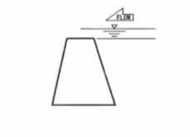
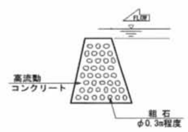
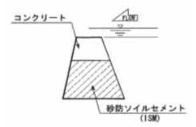
Name	Gravity Concrete Type			Steel Frame Type	Grouting Type
General Layout					 
	 Mass concrete structure	 Rubble concrete structure	 Soil cement structure		
General Structure	Concrete is filled in between upstream and downstream formings.	Concrete volumeis reduced by the use of rubble stone.	Soil on site and cement milk is mixtured on site.	Filling material such as cobbles is put inside the steel frame fabricated by factory-made steel beams.	The wall material using grouting is placed downstream and the steel sheet pile is installed upstream for debris flow. The wall material is connected by tierod to tie the filling materials.
Material	Concrete, Forming	High viscous Concrete, Forming Rubble stone(φ0.3m):on site It is necessary to collect rubble stone and transport on site.	Concrete, Forming Soil on site	Factory-made steel bars	Steel sheet pile, grouting, other steel bars
Applicability for Site Condition	The dam itself is heavy, so the weak ground is not appropriate. Cracks can happen when the dam is placed on the weak ground. The shape of the dam is flexible.			Since the filling material is cobble stone, the dam itself is not heavy. It can be placed on the comparatively weak ground. The joint of each member is hinge-type. The dam can follow the non-uniform subsidence.	Since the filling material is cobble stone, the dam itself is not heavy. It can be placed on the comparatively weak ground. The resistance for lateral deflection is low. The longitudinal deflection is flexible because of the joint by tie rod.
Resistance to Debris Flow	The dam has enough streangth for debris flow. This type of dam is appropriate for the debris flow trapping. A			The deflection and break of the steel material are caused by debris flow hit. The upstream side of the dam should have the shock absorber. D	The steel sheet pile upstream is strong enough for debris flow. It is appropriate as the debris flow trapping. B
Construction	The access road is necessary for the transpotation of construction machine and materials. The quality control for the concrete is important. C			The dam can be fabricated by bolt locking. In general, any special skill is not needed for the fabrication. Since the quality control for concrete is not necessary, the construction period can be reduced. B	The main construction work is to install the steel sheet pile. In general, any special skill is not needed for the fabrication. It is not affected by weather conditins. Quality control for filling material is necessary. Since the quality control for concrete is not necessary, the construction period can be reduced. B
Economic Aspect	In the case of large dam, the greate amount of excavated material has to be disposed. If the disposal site is near the dam site, the construction cost is comparatively cheap. C			This type is economical in the case of small dam. If the stream bed material can be used as the filling material, it can be advantageous. B	The cost for the wall material is a lot of portion in the entire construction cost, so that the large scale dam is advantageous. Also the excavated materila can be used for the filling material for the dam and the disposal site is not necessary. C
Evaluation	The most appropriate type as long as the disposal site is near the dam site.			Not appropriate for the debris flow trapping.	It is appropriate for the large scale dam when the excavated material ca be used for the filling material of the dam.

Table 4.3.5.1 Evaluation of Present System, Limitation and Recommendation for Early Warning and Evacuation

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

Table 4.3.5.2 Draft Agreement on Institutional Arrangement for Sediment Disaster Early Warning System in the Metropolitan District of Caracas

Draft Agreement on Institutional Arrangement for Sediment Disaster Early Warning System in the Metropolitan District of Caracas between National Civil Protection, Ministry of Environment and Natural Resources, Metropolitan District of Caracas, and the Municipalities of Libertador, Chacao and Sucre, and UCV.

Chapter 1 General

1.1 Purpose

- The purpose of the agreement is to establish the necessary institutional arrangement (or the basic frame work) on the sediment disaster early warning system in the Metropolitan District of Caracas in order to save life and mitigate the damage for property.
- The coverage of the agreement is limited to the institutional arrangement in order to distribute properly the necessary information for the early warning between National Civil Protection, Ministry of Environment and Natural Resources, Metropolitan District of Caracas, and the Municipalities of Libertador, Chacao and Sucre, and UCV.

1.2 Definition

- Sediment disaster means the sediment related disasters, namely the debris flow caused by the rainfall on the south slope of the Avila and the landslide / steep slope failure caused by the rainfall that impact the municipalities.
- MARN means the Ministry of Environment and Natural Resources.
- ADMC means the Mayor of the Metropolitan District of Caracas.
- UCV means the Central University of Venezuela.
- Municipalities mean the governments of Libertador, Chacao, Sucre, Baruta and El Hatillo.

1.3 Responsibility of National Civil Protection

- National Civil Protection is responsible for the national level coordination among MARN, ADMC and Municipalities.

1.4 Responsibility of Ministry of Environment and Natural Resources

- Ministry of Environment and Natural Resources (Caracas Regional Office of INAMEH, herein called INAMEH- CRO) has responsibility to collect and distribute the information on hydrology and meteorology such as weather synopsis, rainfall forecast by INAMEH radar system, real time rainfall amount and water level in river and mountain streams, which would become the factors on sediment disasters.
- INAMEH-CRO will issue the regional warning for the entire Caracas Metropolitan Area based on its own criteria.
- All equipment for the hydro-meteorological data measurement will be operated and maintained by INAMEH-CRO.
- INAMEH-CRO will make suggestions and recommendation on technical part for the disaster prevention plan prepared by the ADMC.

1.5 Responsibility of Metropolitan District of Caracas

- Metropolitan District of Caracas (herein after ADMC) has responsibility to establish an Operation Control Center (herein after OCC) within the Metropolitan District of Caracas. The function of the OCC is to issue the local warning on the sediment disasters. The OCC will be specified project in the Disaster Prevention Plan prepared by ADMC.

1.6 Responsibility of Municipalities

- Municipalities have the responsibility and the obligation to support the OCC directories in regards to operations and logistics.
- Municipalities shall support the creation of self-directed (managed) prevention groups in the communities.

1.7 Responsibility of Specific Organizations

- Specific organization such as Universities, public services will provide information and technical advises necessary for the operation of OCC.

1.8 Responsibility of Communities

- Communities groups in the municipalities have responsibility to create self-directed prevention groups.
- Communities groups shall appoint representatives to work with the OCC in emergency and organize the people and execute the prevention measures and evacuation.
- Communities shall observe water level and rainfall amount voluntarily both in normal time and emergency time and report those information to OCC.

Chapter 2 Organizations on Early Warning for Sediment Disaster

2.1 Establishment of Technical Committee on Early Warning

- ADMC will establish the standing technical committee on early warning whose secretariat is the Civil Protection Department.

2.1.1 Responsibility

- The committee has responsibility to review the current early warning system, evaluate the past operations of OCC on early warning and make recommendations to the director of OCC on the updating of the early warning system.
- The committee has responsibility to draft any legal instruments (degree or ordinance) for implementing the early warning.

2.1.2 Organization

- The committee shall be composed of a permanent representative of Protection Civil, Fire Fighter Department, MARN, Civil Protection of the municipalities and UCV. Other members can be appointed. The Protection Civil of ADMC shall serve as committee secretary.

2.2 Operation on Early Warning in Operation Command Center (OCC)

- ADMC will establish an OCC within the ADMC which can operate early warning for Caracas. The Early Warning system will be operated as a function of the Planning/Intelligence Section of the OCC and will have a separate operation room.

2.2.1 Making of Planning/Intelligence Section

- The Planning/Intelligence Section within the OCC maintains databases on the weather synopsis and past – cumulative hydrological information provided from the INAMEH-CRO.
- The information provided by the Planning/Intelligence Section will be distributed to communities organizations and private emergency organizations through a mechanism established by the Civil Protection of ADMC.

2.2.2 Organization

- The Major of ADMC appoints the OCC director.
- The organization of OCC is composed of one (1) management and four (4) sections, namely Operation Section, Planning/Intelligence Section, Logistics Section and Finance/administration Section.
- The head of the Planning/Intelligence Section is appointed by the OCC director.
- The Planning/Intelligence Section is composed of the staff capable of maintaining data bases, establishing early warning protocols and distribution of alerts to the operation division and communities groups.

2.2.3 Responsibility of Planning/Intelligence Section in OCC

- Planning/Intelligence Section receives the meteorological and hydrological information provided by INAMEH-CRO and prepares the necessary processing for the decision making of issuing of local warning.

- OCC director decides the issuing of local warning and recommendation of evacuation to the communities.
- Planning/Intelligence Section receives the hydrological information observed in communities and report them as they are to the INAMEH-CRO.

2.2.4 Transfer of the right of the mayor of Municipalities to OCC

- During the operation of Planning/Intelligence Section is activated in a certain level, some rights of the mayor of municipalities shall be transferred to OCC in order to concentrate the rights to OCC.

2.3 Dispatch of Human Resources to OCC

- When the Planning/Intelligence Section is activated in a certain level, INAMEH-CRO, Municipalities and the related organization will dispatch their staff to the Planning/Intelligence Section in OCC as supporting staff based on the request from the OCC to each organization.
- All the dispatched staff from the above organizations shall be under the command of the head of OCC resources.
- The necessary financial measures in terms of the dispatching of staff shall be specified in an agreement between the related organizations.

Chapter 3 Early Warning General Guidelines

3.1 General

- Early Warning shall be issued in order to save the life and mitigate the damage of the property.
- The method to issue an early warning, distribute the early warning, recommend the evacuation and cancel of the issued warnings shall be specified by the committee on early warning through a written protocol adopted by the OCC.
- Nobody can use the similar early warning method.

3.2 Issue of Warning

- There are two (2) kinds of warning in terms of its locality, namely regional warning and local warning. The regional warning shall be issued by the INAMEH-CRO for the region of entire Caracas based on the definition of INAMEH. The local warning shall be issued by Planning/Intelligence Section in OCC for specific areas in Caracas.
- The local warning shall be categorized into two (2) in terms of the seriousness. The categorization and the corresponding hydrological index such as critical rainfall shall be decided by the technical working group of the technical committee on early warning specified in section 2.1.
- When the head of OCC issues the local warning, he has to inform the issuing to the related organizations.
- When the municipal protection civils receive or knows the issued warning, they distribute this to their related organizations.
- If the issuing of warning needs the urgent operation, the OCC director may utilize public utilities such as telephone lines and TV broadcasting stations exclusively.
- If the OCC director and the OCC management group recognize the anticipated issuing of warning, they shall activate the operations Section for the filed activities.

3.3 Cancellation of Local Warning

- The Planning/Intelligence Section will cancel the issued local warning based on the weather synopsis provided by the INAMEH-CRO and the local hydrological information observed by communities. The Planning/Intelligence Section has to inform the cancellation to the public widely.

Caracas, December 15, 200X

Mr. A
National Civil Protection

Mr. X
Director of Caracas Regional Office of INAMEH
Ministry of Environment and Natural Resources

Mr. Y
Major of ADMC

Mr. Z1
Major of Municipality of Libertador

Mr. Z2
Major of Municipality of Chacao

Mr. Z3
Major of Municipality of Sucre

Mr. Z4
Major of Municipality of Baruta

Mr. Z5
Major of Municipality of El Hatillo

Prof. A
Central University of Venezuela

Mr. N
Witness
JICA Expert

Table 4.3.5.3 Definitions of Rainfall Indexes

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

Table 4.3.5.4 Definitions of Timing for Warning and Evacuation

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

Table 4.4.2.1 Existing Rainfall Stations in Caracas

Code	Station	Organization	Period	Remarks
514	Los Venados	MARN / UCV	1994-	Telemeter System
519	Hotel Humboldt	MARN / UCV	1958-74, 2000-	Telemeter System
531	Cagigal	Armada	1891-	
539	UCV	UCV	1949-	
544	La Carlota	FAV	1964-	
5021	Chacaito	MARN	1967-83, 2000-	
5027	Caurimare	MARN	1949-	

Table 4.4.2.2 Features of Proposed Installation Sites

Site	Campo Alegre	San Jose del Avila	Teleferico	Los Chorros	Topo Santa Rosa
Location	On the ridge of Qda. Catuche and Qda. Agua Salud	Qda. Catuche floodplain	Qda. Canoas near Cota Mil	Qda. Tocome near Cota Mil	Upstream of Qda. Caurimare
Elevation (MSL)	1,600 m	Approx. 1,000 m	Approx. 1,000 m	Approx. 1,000 m	2,200 m
Existence of past station	Totally new installation	In 1960's to 1980's, the stations were operating.			Totally new installation
Accessibility	easy access by vehicle	easy access because it is in urban area below the Cota Mil	easy access because it is near the Cota Mil	easy access because it is near the Cota Mil	1 hour walking distance from Santa Rosa
Disaster in Dec. 1999	Debris flow occurred in the mountain resulting into sediment flood in the fan apex.	not affected	not affected	Debris flow occurred in the mountain but resulting into local inundation in the fan apex.	Debris flow occurred in the mountain but resulting into local inundation in the fan apex.

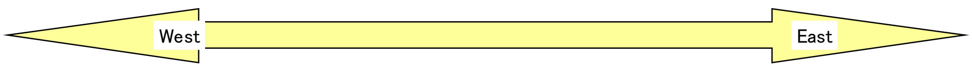


Table 4.4.3.1 Installation Site of Staff Gauge

No.	Location (Stream)	Observation	No.	Location (Stream)	Observation
1	Caurimare	Community	11	Chacaito (2)	Community
2	Galindo	Sucre Municipality	12	Galindo	Community
3	Tocome (1)	Community	13	Anauco (1)	Community
4	Tocome (2)	Community	14	Cotiza	Metropolitan Police
5	Agua de Maiz (1)	Community	15	Anauco (2)	Community
6	Agua de Maiz (2)	Community	16	Catuche (1)	Community
7	Sebucan	Community	17	Catuche (2)	Community
8	Pajarito	INPARQUES	18	Agua Salud	Community
9	Seca	National Guard	19	Agua Salada	Community
10	Chacaito (1)	Community	20	Caroata	Community

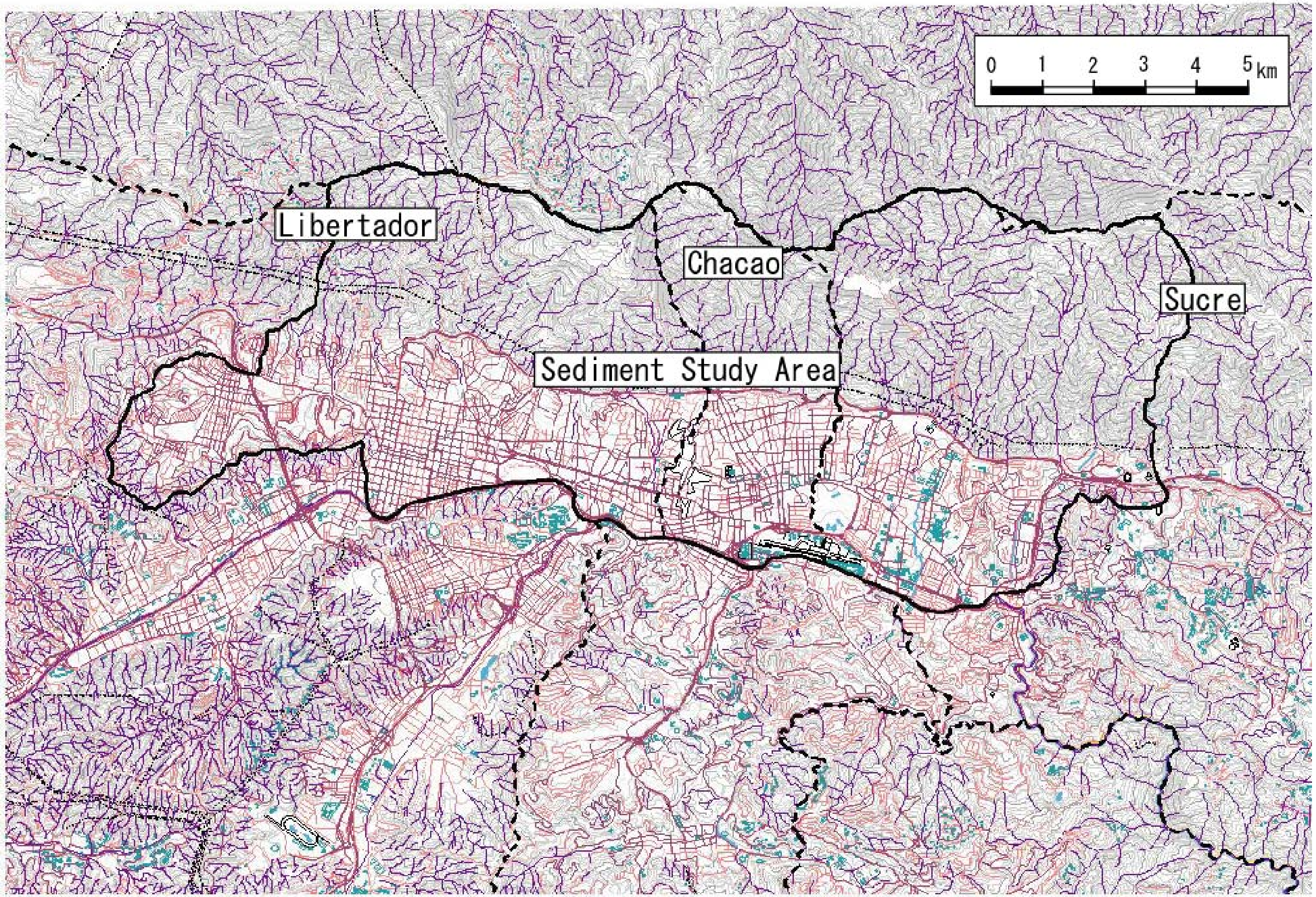
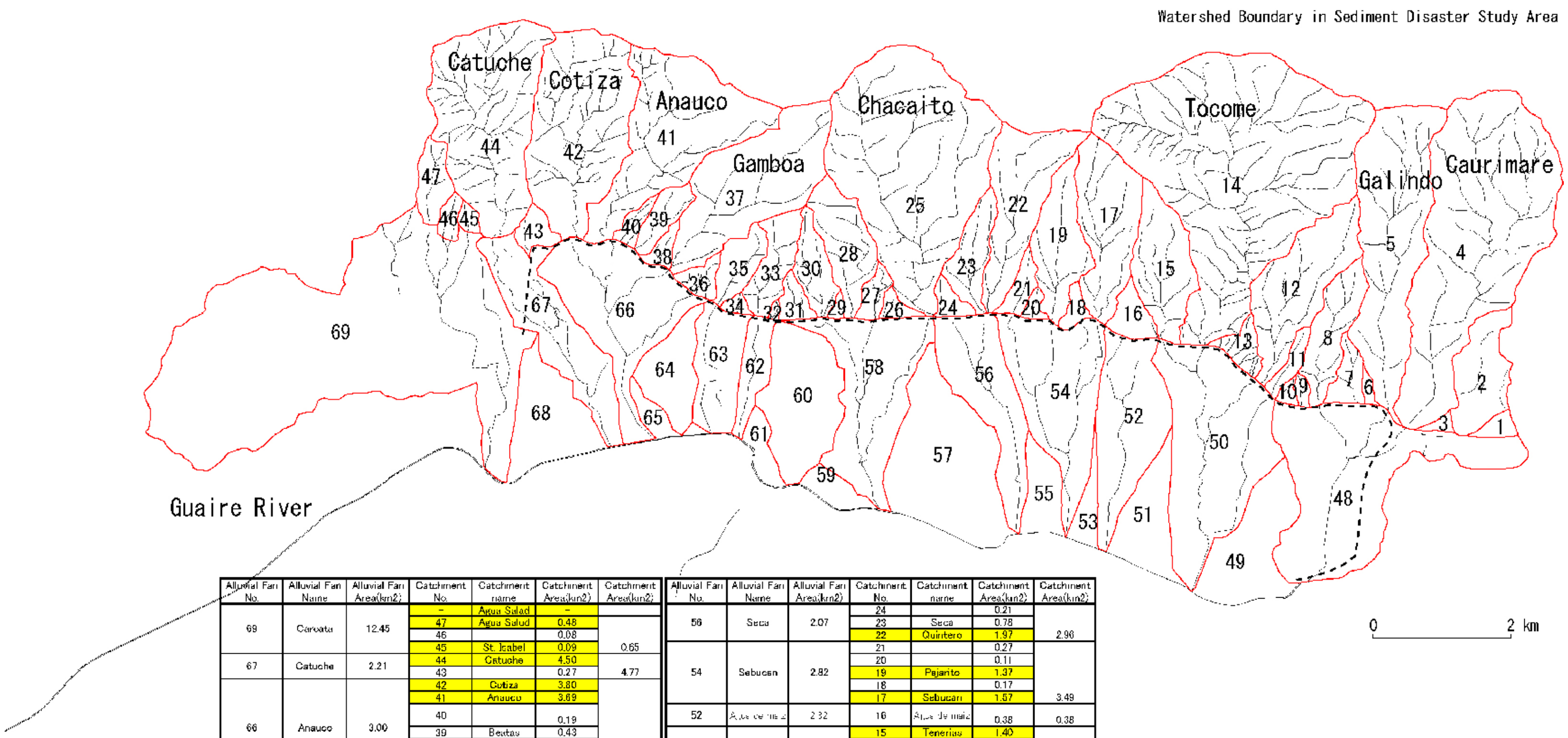


Figure 4.1.1.1(1/2)　Sediment Study Area



Alluvial Fan No.	Alluvial Fan Name	Alluvial Fan Area(km2)	Catchment No.	Catchment name	Catchment Area(km2)	Catchment Area(km2)
69	Caroata	12.45	–	Agua Salad	–	
			47	Agua Salud	0.48	
			46		0.08	
			45	St. Isabel	0.09	0.65
67	Catuche	2.21	44	Catuche	4.50	
			43		0.27	4.77
66	Anauco	3.00	42	Cotiza	3.80	
			41	Anauco	3.69	
			40		0.19	
			39	Beatas	0.43	
			38		0.19	
			37	Gamboa	3.07	
			36		0.27	11.64
63	Canoas	1.23	35	Canoas	0.57	
			34		0.09	0.66
62	Mariperez	0.60	33	Mariperez	0.70	
			32		0.06	0.75
58	Chacaito	2.86	31		0.24	
			30	Cuno	0.60	
			29		0.07	
			28	Chapellin	1.19	
			27		0.25	
			26		0.16	
			25	Chacaito	6.33	8.84

Alluvial Fan No.	Alluvial Fan Name	Alluvial Fan Area(km2)	Catchment No.	Catchment name	Catchment Area(km2)	Catchment Area(km2)
56	Seca	2.07	24		0.21	
			23	Seca	0.78	
			22	Quintero	1.97	2.96
54	Sebucan	2.82	21		0.27	
			20		0.11	
			19	Pajarito	1.37	
			18		0.17	
			17	Sebucan	1.57	3.49
52	Agua de maiz	2.32	16	Agua de maiz	0.38	0.38
50	Tocome	4.14	15	Tenerias	1.40	
			14	Tocome	9.45	
			13		0.33	
			12	La Julia	2.10	
			11	Gamburi	0.25	13.53
48	Caurimare	4.75	10		0.06	
			9		0.12	
			8	Pasaquire	1.14	
			7		0.36	
			6		0.09	
			5	Galindo	3.85	
			4	Caurimare	6.35	
			3		0.08	
			2		0.99	
			1		0.16	13.18
	Total	38.45			60.84	60.84

Figure 4.1.1.1(2/2) Sediment Study Area

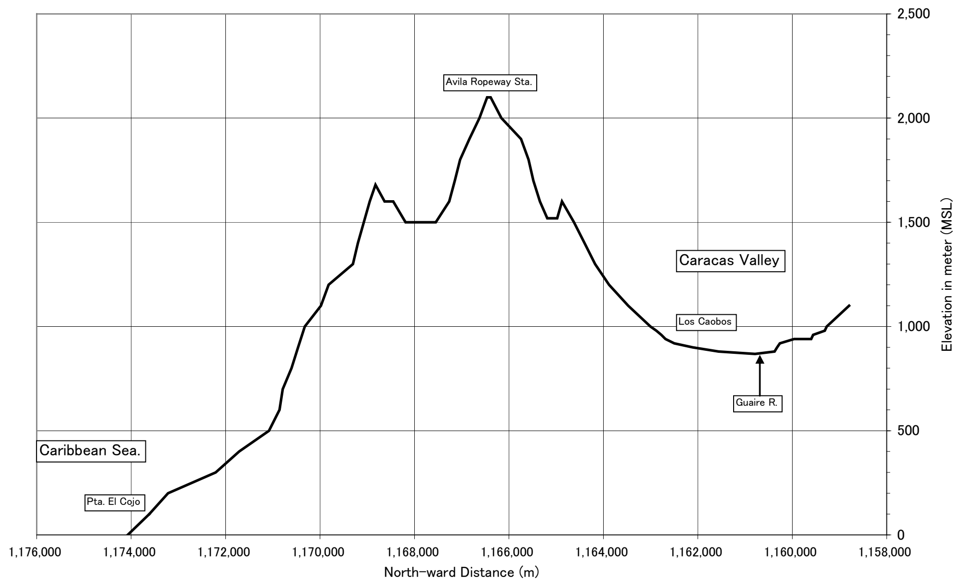


Figure 4.1.1.2　Typical Section of the Avila

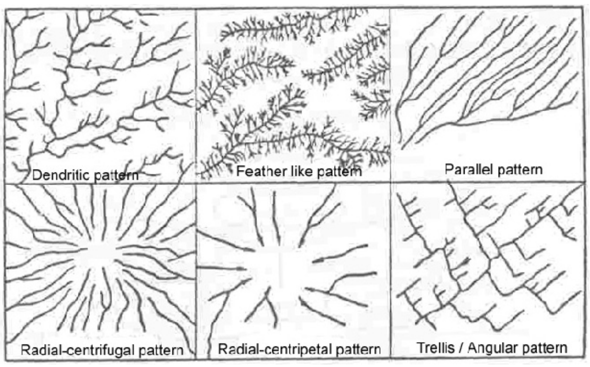


Figure 4.1.1.3　Typical Stream Pattern

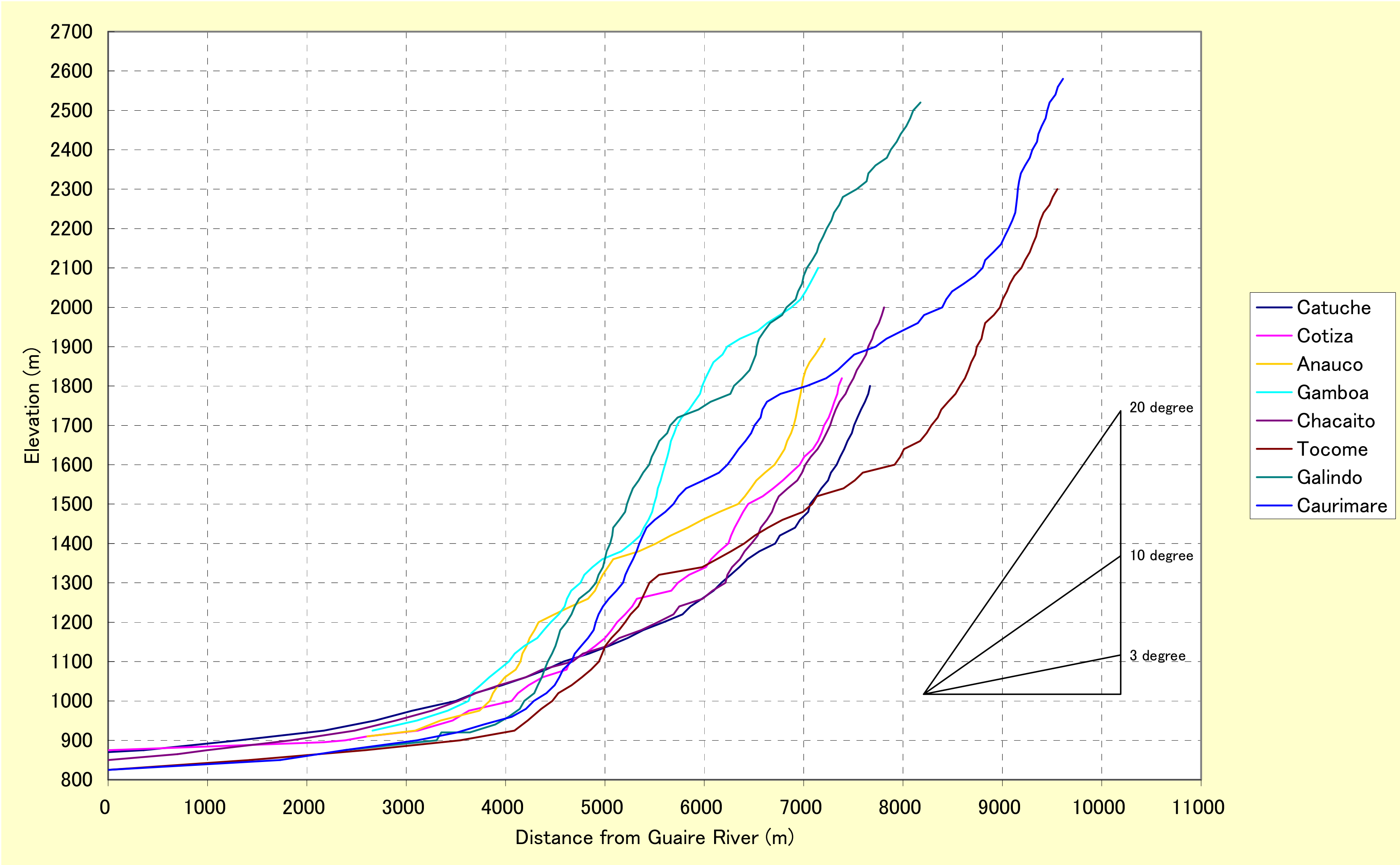


Figure 4.1.1.4 Profiles of the Mountain Streams

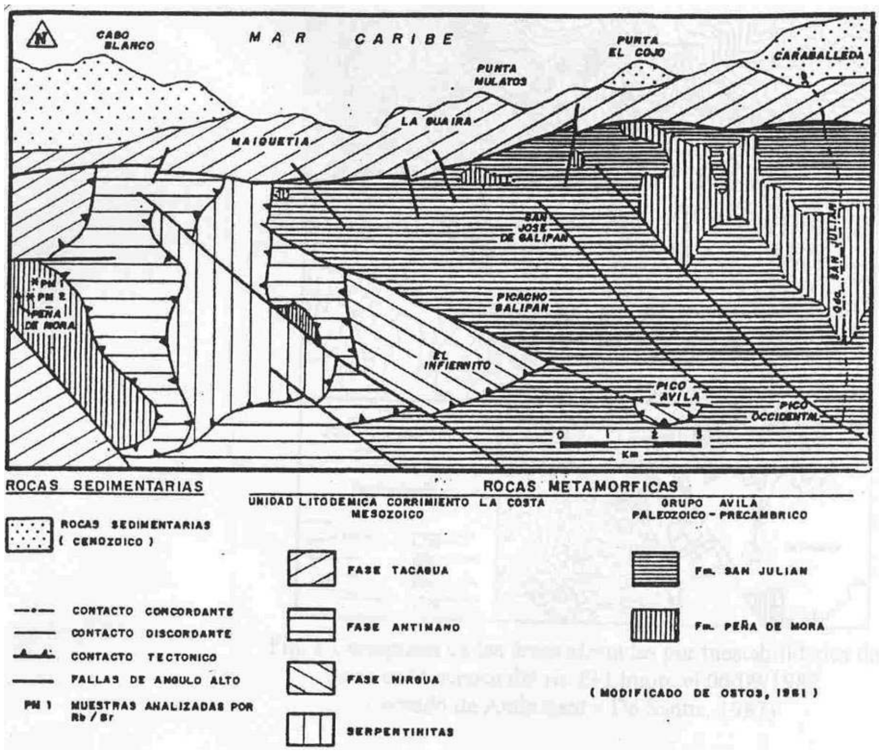


Figure 4.1.1.5 Geology in and Around the Caracas Valley

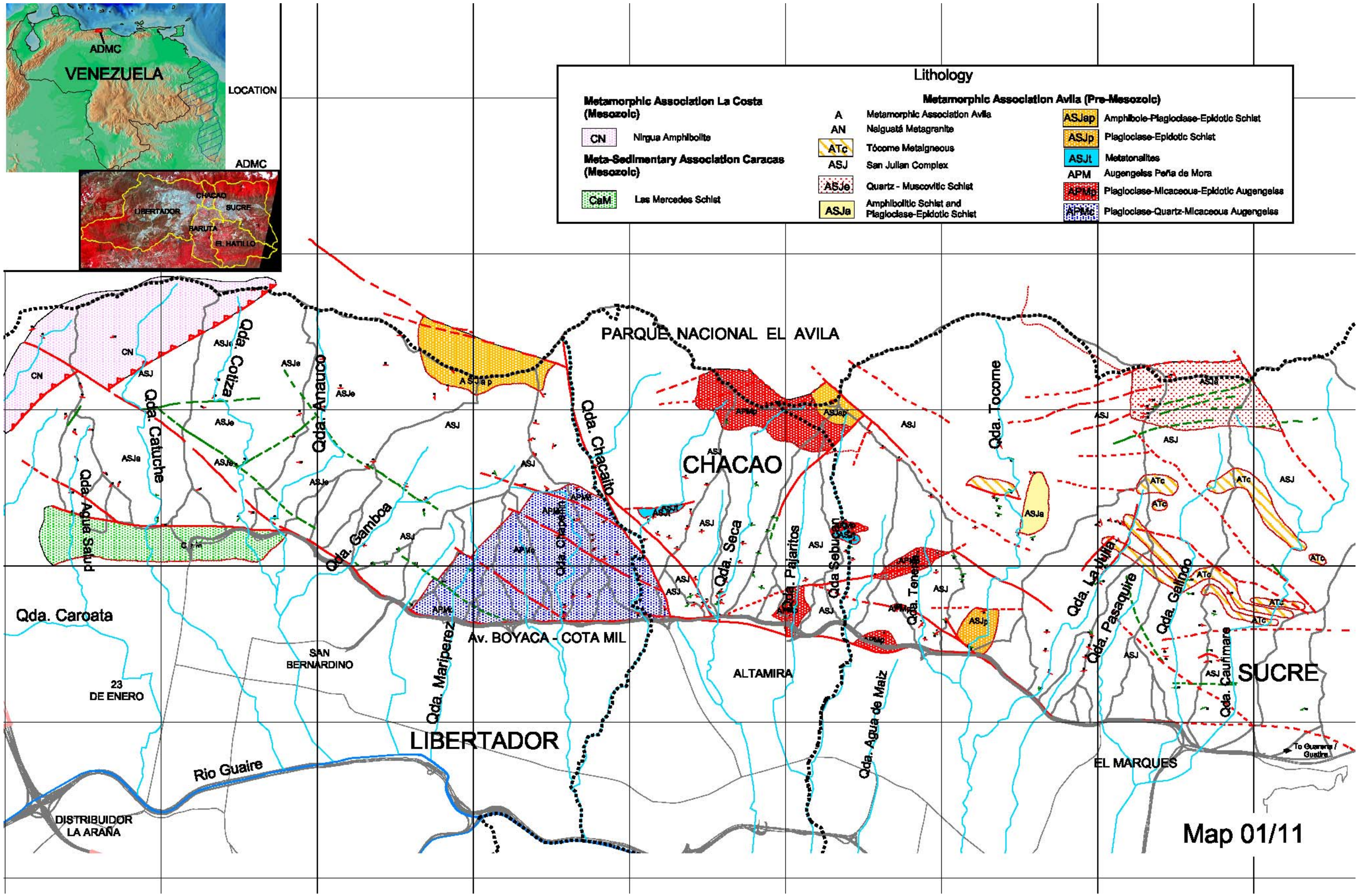
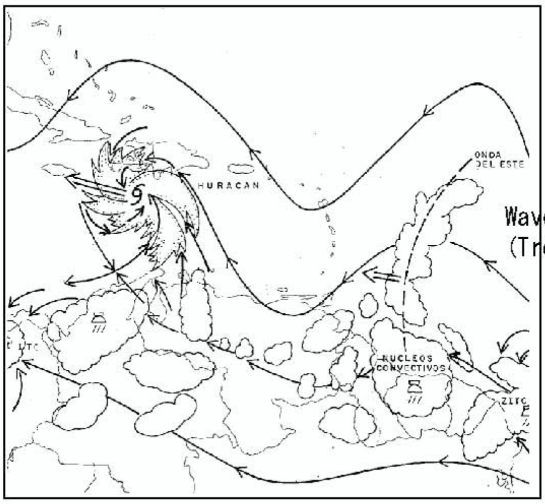
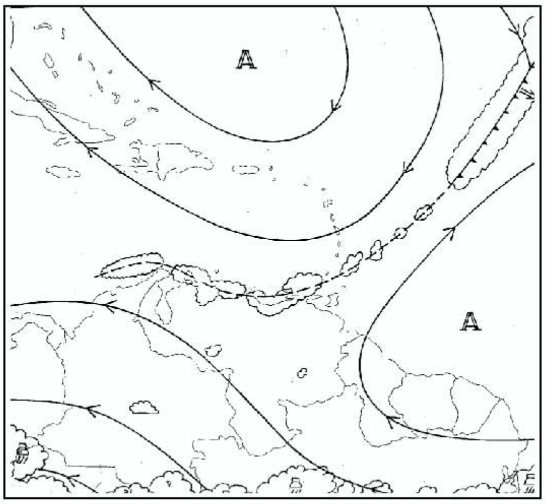


Figure 4.1.1.6 Geological Map

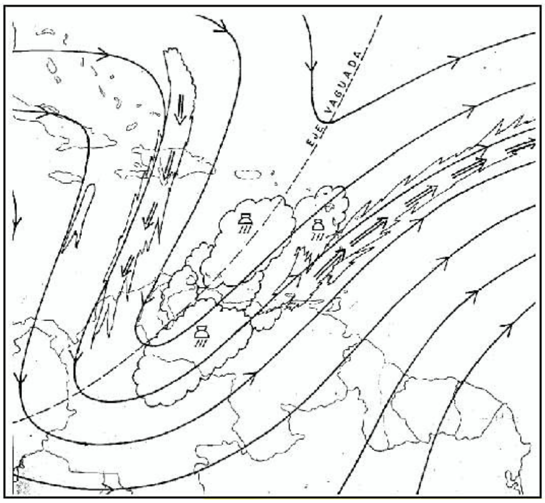
Hurricane/Tropical Depression Trail



Wave of the East
(Tropical Waves)



Cold Front



Low Pressure Zone on the High
(Vaguadas)

Figure 4.1.1.7 Significant Weather Patterns in Venezuela

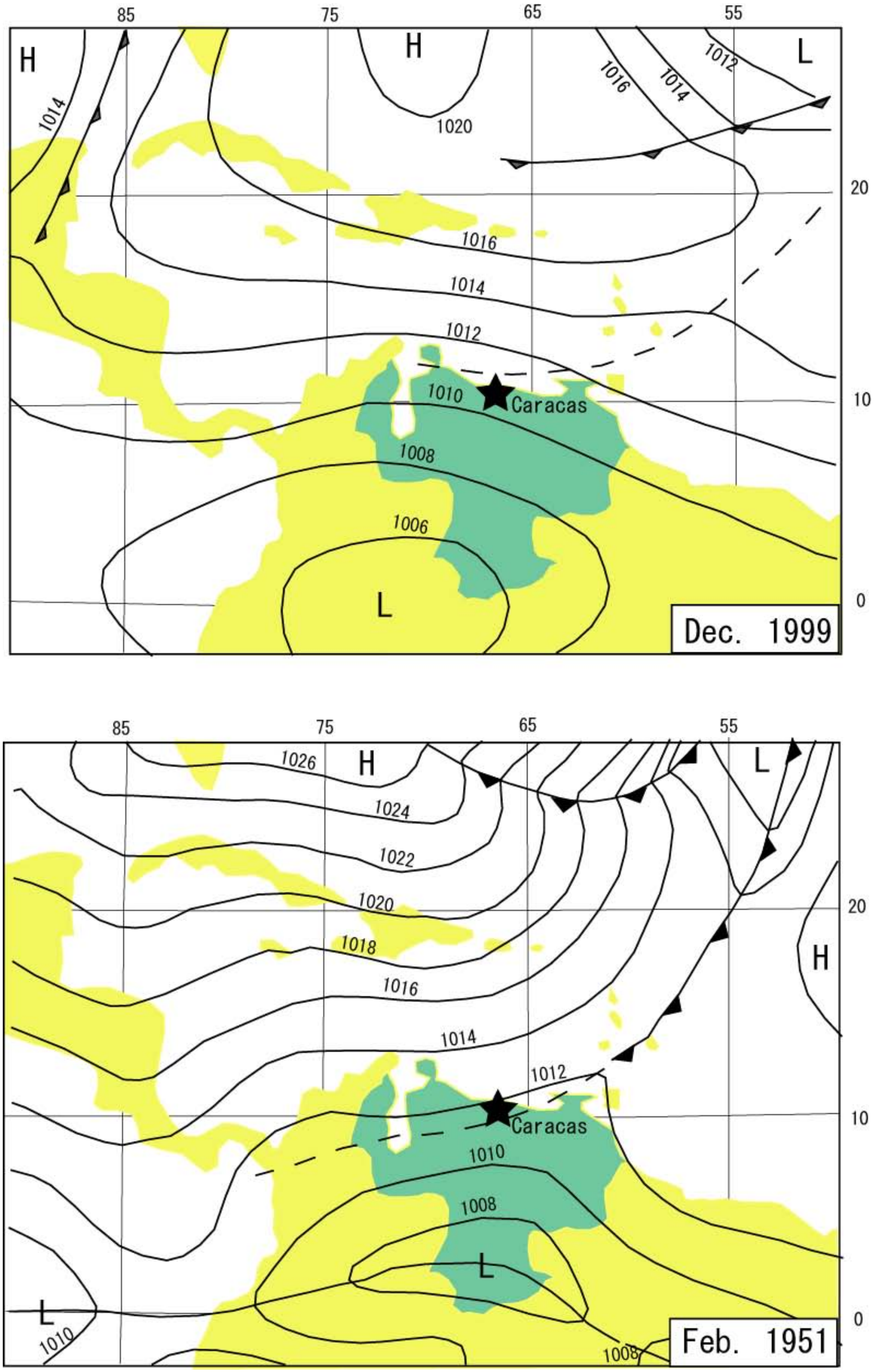


Figure 4.1.1.8 Meteorological Synopsis around Venezuela

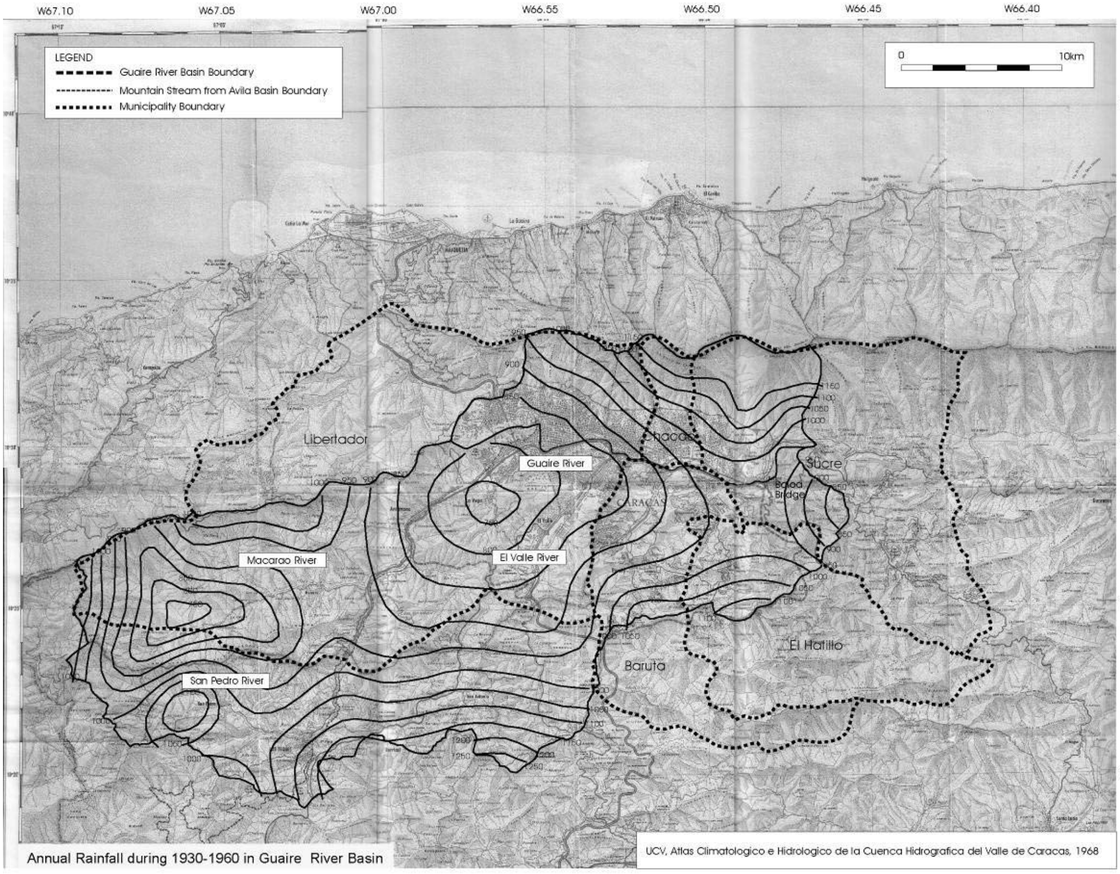
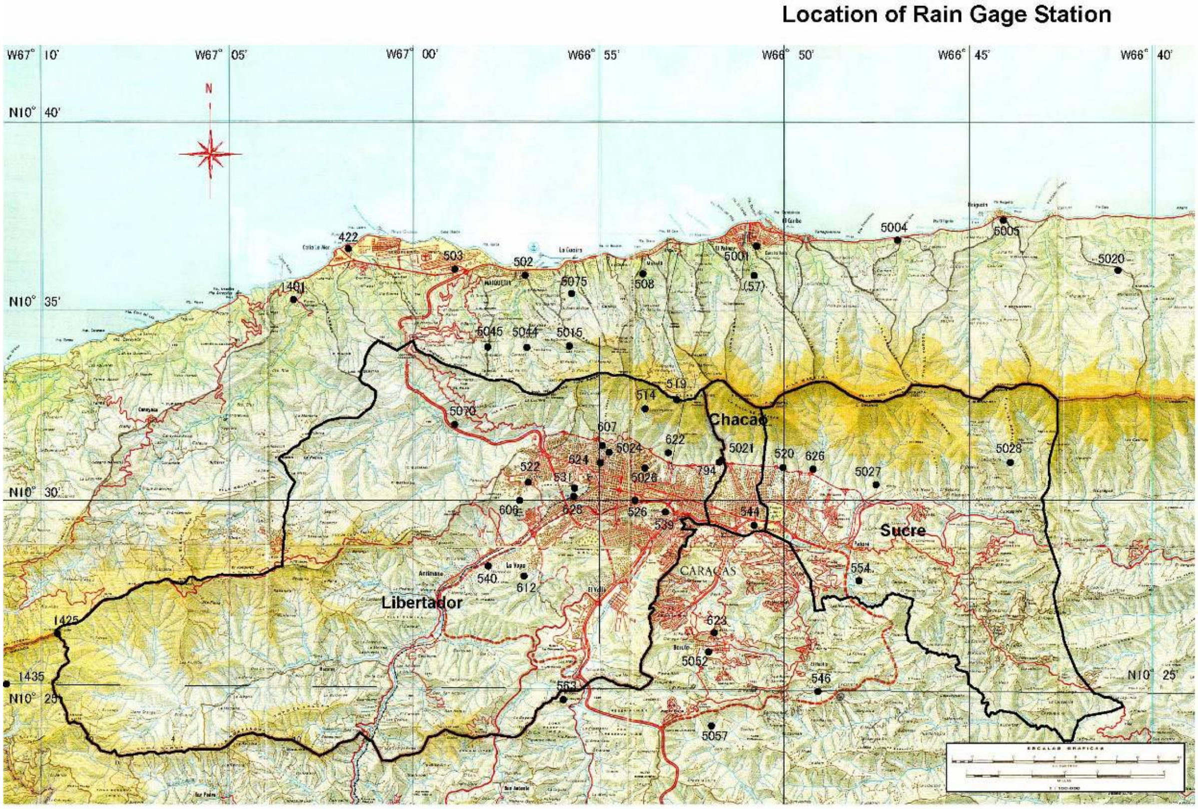
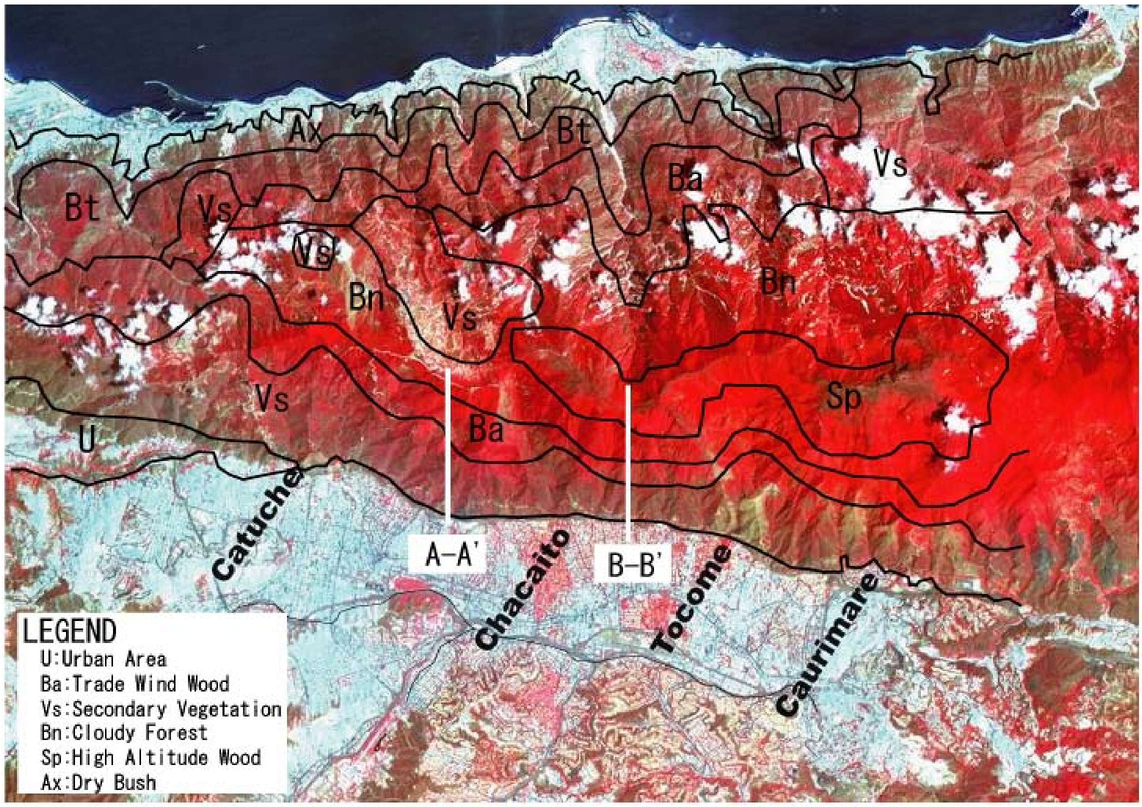


Figure 4.1.1.9 Annual Rainfall during 1930-1960 in the Guaire River Basin



No	Code	Station	Organization	Altitude (m)	Latitude	Longitude	Period Daily (Hourly)	No	Code	Station	Organization	Altitude (m)	Latitude	Longitude	Period Daily (Hourly)
	422	Catia La Mar						18	612	Ccs-Circulo Militar	MARN	920	102800	665700	67-82
1	502	Maiquetía (MARN)	MARN	75	103600	665700	48-83	19	622	Ccs-Teleférico	MARN	1160	103110	665310	68-80
2	503	Maiquetia-Aerop.(FAV)	FAV	43	1031	6659	64- (98-)	20	623	Ccs-La Trinidad	MARN	962	102634	665158	68-99
3	508	Macuto	MARN/UCV	53	103601	665347	75-96 / 01- (01-)	21	624	Ccs-Urb Miranda	MARN	1000	103100	665500	68-82
4	514	Ccs-Los Venados	MARN	1540	103219	665341	94- (01-)	22	626	Los Chorros	MARN	1000	103050	664926	67-83
5	519	Hotel Humboldt	MARN/UCV	2129	103240	665254	58-74 / 00- (01-)	23	628	Ccs-Zona Uno(San Martin)	MARN	920	103010	665540	86-99
6	520	Ccs-La Salle	MARN	1007	103048	665000	60-83	24	794	Ccs-Edif. La Paz	MARN	900	103129	665200	62-80
7	522	Ccs-Catia	MARN	970	103029	665648	53-83	25	1072	Tacamahaca	MARN	1300	105700	663900	78-94
8	526	Ccs-Torre Sur	MARN	1060	103000	665400	65-83	26	1510	Fila de Turgua	MARN	1107	102229	664524	67-99
9	531	Cagigal	Armada	1042	103025	665539	1891-	27	5005	Naiguata	MARN	49	103725	664408	75- (00-)
10	539	UCV	MARN/UCV	884	102941	665312	49-80 / 81- (01-)	28	5011	Los Caracas	MARN	15	103722	663722	77- (01-)
11	540	Ccs-Had. Montalban	MARN	937	102822	665805	75-83	29	5021	Ccs-Chacaito	MARN	1205	103127	665149	67-83 / 00- (00-)
12	544	La Carlota	FAV	835	1030	6653	64- (98-)	30	5024	Ccs-Subida Avila	MARN	1000	103121	665457	67-74
13	546	El Hatillo	MARN	1132	102500	664900	77-83	31	5026	Ccs-San Bernardino	MARN	-	103052	665347	75-83
14	555	Ccs-Petare-Caurimare	MARN	700	102800	664800	79-83	32	5027	Ccs-Caurimare	MARN	965	102519	665329	49- (00-)
15	563	Ccs-La Mariposa	MARN	980	102444	665536	49- (99-)	33	5028	Macanillal	MARN	1397	103100	664400	77-83
16	606	Ccs-Cuartel Urdaneta	MARN	970	103000	665700	66-77	34	5057	Ccs-USB	MARN	1225	102507	665248	71-98
17	607	Ccs-San José Avila	MARN	999	103121	665458	67-83	35	5070	Ojo De Agua	MARN	608	103156	665853	76-96

Figure 4.1.1.10 Location of Rain Gauge Station



Remarks:Satellite Image Infrared by ASTER
Vegetation of Western Part of the Avila Mountain(HUBER & ALARCON)

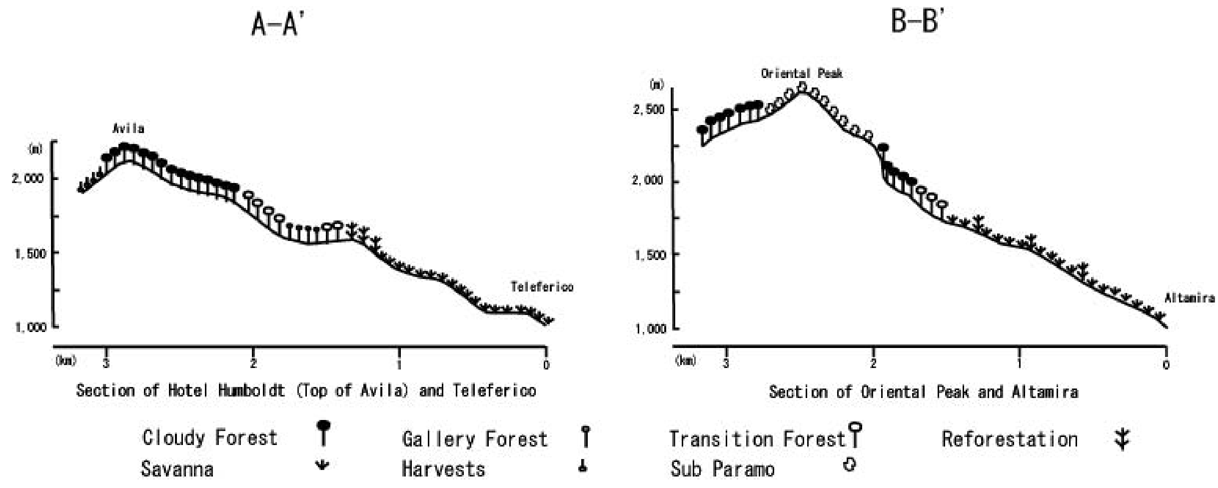


Figure 4.1.1.11 Vegetation in El Avila Mountain