Capital District of Bogotá and Soacha Municipality The Republic of Colombia

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

FINAL REPORT

VOLUME 3 SUPPORTING REPORT

MARCH 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

PACIFIC CONSULTANTS INTERNATIONAL OYO INTERNATIONAL CORPORATION



No.

Capital District of Bogotá and Soacha Municipality The Republic of Colombia

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

FINAL REPORT

VOLUME 3 SUPPORTING REPORT

MARCH 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

PACIFIC CONSULTANTS INTERNATIONAL OYO INTERNATIONAL CORPORATION

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

CONTENTS OF SUPPORTING REPORT

- S1 TOPOGRAPHY AND GEOLOGY
 - S1-1 Topography and Geology of Colombia
 - S1-2 Topography and Geology of Bogota and Surroundings

S2 METEOROLOGY AND HYDROLOGY, MONITORING SYSTEM AND RAINFALL AND DISASTER RECORD

- S2-1 Meteorology and Hydrology
- S2-2 Meteo-hydrological Monitoring and Forecasting
- S2-3 Rainfall and Disasters Record

S3 AERIAL PHOTO INTERPRETATION AND CREEK CONDITIONS

- S3-1 Aerial Photo Interpretation
- S3-2 Creek Conditions
- S3-3 Outcrops

S4 SOCIO-ECONOMY CONDITIONS

- S4-1 Socio-Economy Conditions in Bogota
- S4-2 Socio-Economy Conditions in Soacha
- S5 LANDSLIDE STUDY
 - S5-1 Landslide in Bogota
 - S5-2 Landslides in Soacha Municipality
- S6 FLOOD STUDY
 - S6-1 General Description of Study Area
 - S6-2 Analysis of Major Flood
 - S6-3 Hydrological Modeling
 - S6-4 Mapping of Flood Susceptibility
- S7 COMMUNITY ACTIVITIES
- S8 PILOT PROJECT
 - S8-1 Landslide
 - S8-2 Flood

SUPPORTING REPORT

S1

TOPOGRAPHY AND GEOLOGY

TABLE OF CONTENTS OF S1 TOPOGRAPHY AND GEOLOGY

CHAP	TER 1 TOPOGRAPHY AND GEOLOGY OF COLOMBIA	S1-1-1
1.1	The Andes	S1-1-1
1.2	Topography of Colombia	S1-1-1
	Geology	S1-1-1
	TER 2 TOPOGRAPHY AND GEOLOGY OF BOGOTA AND SURROUNDINGS	S1-2-1
		S1-2-1 S1-2-1
2.1	SURROUNDINGS	

List of Tables

Table S1-1-1	Geological Formation and Zones in Colombia	
	(USGS-INGEOMINAS, 1984)	S1-1-3
Table S1-2-1	Geological Stratigraphy and Geology Distribution in each River	
	Basin	S1-2-4

List of Figures

Figure S1-1-1	Topographic Map of Colombia and Cross Section of Andes Mountains	S1-1-2
Figure S1-1-2	Topographic Classification in Colombia	S1-1-2
Figure S1-2-1	Topographic Map of Sabana de Bogota	S1-2-1
Figure S1-2-2	Topographical Cross Section Correspond to the Line in Figure	S1-2-1
Figure S1-2-3	Sediment in Sabana de Bogota (Bogota Plateau, Section A)	S1-2-2
Figure S1-2-4	Geology Map in Study Area	S1-2-3

CHAPTER 1 TOPOGRAPHY AND GEOLOGY OF COLOMBIA

1.1 The Andes

The Andes are huge South American mountain system that extends north to south along the western coast from Panama to Tierra del Fuego. It consists of several ranges and has its highest peak at Aconcagua 6,960 m. The mountain belt is generally about 300 km wide, except in Bolivia, where it expands to twice that width. From north to south the belt can be divided into three regions: a northern section in Venezuela, Colombia, and northern Ecuador; a central section in southern Ecuador, Peru, Bolivia, and the northern regions of Argentina and Chile; and a southern section in the southern regions of Argentina and Chile.

1.2 Topography of Colombia

The territorial area of Colombia is 1,138,910 km², ranging between latitude 4.2 degree south and 12.4 degrees north, and between longitude 66.9 degrees west and 78.8 degrees west. Colombia faces Pacific Ocean in west side, Caribbean Sea in north side, and is bordered on the northwest by Panama, on the east by Venezuela and Brazil, and on the southwest by Peru and Ecuador.

The northern Andes in Colombia curve in an arc from northeast to southwest. The arc consists of three main parallel ranges, known as the Cordillera Occidental (Western Cordillera), the Cordillera Central (Central Cordillera), and the Cordillera Oriental (Eastern Cordillera). There are plateaus and valleys between the each cordillera in which are the most densely populated parts of the country. In addition to three main ranges, there is a coastal mountain range on the Pacific coast of Colombia, the Baudó Mountains (Serranía de Baudó). Geologically, the Baudó Mountains represent an extension of the Isthmus of Panama. They are separated from the Cordillera Occidental by the Atrato valley where the Atrato River flows and Quibdó is located.

The rivers flowing toward the Pacific are short and small in volume because the rainfall on the western slopes of the mountains is limited. The streams to the east are long and supplied with an abundance of water from the trade winds, which deposit precipitation as they approach the mountains. These mountain streams are the source of the major headstreams of the three great river systems of South America: the Amazon, which flows through Peru and Brazil; the Orinoco of Colombia and Venezuela; and the Parana-Paraguay-Uruguay river system, which empties into the Rio de la Plata, a large marine estuary along the Atlantic coast between Uruguay and Argentina.

As shown in Figure S1-1-1, Bogota is located at an elevation of about 2640 m on a mountain-rimmed plateau high in the Cordillera Oriental of the Andes Mountains.

1.3 Geology

Colombia is generally classified into two measure geological areas, Orogeny and Shield. The south-eastern part of Colombia is flat land of the Shield area which is the oldest and most stable structural element of the continent. It comprises a Precambrian (before 570 million years ago) complex of igneous and metamorphic rocks. In most places the shield is overlaid by sedimentary rocks, mostly of Paleozoic age (570 million to 225 million years ago). The north-western part of Colombia is the Orogenic area where is active area of folding, faulting, and uplift of the Earth's crust to form the Andes Mountain ranges, often accompanied by volcanic and seismic activity. The Orogenic area in Colombia is the northern end of the Andean range formed by collision of eastward subjecting Nazca plate with a moving rate of 70 mm / year.

Colombia is distinguished into nine areas harmonizing furthermore with the topographic classifications, and the areas correspond with geological features as shown Figure S1-1-2 and below.

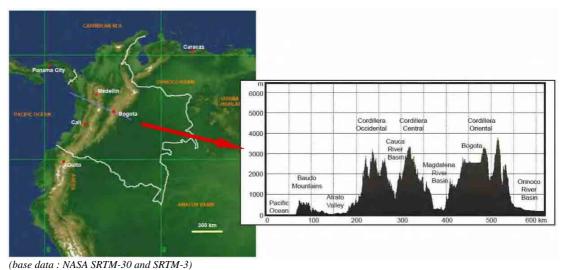
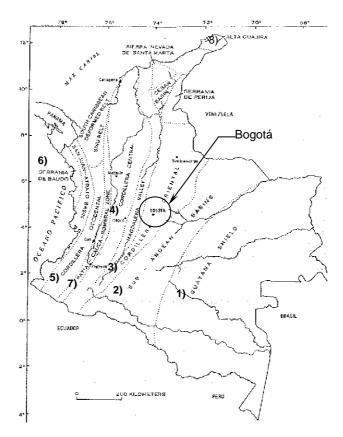


Figure S1-1-1 Topographic Map of Colombia and Cross Section of Andes Mountains



(USGS-INGEOMINAS, 1984)

Figure S1-1-2 Topographic Classification in Colombia

The Shield Area 1) Guayama Shield 2) Sub-Andean Basins

<u>The Orogenic Area</u> 3) Cordillera Oriental, Serrania de Perija

- 4) Cordillera Central
- 5) Cordillera Occidental
- 6) Serrania de Baudo
- 7) Patia-Cauca-Romeral
- 8) Mountain and sedimentary basin in Guajira Peninsula
- 9) Inland basin between mountains

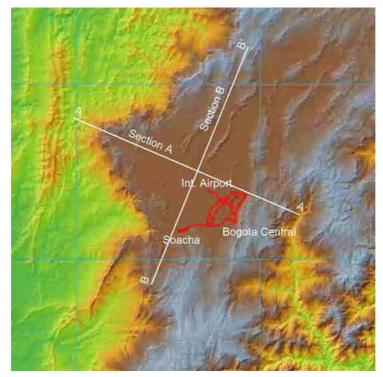
Nar	me of Geological Zone	Location	Geological Time	Explanation
1)	Guayana Shield	Vast reaches of lowland drained by tributaries of the Amazon and Orinoco		high-grade metamorphic rock, low grade metamorphic rock, and intrusive granite series
2)	Sub-Andean Basins	East of the Cordillera Oriental	Tertiary and Quaternary	Tertiary and Quaternary deposit
3)	Cordillera Oriental, Serrania de Perija	Cordillera Oriental	Palaeozoic Cretaceous	metamorphic rock of Precambrian to Palaeozoic and intrusive plutonic rock covered by gravel stone, sand stone and silt stone of continental sediment in the south area, covered by sandstone and claystone of Cretaceous epi-continental sediment in the central area (Bogotá, etc)
4)	Cordillera Central	Cordillera Central		crystalline rock in north area, partially metamorphic craton and oceanic deposit in central area, and volcanic association in central to south area
5)	Cordillera Occidental	Cordillera Occidental	Late Mesozoic	basic deposit by submarine volcano of late Mesozoic, flysch deposit, etc
6)	Serrania de Baudo	Serrania de Baudo	Mesozoic to Tertiary	mud stone, silt stone, sandstone and chert of late Mesozoic to Tertiary
7)	Patia-Cauca-R omeral	Between Cordillera Central and Cordillera Occidental		central mountain range consisted of continental crust and west side mountain range consisted of oceanic crust
8)	Mountain and sedimentary basin in Guajira Peninsula	Guajira Peninsula	Cretaceous and/or Tertiary	Cretaceous and/or Tertiary sedimentary rock, and granite in large mass of Jurassic and in small mass of Tertiary
9)	Inland basin between mountains	Between Cordillera Oriental and Cordillera Central	Tertiary	Tertiary sedimentary basin between mountains

Table S1-1-1 Geological Formation and Zones in Colombia (USGS-INGEOMINAS, 1984)

CHAPTER 2 TOPOGRAPHY AND GEOLOGY OF BOGOTA AND SURROUNDINGS

2.1 Topography

Bogota locates in a flat plateau that is namely Bogota Plateau or Sabana de Bogota, which is averagely 2,560 m above mean sea level and the height of eastern mountainous area reaches 3,000 m and more, beside the west side slope of the Cordillera Oriental as shown in Figure S1-1-1. Bogota Plateau (Sabana de Bogota) is extending about 40 km from northwest to southeast and 60 km from northeast to southwest as shown in Figures S1-2-1 and S1-2-2. City growth of Bogota in Bogota Plateau is limited by surrounding hills in the east and by Bogota River in the west.



(base data : NASA SRTM-3)

Figure S1-2-1 Topographic Map of Sabana de Bogota

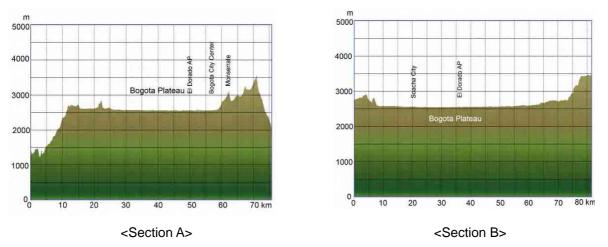
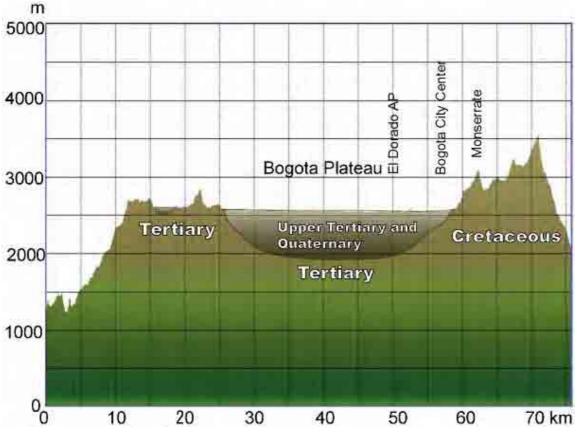


Figure S1-2-2 Topographical Cross Sections correspond to the Lines in Figure (base data NASA-SRIM-3)

2.2 Geology

Geology in the area and its environment distributes sandstone, siltstone and claystone of Cretaceous to Tertiary in mountainous area. Quaternary sediment of lake origin spreads in Bogota Plateau (Sabana de Bogota), while the mountains area in the east and south of Bogota Plateau is mostly composed of Cretaceous or Tertiary origin sediment rock. They are made of mostly sandstone or siltstone. Thickness of the Quaternary sediment in Bogota Plateau is over 500 m as shown in Figure S1-2-3.

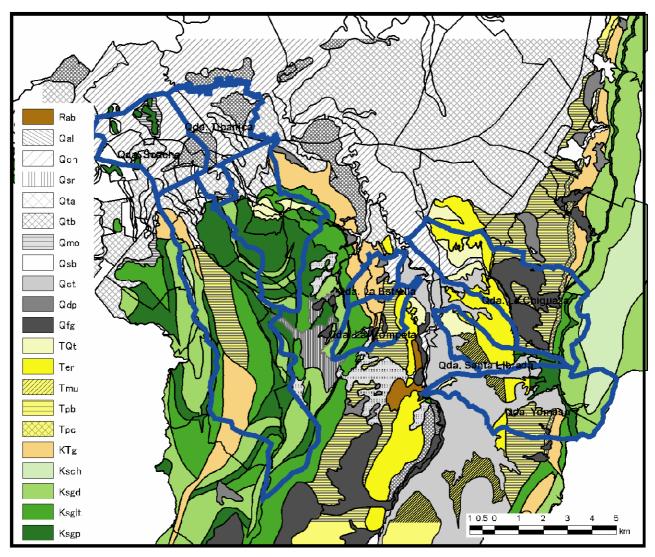


(prepared based on IGAC, 1995)

Figure S1-2-3 Sediment in Sabana de Bogota (Bogota Plateau, Section A)

2.3 Geology of Study Area

Figure S1-2-4 and Table S1-2-1 shows geology map in study area and stratigraphy and geology distribution conditions in each river basin, respectively.



(Source: existing JICA Study)

Figure S1-2-4 Geology Map in Study Area

Landslides in Bogota

Landslides in Bogota are generally distributed at steep slopes in the eastern part of the Bogota. Many landslides are located along Bogota Fault which runs along the eastern rim of Bogota Plateau.

Landslides in Soacha

There are large scale quarries, from which sand and stone as material for bricks and construction is extracted, along Soacha River. Many of the open quarries are abandoned and there are many residential houses in the abandoned quarries. Most of the landslide disasters have occurred along excavated steep slopes in the abandons quarries.

Rivers

The total area of the river basin in Bogota and in Soacha is 41.8 km² that consist of Chiguaza River (18.7 km²), Santa Librada River, (15.4 km²), Yomasa River (5.5 km²), La Estrella-El Trompeta River (2.2 km²) and is 40 km² that consist of Soacha River (30 km²), Tibanica River, (10 km²), respectively

.⊆
asir
ш
River
i R
_
ac
stribution in each
. <u> </u>
Б
Ē
<u>9</u>
Distrik
⊡ ≥
g
9
ĕ
G
nd Geology
a /
Ę
ap
g
ъ
な
Seological Stratigraphy and Geology Dist
G
ğ
eo
G
7
<u>5</u>
Table S1-2-1 Ge
<u>e</u>
ab
F

GEOLOG	GEOLOGICAL AGE	GEOLOGICAL UNIT	LEGEND	LITHOLOGICAL DESCRIPTION	Chi	San Yom		Est T	Tib S	Soa
		Artificial fill, garbage	Rab	Garbage deposits technically formed or disposed in the creeks beds		-	0			
		Chia Formation	Qch	Lacustrine clay and/or flood origin locally silt stone and diatomic clay.	0			0	0	0
		Slope Deposit	Qdp	Supported matrix deposit. Pebble and quartz sandstone blocks, inside a clayey matrix and clayey sand. Clastic-supported deposit specially sandstone blocks	0			0		
		Mondoñedo Formation	Qmo	Slope silt deposit locally sand with fragments of sub-angular rock, with black and grey soil	-					0
		Residual Soil	Qsr	Clayey sand material, product of weathering and alteration from parental material, especially over soft formations						0
Quat	Quaternary	Lower Terrace Deposit	Qtb	Mud and clay, in part organics that are forming the soft infilling of the Sabana de Bogotá					0	0
		High Terrace Deposit	Qta	Constituted by conglomerates, angular, clastic-supported. Transported materials and deposited on the transition zone, between the rocky formations and the flat zone.	•			0	0	0
		Sabana Formation, Sabana Soil	Qsb	Red soil, brownish and black soil complex in the high part f the hills.				0		0
		Tunjuelito Formation	Qct	Gravel, boulder and rounded to sub-rounded blocks, inside a mud-clayey matrix	0	0	0	0		
		Fluvial - Glacial Deposit	Qfg	Sandstone blocks and pebbles of sub-rounded to angular forms, flattened, and embedded in a clayey silt matrix, produced by transport of big flows provided from Sumapáz Paramo.	•		0	0		
Tertiary – Quaternary	Pleistocene	Tilata Formation	TQt	Clay and clayey sand of white color, peat and small size pebbles levels.	0	0	0	0	0	
	Oligocene – Miocene	Usme Formation	Tmu	Bright grey colored mudstone bands, with quartz and feldspar sandstone, fine grained, in mid parallel bands.		0	0			
Tertiarv	Middle Eocene	La Regadera Formation	Ter	The superior group is conformed by bands of quartz-feldspar sandstone and claystone, and inferior group by quartz-feldspar sandstone, course grained to conglomeratic, grey colored.	•	0	0	0		
	Upper Paleocene to Eocene	Bogota Formation	Трb	Mudstone, siltstone and claystone, separated by soft clayey sandstone stratum.	0		0	0		0
1	Upper Paleocene	Cacho Formation	Трс	Claystone violet colored.	0		0			

GEOLO	GEOLOGICAL AGE	GEOLOGICAL UNIT	LEGEND	LITHOLOGICAL DESCRIPTION	Chi (San Yom	om Est		Tib Soa
Cretaceous				Superior group: Claystone bands with thin mantles of coal					
- leiliaiy	Maestrichtian to Lower	Maestrichtian to Lower	K-Tg	Mead group: Sandstone on the base and laminated sandstone on the ceiling, separated by compact claystone which contains mantles of coal	0		0		0
	Paleocene			Inferior group: Dark grey colored claystone.					
				Soft sand stone: Sandstone course grained to conglomeratic, with thin mudstone bands, silt stone and clay stone	-				
				Labor sand stone: Sandstone fine grained, clayey, compact, separated by thin bands of claystone					
	Maestrichtian	Maestrichtian Guadalupe Group	Ksgl-t	Hard sandstone: Constituted by a sequence of sandstone in thick banks, with bands of siltstone, mudstone, lidite rock and claystone, in fine layers.	0	0	0	0	0
Cretaceous				Plaeners: Sequence of siliceous claystone and lidite rock. Bands of siliceous siltstone, green claystone and thin stratums of fine to mid grained sandstone. Between lutites rocks are found thin layers of fine grey sandstone, associated to coal and discontinuous sandy layers.					
	Lower Maestrichtian	Guadalupe Group, Planeners Formations	Ksgp	Siliceous siltstone, porcelainite, lidite and fine grain size.	0	0	0	0	0
	Upper Coniasian to Campanian	Guadalupe Group, Dura Sandstone Formation	Ksgd	Sandstone in very thick banks with thin siltstone, mudstone and claystone intercalations	0	0	0	0	0
	Cenomanian to Coniacian	Chipaque Formation	Ksch	Dark lutites with calcareous-sand intercalations	0		0		0
*: Abbrevia	tion of the river l	asin. Chi. Cionaza San. So	nnta Librado	*. Abhreviation of the river busin: Chi-Cionaza Sant Librada Yom: Yomasa Est: Estrella and Tramneta Tib: Tibanica Soa: Soacha					-

SUPPORTING REPORT

S2

METEOROLOGY AND HYDROLOGY, MONITORING SYSTEM AND RAINFALL AND DISASTER RECORD

TABLE OF CONTENTS

OF

S2 METEOROLOGY AND HYDROLOGY, MONITORING SYSTEM AND RAINFALL AND DISASTER RECORD

CHAP	TER 1 METEOROLOGY AND HYDROLOGY	S2-1-1
1.1	General Description in Cundinamarca including the Study Area	S2-1-1
1.2	Meteorological/Hydrological Stations in and around the Study Area	S2-1-2
1.3	Characteristic of Rainfall in and around the Study Area	S2-1-8
	1.3.1 Annual Rainfall	
	1.3.2 Monthly Rainfall	
	1.3.3 Number of Rainy Days in Month	S2-1-13
	1.3.4 Daily Rainfall	S2-1-13
	1.3.5 Hourly Rainfall	S2-1-15
1.4	Correlation of Rainfall Stations-Correlation of Rainfall Pattern-	S2-1-20
	1.4.1 Correlation of Rainfall Stations in and around the Study Area	S2-1-20
	1.4.2 Correlation of DPAE Rainfall Stations	
СНАР	TER 2 METEO-HYDROLOGICAL MONITORING AND FORECASTING	S2-2-1
2.1	Existing Situation about Hydrological-Meteorological Monitoring System	S2-2-1
	2.1.1 Allocation of Observing Stations in the Study Area	S2-2-1
	2.1.2 IDEAM	S2-2-3
	2.1.3 DPAE	S2-2-7
	2.1.4 EAAB	S2-2-9
	2.1.5 CAR	S2-2-12
	2.1.6 Data Exchange Among Organizations Concerned	S2-2-12
2.2	Weather Forecasting by IDEAM	S2-2-13
	2.2.1 Weather Forecasting	S2-2-13
	2.2.2 Types of Alert and Criteria	S2-2-14
	2.2.3 Background Information of Weather Forecasting	S2-2-16
	2.2.4 Difficulty of Weather Forecasting in Colombia	S2-2-16
	2.2.5 Upgrade of Weather Forecasting	
2.3	Monitoring by DPAE	
	2.3.1 General	S2-2-20
	2.3.2 Existing Warning Criteria	
	2.3.3 Improvement of Accuracy of Warning	
СНАР	TER 3 RAINFALL AND DISASTERS RECORD	S2-3-1
3.1	Analyses for Target Basins in Bogota	S2-3-1
	3.1.1 General Characteristic of Disasters and Selection of Disaster Events for	
	Analyses	S2-3-1
	3.1.2 Analysis for Relation between Rainfall and Selected Disaster Events	
3.2	Analyses for Soacha	
	3.2.1 Disaster Events for the Analyses in Soacha	
	3.2.2 Analysis for Relation between Hydrological Conditions and Selected	
	Disaster Events	S2-3-27

List of Tables

Table S2-1-1	Monthly Humidity in San Jorge (GJA) Station (IDEAM)	S2-1-2
Table S2-1-2	Multi-Annual Average Temperature in Bogota	S2-1-2
Table S2-1-3	Monthly Temperature in San Jorge (GJA) Station (IDEAM)	S2-1-2
Table S2-1-4	List of Meteorological/Hydrological Stations in and around the	
	Study Area	S2-1-4
Table S2-1-5	Collected Hydrological Data from DPAE	S2-1-5
Table S2-1-6	Collected Hydrological Data from EAAB	S2-1-6
Table S2-1-7	Collected Hydrological Data from CAR	S2-1-7
Table S2-1-8	Collected Hydrological Data from IDEAM	S2-1-7
Table S2-1-9	Number of Rainy Days in 2003	S2-1-13
Table S2-1-10	Probable Daily Rainfall	S2-1-14
Table S2-1-11	Rainfall Intensity in each Zone	S2-1-18
Table S2-2-1	Time Lag of GOES System	S2-2-4
Table S2-2-2	Contents of weather Forecasting by IDEAM	S2-2-14
Table S2-2-3	Contents of Alerts by IDEAM	S2-2-15
Table S2-2-4	Meteorologists in IDEAM	S2-2-17
Table S2-3-1	Inundation Record by DPAE in Target Basins in Bogota	S2-3-3
Table S2-3-2	Inundation Record in 2000 - 2005 by IDEAM Study in Target	
	Basins in Bogota	S2-3-4
Table S2-3-3	Selected Landslide Events for Analysis in Target Basins in Bogota	S2-3-6
Table S2-3-4	Summary of Relation between Annual Top 10 of Daily Rainfall and Inundation Events	S2-3-9
Table S2-3-5	Summary of Relation between Annual Top 10 of Hourly Rainfall	
	and Inundation Events	S2-3-11
Table S2-3-6	Summary of Relation between Inundation Events and Daily Rainfall	S2-3-17
Table S2-3-7	Thresholds of Daily Rainfall for Inundation	S2-3-17
Table S2-3-8	Average Number of Days of Daily Rainfall Amount per Year	S2-3-18
Table S2-3-9	Daily Rainfall of the Day of Landslides Occurrence	S2-3-18
Table S2-3-10	Summary of Relation between Landslide Events and Rainfall	S2-3-22
Table S2-3-11	Example of Thresholds for General Warning of Landslide	S2-3-22
Table S2-3-12	Inundation Records in Soacha Urban Area	S2-3-26
Table S2-3-13	Landslide Records in Soacha Urban Area	S2-3-27
Table S2-3-14	Selected Landslide Events for Analysis in Soacha	S2-3-27
Table S2-3-15	Summary of Relation between Inundation Events and Daily Rainfall	S2-3-29
Table S2-3-16	Differences between Average Water Level and Water Levels in	
	Inundations	S2-3-29
Table S2-3-17	Summary of Relation between Inundation Events and Daily Rainfall	S2-3-31
Table S2-3-18	Thresholds for Inundation in Soacha	S2-3-32
Table S2-3-19	Average Number of Days of Daily Rainfall Amount per Year	S2-3-32
Table S2-3-20	Summary of Relation between Landslide Events and Rainfall	S2-3-33
Table S2-3-21	Example of Threshold for General Warning of Landslide	S2-3-34

List of Figures

Figure S2-1-1	Displacement of ITCZ	S2-1-1
Figure S2-1-2	Location Map of Meteorological/Hydrological Stations in and	
-	around the Study Area	S2-1-3
Figure S2-1-3	Annual Rainfall Distribution (2002)	S2-1-8
Figure S2-1-4	Annual Rainfall Distribution (2003)	S2-1-9

Figure S2-1-5	Annual Rainfall Distribution (2004)	S2-1-9
Figure S2-1-6	Monthly Rainfall Distribution (January - December, 2003) (1/3)	S2-1-10
Figure S2-1-6	Monthly Rainfall Distribution (January - December, 2003) (2/3)	S2-1-11
Figure S2-1-6	Monthly Rainfall Distribution (January - December, 2003) (3/3)	S2-1-12
Figure S2-1-7	Monthly Rainfall Variation in 2003 (1/2)	S2-1-12
Figure S2-1-8	Rainy Days in Month in 2003	S2-1-13
Figure S2-1-9	Maximum Daily Rainfall in DPAE Stations in Eastern Side of Rio	52 1 15
1 iguie 52 1 9	Tunjuelo from 2000 to 2006	S2-1-14
Figure S2-1-10	Maximum Daily Rainfall in DPAE Stations in Western Side of Rio	52 1 1 1
1 Igure 52-1-10	Tunjuelo from 2000 to 2006	S2-1-14
Figure S2-1-11	Daily Rainfall Distribution (May 8 - 12, 2006)	S2-1-14 S2-1-15
U	Maximum Hourly Dainfall in DDAE Stations in Eastern Side of Die	52-1-15
Figure S2-1-12	Maximum Hourly Rainfall in DPAE Stations in Eastern Side of Rio	S2 1 16
E	Tunjuelo from 2000 to 2006	S2-1-16
Figure S2-1-13	Maximum Hourly Rainfall in DPAE Stations in Western Side of Rio	02 1 17
E. CO 1 14	Tunjuelo from 2000 to 2006	S2-1-17
Figure S2-1-14	Zoning of Rainfall Pattern	S2-1-17
Figure S2-1-15	Relation between Daily Rainfall and Hourly Rainfall in DPAE	GA 1 10
	Stations in 2000-2006	S2-1-18
Figure S2-1-16	Rainfall Distribution in 1:00-24:00 in Tanque Quiba Station	S2-1-19
Figure S2-1-17	Rainfall Distribution in 1:00-24:00 in Micaela Station	S2-1-19
Figure S2-1-18	SCS 24-hour Rainfall Distributions	S2-1-20
Figure S2-1-19	Correlation of Monthly Rainfall (2000 - 2006)	S2-1-22
Figure S2-1-20	Correlation of Daily Rainfall (2003)	S2-1-23
Figure S2-1-21	Correlation of Monthly Rainfall in DPAE Stations (2000-2006)	S2-1-24
Figure S2-1-22	Correlation of Daily Rainfall in DPAE Stations (2003)	S2-1-25
Figure S2-2-1	Meteorological and Hydrological Stations	S2-2-1
Figure S2-2-2	Meteorological and Hydrological Stations around the Study Area	S2-2-2
Figure S2-2-3	Station Network around the Study Area	S2-2-2
Figure S2-2-4	Composition of Minuto Station	S2-2-3
Figure S2-2-5	San Jorge Station	S2-2-3
Figure S2-2-6	Geostational Meteorological Satellites around the Earth	S2-2-4
Figure S2-2-7	GOES Antennas on the Roof of IDEAM	S2-2-4
Figure S2-2-8	Data Collecting System in IDEAM	S2-2-5
Figure S2-2-9	Sample of the River Data in IDEAM Web Site	S2-2-6
Figure S2-2-10	Composition of San Benito Station	S2-2-7
Figure S2-2-11	Data Collecting System in DPAE	S2-2-8
Figure S2-2-12	Sample of the DPAE Web Site	S2-2-9
Figure S2-2-12	Composition of Las Huertas Station (Telemetry & Conventional)	S2-2-10
Figure S2-2-14	Data Collecting System in EAAB	S2-2-10 S2-2-10
Figure S2-2-14	Sample of the EAAB Web Site	S2-2-10 S2-2-11
Figure S2-2-15 Figure S2-2-16		S2-2-11 S2-2-12
•	San Jorge Station.	
Figure S2-2-17	On-line Data Exchanging via Internet	S2-2-13
Figure S2-2-18	Off-line Data Exchanging	S2-2-13
Figure S2-2-19	Enlarged and Global Satellite Image in IDEAM Web Site	S2-2-14
Figure S2-2-20	Special Information by IDEAM.	S2-2-15
Figure S2-2-21	Data Utilization Flow in IDEAM	S2-2-16
Figure S2-3-1	Frequency of Inundation Events (2001 Aug 2006 Jun.) in	
	Tunjuelito, Rafael Uribe, San Cristobal, Ciudad Bolivar and USME	<i></i>
	Localities	S2-3-1
Figure S2-3-2	Inundation Frequency in Target Basin in Bogota	S2-3-2
Figure S2-3-3	Frequency of Landslide Events (2002 Jan - 2006 Jul) in Tunjuelito,	
	Rafael Uribe, San Cristobal, Ciudad Bolivar and USME Localities	S2-3-5

Figure S2-3-4 Figure S2-3-5	Selected Stations for Analysis Relation between Annual Top 10 of Daily Rainfall in La Picota	S2-3-7
	Station (CAR) and Inundation Events in Chiguaza Basin (2001 Jul – 2005 Dec)	S2-3-8
Figure S2-3-6	Relation between Annual Top 10 of Daily Rainfall in Juan Rey	52 5 6
119410 52 5 0	Station (EAAB) and Inundation Events in Chiguaza and Santa	
	Librada Basins (2001 Jan – 2005 Dec)	S2-3-8
Figure S2-3-7	Relation between Annual Top 10 of Daily Rainfall in Micaela	0200
1 igui 0 52 5 7	Station (DPAE) and Inundation Events in Santa Librada and	
	Yomasa Basins (2001 Jan - 2006 Jun)	S2-3-9
Figure S2-3-8	Relation between Annual Top 10 of Daily Rainfall in Tanque Quiba	5259
1.8010.02.0.0	Station (DPAE) and Inundation Events in La Estrella and Trompeta	
	Basins (2001 Jan - 2006 Jun)	S2-3-9
Figure S2-3-9	Relation between Annual Top 10 of Hourly Rainfall in Micaela	52 5 7
1 iguite 52 5 5	Station (DPAE) and Inundation Events in Santa Librada and	
	Yomasa Basins (2001 Jan - 2006 Jun)	S2-3-10
Figure S2-3-10	Relation between Annual Top 10 of Hourly Rainfall in Tanque	52010
1.8010 02 0 10	Quiba Station (DPAE) and Inundation Events in La Estrella and	
	Trompeta Basins (2001 Jan - 2006 Jun)	S2-3-10
Figure S2-3-11	Rainfall Distribution in 1:00-24:00 (0:00) in Micaela Station and	52 5 10
119410 52 5 11	Inundation in Santa Librada Basin	S2-3-11
Figure S2-3-12	Rainfall Distribution in 1:00-24:00 in Tanque Quiba Station and	02 5 11
1 iguite 52 5 12	Inundation in La Estrella Basin	S2-3-12
Figure S2-3-13	Relation between Inundation Events in Chiguaza Basin and Daily	02 5 12
1 iguite 62 5 15	Rainfall in Juan Rey (EAAB) and La Picota (CAR) Stations	S2-3-12
Figure S2-3-14	Relation between Inundation Events in Yomasa Basin and Daily	52 5 12
119410 52 5 11	Rainfall in Micaela (DPAE) Station	S2-3-13
Figure S2-3-15	Relation between Inundation Events in Santa Librada Basin and	52 5 15
1 iguie 62 5 15	Daily Rainfall in Juan Rey (EAAB) and Micaela (DPAE) Stations	S2-3-13
Figure S2-3-16	Relation between Inundation Events in La Estrella Basin and Daily	02 5 15
119410 52 5 10	Rainfall in Tanque Quiba (DPAE) Station	S2-3-14
Figure S2-3-17	Relation between Inundation Events in Trompeta Basin and Daily	52 5 11
119410 52 5 17	Rainfall in Tanque Quiba Station (DPAE)	S2-3-14
Figure S2-3-18	Antecedent Rainfall in Micaela Station (EAAB) when Inundation	02 5 11
119410 52 5 10	Occurred in Yomasa Basin	S2-3-15
Figure S2-3-19	Antecedent Rainfall in Juan Rey Station (EAAB) when Inundation	52 5 10
119410 52 5 17	Occurred in Santa Librada Basin	S2-3-15
Figure S2-3-20	Antecedent Rainfall when Inundation Occurred	
Figure S2-3-21	Various Rainfall Amount in Landslides Occurrence and Average	52010
1.8010.02.0.21	Values in Juan Rey Station (EAAB)	S2-3-19
Figure S2-3-22	Correlation of 3 days Rainfall and Accumulative Rainfall in	52017
1 iguit 62 5 22	Chiguaza Basin	S2-3-19
Figure S2-3-23	Correlation of 3 days Rainfall and Accumulative Rainfall in Yomasa	52 5 17
1.8010 02 0 20	Basin	S2-3-20
Figure S2-3-24	Correlation of 3 days Rainfall and Accumulative Rainfall in La	52 5 20
119410 52 5 21	Estrella Basin	S2-3-20
Figure S2-3-25	Correlation of 3 days Rainfall and Accumulative Rainfall in	52 5 20
1 iguite 52 5 20	Trompeta Basin	S2-3-20
Figure S2-3-26	Distribution of 3 days Rainfall and Accumulative Rainfall in Juan	52 5 20
	Rey Station	S2-3-21
Figure S2-3-27	Distribution of 3 days Rainfall and Accumulative Rainfall in	~_ ~ 1
	Micaela Station	S2-3-21
Figure S2-3-28	Distribution of 3 days Rainfall and Accumulative Rainfall in Tanque	
	Quiba Station	S2-3-21
	X	

Figure S2-3-29	Number of Inundation Events in Barrio in Soacha Urban Area	S2-3-24
Figure S2-3-30	Number of Landslide Events in Barrio in Soacha Urban Area	S2-3-25
Figure S2-3-31	Selected Stations for Analyses	S2-3-28
Figure S2-3-32	Relation between Inundation Events and Daily Rainfall	S2-3-29
Figure S2-3-33	Comuna in Soacha	S2-3-30
Figure S2-3-34	Daily Rainfall in Inundation Events in Each Comuna (1/2)	S2-3-30
Figure S2-3-34	Daily Rainfall in Inundation Events in Each Comuna (2/2)	S2-3-31
Figure S2-3-35	Daily, 3 days and Accumulative Rainfall when Landslides Occurred	S2-3-32
Figure S2-3-36	Correlation of 3 days and Accumulative Rainfall when Landslide	
	Occurred	S2-3-33
Figure S2-3-37	Distribution of 3 days Rainfall and Accumulative Rainfall	S2-3-33

List of Photos

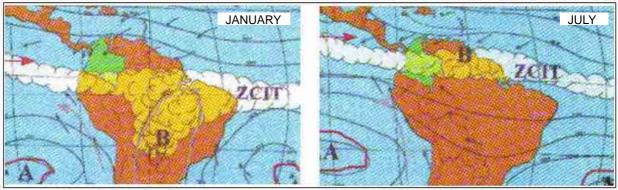
Photo S2-2-1	Minuto Station	S2-2-3
Photo S2-2-2	San Jorge Station	S2-2-3
Photo S2-2-3	Sierra Morena Station	S2-2-7
Photo S2-2-4	Transmitter	S2-2-7
Photo S2-2-5	Las Huertas Telemetry Station	S2-2-10
Photo S2-2-6	San Jorge Station	S2-2-12

CHAPTER 1 METEOROLOGY AND HYDROLOGY

1.1 General Description in Cundinamarca including the Study Area^{1, 2}

Colombia is located in the equatorial zone and presents an inverse relationship between clouds cover and sun brightness, registering a high cloud covering with high rainfall. The climate is affected by the relief, whose more important effect is the temperature conditioning. In the west cordillera that influences Cundinamarca, the variation of the temperature is 0.63°C for each 100 meters in their west flank (Sabana de Bogotá and Bogota's east hills), this variation is known as "Thermal Floors" or "Pisos Térmicos" in Spanish. According with this, Sabana de Bogotá corresponds to the cold thermal floor among 2000-3000m (height above sea level) and its temperatures is among 12-18°C.

In Colombia, the rainfall values varied due to interaction between equatorial zone and Andes cordillera. Colombia is included in the Inter tropical Convergence Zone (ITCZ), for this reason, the trade winds from northeast and southeast to get into the territory, generating the rains for convective phenomena. The ITCZ is displacing in latitudinal sense, and is located at the south in the first months of the year, and in the northern extreme of the country during July - August, with intermediate position during the rest of the year. Displacement of ITCZ is shown in Figure S2-1-1.



POSICIÓN DE LA ZCIT EN ENERO

POSICIÓN DE LA ZCIT EN JULIO

(Source: ("Fig.25,ESTUDIO DE LA CARACTERIZACIÓN CLIMÁTICA DE BOGOTA Y CUENCA ALTA DEL RIO TUNJUELO", FOPAE - IDEAM, 2006)

Figure S2-1-1 Displacement of ITCZ

The ITCZ displacement generate two (2) types of temporary rain fluctuation, registering in Cundinamarca the bimodal pattern, that is to say, two (2) wet or rainy periods alternated with two (2) dry periods. The varied relief is conditioning for the rainfall regime, because it serve as an obstacle for the air currents and it originates high rainfall volumes when the winds collide with the cordillera, and the air masses ascend and are condensed. The forced ascent for the air masses due to the relief, produce an orographic rain type that are characteristic for the Andean zone. In some sectors will be produced some temporary droughts in the interior area caused by masses of air that ascend by windward and they descend for leeward, warming and drying off (Phenomena of Fohen).

The inter-Andean valleys, such as the cordilleras above the 2,000 meters, present different annual rainfall amount (\approx 1,500 - 3,000 mm/year) with a bimodal regime of two (2) dry periods alternating with two (2) high rainfall periods.

In general, the relative humidity varies from high to low through the year. In the middle Magdalena valley including Cundinamarca, the relative humidity is contrasting the values below 60% during the first months of the year and from July to September with the values of about 80% in other period. On the other hand, the relative humidity in Sabana de Bogota is almost constant in 76-85% through the

¹ IGAC, 2002, Atlas de Colombia

² IDEAM, 2000, Proyecto red de alertas hidrometeorológicas para inundaciones y fenómenos de remoción en masa

year. The example of monthly humidity in San Jorge station located in Soacha is shown in Table S2-1-1.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
SAN JORGE (GJA)	81	81	82	84	83	82	82	82	82	83	84	82	82
(IDEAM)													

Table S2-1-1 Monthly Humidity in San Jorge (GJA) Station (IDEAM)

(Source: "Tabla 2, ESTUDIO DE LA CARACTERIZACIÓN CLIMÁTICA DE BOGOTA Y CUENCA ALTA DEL RIO TUNJUELO", FOPAE -IDEAM, 2006)

The average temperature in Bogota (Multi-Annual Average Temperature, MAT) is registered in Table S2-1-2, and monthly temperature in San Jorge station is shown in Table S2-1-3.

	Tab	le S2-	1-2 M	ulti-An	nual A	verag	e Tem	peratu	ure in l	Bogota	a		
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MAT (°C)	12.8	13.3	13.0	13.0	13.4	12.8	12.6	12.9	13.0	12.8	12.8	12.8	12.9

(°C)	12.8	13.3	13.0	13.0	13.4	12.8	12.6	12.9	13.0	12.8	12.8	12.8	1

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Average	11.5	11.6	11.8	11.9	11.9	11.6	11.1	11.3	11.5	11.5	11.7	11.6	11.6
SAN JORGE	Maximum	20.8	20.6	20.2	19.4	20.2	19.4	19.4	19.0	20.0	19.4	19.6	20.0	20.8
(GJA)	Minimum	0.5	0.2	0.2	2.0	0.7	0.5	0.0	3.8	0.5	0.7	3.2	1.0	0.0
(IDEAM)	Average Maximum	16.5	16.7	16.6	16.0	16.2	15.6	15.0	15.4	15.8	16.0	16.0	16.2	16.0
	Average Minimum	6.3	6.9	7.3	7.7	7.5	7.3	7.2	7.1	6.9	7.1	7.2	6.8	7.1

Table S2-1-3 Monthly	Temperature in	San Jorge	(GJA)	Station (IDEAM)
----------------------	----------------	-----------	-------	-----------------

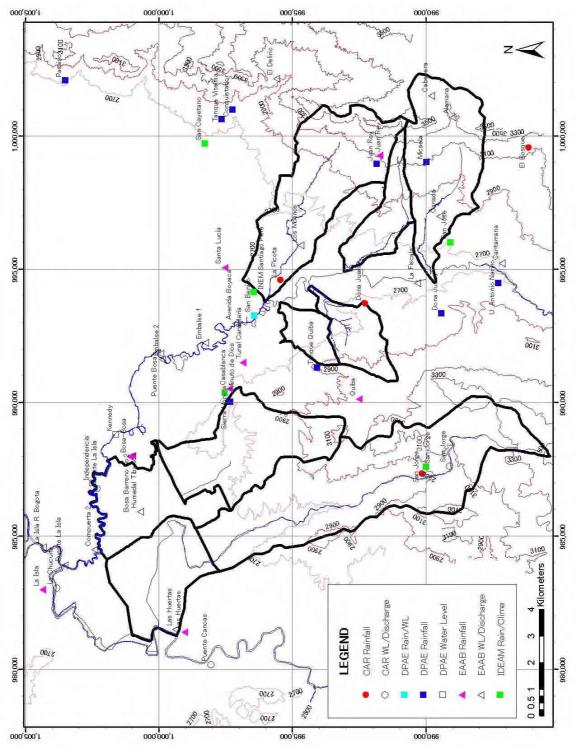
(Source: "Tabla 3, ESTUDIO DE LA CARACTERIZACIÓN CLIMÁTICA DE BOGOTA Y CUENCA ALTA DEL RIO TUNJUELO", FOPAE -IDEAM, 2006)

The historical winds mean values registers 8-10.7 m/s with NE-SW direction and 10.8-13.8 m/s with E-W direction. The calm period of the wind is 21% of the year.

1.2 Meteorological/Hydrological Stations in and around the Study Area

Quite a few meteorological and hydrological stations exist or existed in and around the Study Area, which are/were monitored and operated by DPAE, EAAB, CAR, IDEAM and other organizations. Some of the stations are telemetering stations, but most of the stations are conventional. Figure S2-1-2 shows the location map of meteorological and hydrological stations managed by DPAE, EAAB, CAR and IDEAM in and around the Study Area, and Table S2-1-4 shows the list and conditions of the stations.

Meteorological and hydrological data for the Study are collected from within the stations shown in Table S2-1-4. The list of collected data is shown in Table S2-1-5 to S2-1-8.





marks																																	stolen, since then	"LM".					T		EAAB).					
Present Situation/Remarks				Out of study area		Out of study area			Out of study area	Out of study area												One of the main station in EAAB								It was stolen march 2000.			1 year ago, some equipment was stolen, since ther	the station has been operated as "LM"		One of the main station in CAR.					It was replaced by Las Huertas (EAAB)					
TYPE	DPAE Nam WL		DPAE Rainfall	DPAE Rainfall		DPAE Ranfall	DPAE Rainfall	DPAE Ramfall	DPAE Rainfall	DPAE Rainfall	level	DPAE Water Level	EAAD Namiau	EAAB Rainfall	EAAB Rainfall	EAAB Rainfall	EAAB Rainfall	EAAB Rainfall	EAAB Ramfall	E.A.A.B. WI /Discharge	EAAB WL/Discharge		EAAB WL/Discharge	EAAB WL/Discharge	EAAB WL/Discharge	EAAD WL/Discharge	EAAB WL/Discharge	EAAB WL/Discharge	EAAB WL/Discharge		EAAB WL/Discharge	EAAB WL/Discharge	EWWD W PUDING	ischarge			CAR Rainfall	CAR Kantall	CAR WL/Discharge	CAR WL/Discharge			IDEAM Rain/Clima	IDEAM Rain/Clima	IDEAM Rain/Clima	
Telemeter	Telemeter (Kaulo)	l elemeter (Kadio)	Telemeter (Radio)	Telemeter (Radio)	Telemeter (Radio)	Telemeter (Radio)	Telemeter (Radio)	Telemeter (Radio)	Telemeter (Radio)	Telemeter (Radio)	Telemeter (Radio)	Telemeter (Radio)					Telemeter (GSM)				Telemeter (GSM)	Telemeter (GSM)	Telemeter (GSM)																							
Status in Oct. 2006					No Function				No Function																			No Function	No Function	No Function	No Function	No Function							Mo Europian	No Function						
Elevation INST DATE SUSP DATE					Z				Z					195812																z	z								106712 N							
INST DATE	010000	01007	200010	200010	200010	200010	200010	200010	200010	200010	200303	200010	10061	195705	199008	199001	196811	196510	195704		192607	196811	196510	192701	806641	110001	199009	198603	198701	198501	199001	198507		198811	198903	196212	198006	196004	196004	196402	195809	200111	200111	200111	196004	
Elevation	0402	20./2	3078	2780	3160	3078	2900	3078	2820	2820	2577	2576	0102	2640	2985	3000	2572	2537	2599		2550	2572	2537	2890	2043	2400	2583	2600	2600	3300	2800	3360		2630	2700	2880	2580	0687	7567	2538	2550	2700	3100	2565	2900	
COORD	W/ 100#/ NIICCC#0	U4343UN /41U14W	043235N740921W	043428N740435W	043108N740520W	043431N740418W	043021N740511W	043002N740815W	043742N740331W	042854N740331W	043650N741053W	043719N741154W	W 10/04/ ND14C40	0436N7412W	0431N7405W	0432N7410W	0435N7414W	0438N7413W	0434N7409W	M N H H H	0436N7412W	0435N7414W	0438N7413W	0433N7404W	04.3UN'/4U/W	04.35NT7400337	0435N7409W	0437N7413W	0437N7437W	0429N7404W	0433N7407W	0430N7404W		0434N7409W	0430N7410W	042820N740458W	0434N7408W	0431N/412W	04 3 0 N /4 1 1 W	0438N7414W	0431N7415W	0430N7407W	0435N7405W	0434N7408W	0431N7412W	
e	POCOTA	BUGUIA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA		BOGOTA	BOGOTA	BOGOTA	SOACHA	BOGOTA	BOGOTA	BUGUTA	BOGOTA	SOACHA	BOGOTA	BOGOTA	BUGUTA	BUGUTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	BOGOTA	WIDDOG	BOGOTA	BOGOTA	BOGOTA	BOGOTA	SUACHA	BURCHA	BOGOTA	SOACHA	BOGOTA	BOGOTA	BOGOTA	SOACHA	
DEPTO.		POG	BOGO	BOGO	BOGO	BOGO	BOGO	BOGO	BOGO	BOGO	BOGO	BOGO		BOGO	BOGO	BOGO	CUND	BOGO	BOGO		BOGO	CUND	BOGO	BOGO	D D D D D D D D D D D D D D D D D D D		BOGO	BOGO	BOGO	BOGO	BOGO	BOGO	200a	BOGO	BOGO	BOGO	BOGO	CUND	DOGO BOGO	BOGO	CUND	BOGO	BOGO	BOGO	CUND	
SUBCUENCA DEPTO.	1 unjuento	oranfun r	Tunjuelo	San Cristohal	Q. Chiguaza	San Cristobal	Q. Yomasa	Tunjuelo	Rosales		Tunjuelo	Tunjuelo	Tructure Tructure	1 uujuero Bosa	Q. Chiguaza	Bogota	Bogota	Bogota	Tunjuelo	1 unjuelo Thminelo	Tunjuelo	Bogota	Bogota	San Cristobal	1 unjuelo	Tunjuelo Tuninelito	Tuniuelito	Turritelo	Tunjuelo	Q. Yomasa	Q. Chiguaza	Q. Yomasa		Tunjuelito	Tunjuelito	Tunjuelito	Q. Chiguaza	Soacha	Soacha Thrinelo	i unguero Bogota	Bogota	Tunjuelito	Tunjuelito	Tunjuelito	Soacha	
NAME		Sierra Morena Tanure Oriha	1 auque Quuoa (Quiba-Mirador)	Conquistador (Escuela de Logistica)	Juan Rey	Tanque Vitelma	Micaela (Santa Maria Micaela)	Dona Juana	Paraiso II	U. Antonio Narino (Nariano USME)	Kennedy	Independencia	Date Durite Date Domono No 3	Bosa-Bosa Bosa-Bosa	Juan Rey		ertas		Tunal Candelana	Casaotanca Phente La Isla	Puente Bosa	Las Huertas	La Isla R. Bogota	El Delirio	Cantarrana	La riscala Fimbalee 1	Embalse 2	Humedal Tibanica (Commesta 1)	Compuerta 2	Alemana	Los Molinos	Cabecera	Calidua	Avenida Boyaca	Dona Juana	El Bosque			San Jorge Dirente I o Iclo	ruenie La Isia La Chicrita	SB		San Cayetano	INEM Santiago Pere	San Jorge	
_	2152	2	ΰ	Ü d		PG	DG D	PG	ЪС	D D D		32	2 2	2 2	ЪС	Ð	ΡĞ	D,	M	L.		LG	ĽĊ	LM	LM	I M	LM	ΓW	LM	ΓW	ΓW	LM		LM	СР	ĥ	PG 1	D4	I M	LM L	LM L	9	8	S	CO	
CODE2												1000010	1001212	2120154	2120204	2120205	2120211	2120209	2120059	7610717	2120701	2120806	2020802	2120705	05/0212	0C0U212	2120905	2120943	2120944	2120945	2120956	2120957		2120836	2120630	2120085	2120156	7/.107.17	2120712	2120772	2120829	2120664	2120665	2120666	2120572	
CODE1													2+0-2	16-Sd	P-081	P-090	P-092	P-083	P-045	1cu-7	L-036	L-005	L-004	L-026	L-U33	1-070	120-7	L-034	L-035	L-039	L-111	L-038	F-024	L-060												
ENTITY	DFAE	DFAE	DPAE	DPAE	DPAE	DPAE	DPAE	DPAE	DPAE	DPAE	DPAE	DPAE	CAAD VAD	EAAB	EAAB	EAAB	EAAB	EAAB	EAAB	EAAB	EAB	EAAB	EAAB	EAAB	EAAB	LAAD	EAAB	EAAB	EAAB	EAAB	EAAB	EAAB	awwa	EAAB	CAR	CAR	CAR	CAR	CAR	CAR	CAR	IDEAM	IDEAM	IDEAM	IDEAM	

Table S2-1-4 List of Meteorological/Hydrological Stations in and around the Study Area

	I Ipo de Uatos		10 Minutes Rainfall	10 Minutes Rainfall	10 Minutes Rainfall		Hourly Rainfall		Hourly Rainfall	10 Minutes Rainfall	10 Minutes Rainfall	10 Minutes Rainfall		Hourly Rainfall			5 Minutes WL	5 Minutes WL	
2006	12 1 2 3 4 5 6 7 8																		
2005	3 4 5 6 7 8 9 10 11 12 1																	Image: Constraint of the sector of	
2004	4 5 6 7 8 9 10 11 12 1 2													Image: Section of the sectio				Image: Constraint of the sector of	
2003	4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 1 2 3 4 5 6 7 8 9 10 11 12 1 2																		
2002	7 8 9 10 11 12 1 2 3 4 5																		
	6789101112123456																		
2001	6																		
2000	1 2 3 4 5 5 7 8 9 10 11 12 1 2 3 4																		
NTON ADDE	NOMBRE	Rainfall	SAN BENITO	SIERRA MORENA	TANQUE QUIBA	(QUIBA - MIRADOR)	CONQUISTADOR	(ESCUELA DE LOGISTICA)	JUAN REY	TANQUE VITELMA	DOÑA JUANA	MICAELA	(SANTA MARIA MICAELA)	U. ANTONIO NARIÑO	(NARIANO USME)	Water Level	INDEPENDENCIA	SAN BENITO	

Table S2-1-5 Collected Hydrological Data from DPAE

	Tipu de Datus		Daily Rainfall	(Diaria)	Daily Rainfall	(Diaria)	Daily Rainfall	(Disria (24Hrs))		Daily Discharge	(Diaria)	Daily Water Level	(Diaria)	Daily Discharge	(Diaria)	Daily Discharge	(Diaria)	Nonthly Discharge	(Mensual)	Nontrly Discharge (Mensual)	Daily Discharge	(Diaria)	Daily Discharge	(Diaria)	Daily Water Evel	(Diaria)	Hourly Water Level	(Hourly)	Daily Water Level	(Diaria)	Daily Water _evel	(Uiaria)	Daily Water _evel	(Diaria)	I burly Water Level	(Hourly)
	87 83 89 90 91 32 95 94 95 86 97 98 99 00 21 02 03 04 05 C0 Tiu		ß		PQ		Ð	(Dis		, lie Dail		Daily		Dail		Dailt		Nont [.]	\$	Nont	Daily		Daili		Vaily		ίπομ	-	Daily		Daily		Vaily		- I burk	
	80																																			
	90																																			
	00 66																									_		_							\vdash	
	97 98																																			
	95 80																													-					H	
	90 94																											_		-					H	
	91 92 8																											_		1					F	+
	06 6									_																				1					F	+
	7 83 8																													1						
	80																																			
	09 70 71 72 73 74 75 70 77 78 79 80 31 82 83 84 E5 80																																			
	82 83																																			
	80 31																													-						
	78 79																																			
	70 77					-																						-		+					\vdash	+
,	74 75																											_		+					\vdash	+
	72 73																											_		4						-
•	70 71																											_		4					F	+
	69 8																																			
	0 01																																			
	62																																			
	63 64																																			+
	0, 02					_	_										_											+		+	_				\vdash	+
	00 62																											_		-					H	
	57 58 59 60 6' 62 63 64 65 66 67 68																													1					F	+
	502																																			
	47 43 49 50 51 52 53 54 55 50																																			
	52 55																																			
	50 51																									_										+
	43 49					_							_				_											+		+					\vdash	+
	43 47																											_		4					H	-
	44 45 45											H																							Ħ	+
	43																																			
	41 42																																			
	Code		F-081		F-092		2 E-051			C90-T		L-063		L-053		L-039		L-033		L-094	L-094		L 005		T005		L-005		L-035		L-:92		L-004		L-004	
	NOMBRE	Rainfall	JUAN REY		LAS HUERTAS		BOSA JARENO No.2 F-051		Waterlevel/Discharge	AVENTDA 30YACA		AVENTDA 30YACA		LA FISCALA		ALEMANA		CABECERA		CANADA	CANADA		LAS HUERTAS		LAS HUFRTAS		LAS HUERTAS		PUENTE EOSA		FUENTE LA ISLA		LA ISLA		LA ISLA	
	M	-	Ē		LA3.		BOSA 3.		Waterle	AVENT		AVENT		- W-		TY		CAL		Ů	5		LAS.		T.AS		LAS.		TEUT		FUEN.		L,		Ľ	

Table S2-1-6 Collected Hydrological Data from EAAB

Tipo de Datos		Daily Rainfall	(Diaria)	Daily Rainfall	(Diaria)	Daily Rainfall	(Diaria)	Daily Rainfall	(Diaria)		Daily Discharge	(Diaria)	
8													
8													
4													
0													
0	$\left \right $												
-													
8	$\left \right $												
0	$\left \right $												
00	$\left \right $												
0	\vdash		\vdash							\vdash		\vdash	
0	$\left \right $									$\left \right $			
0 2	\vdash		\vdash						\square	\vdash			
9	\vdash		\vdash							$\left \right $		\vdash	
ත ෆ	\vdash		\vdash							$\left \right $			
6	$\mid \mid$		\vdash							$\left \right $			
6													
0	\vdash		\vdash							$\left \right $			
ő					_								
ő													
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06			\square										
6													
8													
8													
8													
8													
8													
20													
8													
79													
78													
77													
76													
75													
72 73 74 75 76 77 78 79 80 81 82													
73													
72													
	\square												
2													
69													
8	\square		\square										
65 66 67 68 69 70 71										\square			
202													
20	\vdash		\vdash	\vdash			\square		\square	$\left \right $			
U U													
Code		2120156		2120630		2120172		2120085			2120755		
NOMBRE	Rainfall	LA PICOTA		DONA JUANA		SAN JORGE GIA		EL BOSQUE		Waterlevel/Discharge	SAN JORGE GIA		

Table S2-1-7 Collected Hydrological Data from CAR

Table 2-1-8 Collected Hydrological Data from IDEAM

1							1						
	Tipo de Datos		Daily Rainfall	(Diaria)	Daily Rainfall	(Diaria)	Daily Rainfall	(Diaria)	Daily Rainfall	(Diaria)	Hourly Rainfall	(10 minutes)	
	06												
	90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06												
	04												
	03												
	02												
	01												
	00												
	99												
	98												
,	97												
	96												
	95												
	94												
	93												
	92												
	91												
	90												
			4		5		9		2				
	Code		2120664		2120665		2120666		2120572		i		
	NOMBRE	Rainfall	SAN JOSE 2		SAN CAYETANO 2		INEM ANTIAGO 2		SAN JORGE GJA 2		MINUTO DE DIOS	(SIERRA MORENA)	

1.3 Characteristic of Rainfall in and around the Study Area

1.3.1 Annual Rainfall

Annual Rainfall Distribution in area in 2002, 2003 and 2004 are shown in Figure S2-1-3 to S2-1-5. Annual rainfall amount in the Study Area varies by the area from 530 mm to 1150 mm in 2002, from 470 mm to 1040 mm in 2003, and from 600 mm to 1590 in 2004, respectively. Its spatial distribution has a similar tendency that rainfall amount is high in eastern hilly area in Bogota and southern mountain area in Soacha, and it is low in lowland area such as along the Tunjuelo river and near the confluence of the Tunjuelo river and the Bogota river.

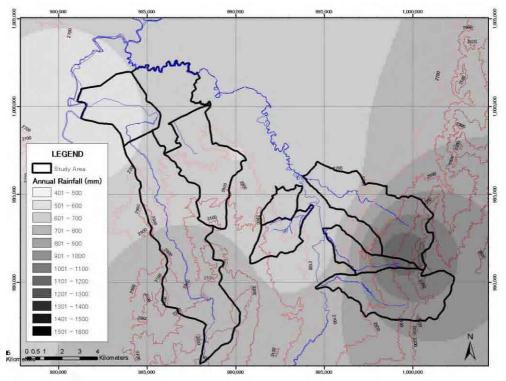


Figure S2-1-3 Annual Rainfall Distribution (2002)

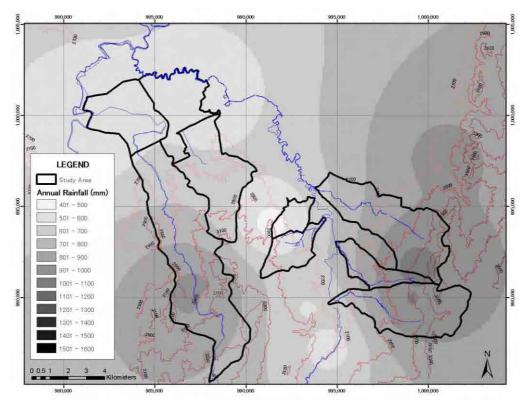


Figure S2-1-4 Annual Rainfall Distribution (2003)

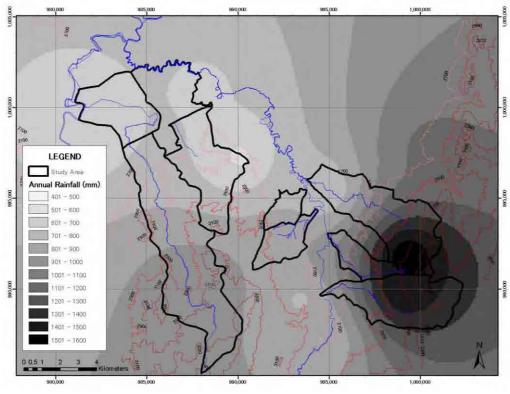


Figure S2-1-5 Annual Rainfall Distribution (2004)

1.3.2 Monthly Rainfall

Monthly rainfall distribution in 2003 and monthly rainfall variation in several stations in the Study Area are shown in Figure S2-1-6 and S2-1-7, respectively. As described in "(1) General Description in Cundinamarca including the Study Area" in this Chapter, there are two (2) rainy season from March to May and from September to November in the Study Area. As for the characteristic of the Study Area, rainfall amount is comparatively high in eastern hilly area in Bogota and southern mountain area in Soacha through the year, and especially rainfall amount in July is also high in these areas apart from the two (2) rainy seasons as typified by Micaela station located in eastern and southern hilly area in the Study Area. This trend is seen also in other years such as 2002, 2004 and 2005.

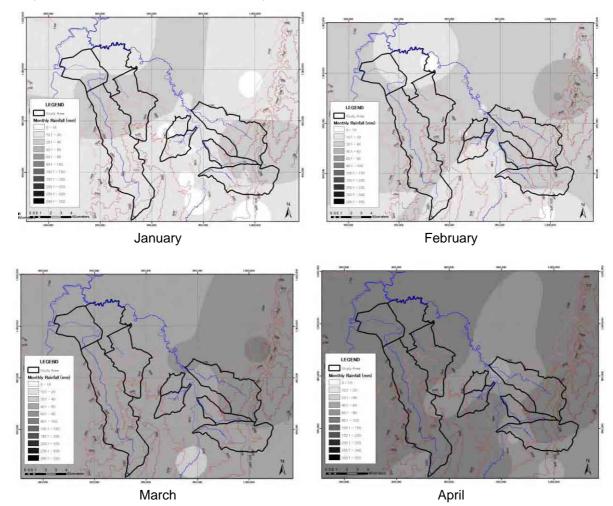
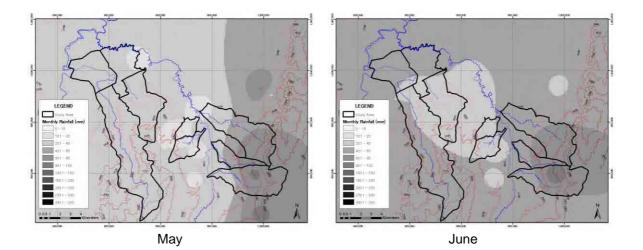
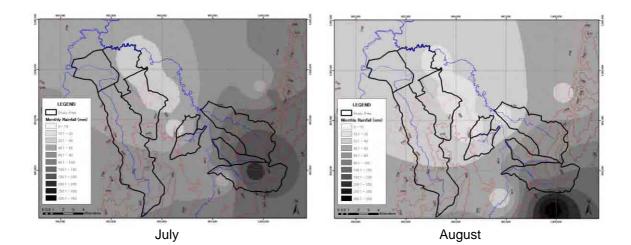


Figure S2-1-6 Monthly Rainfall Distribution (January - December, 2003) (1/3)

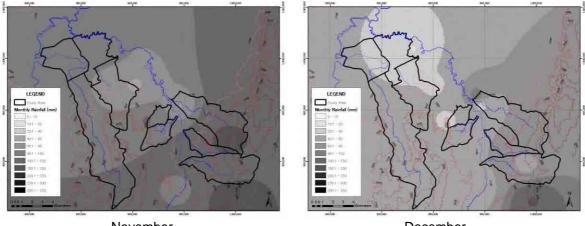




September

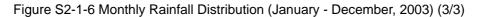
October

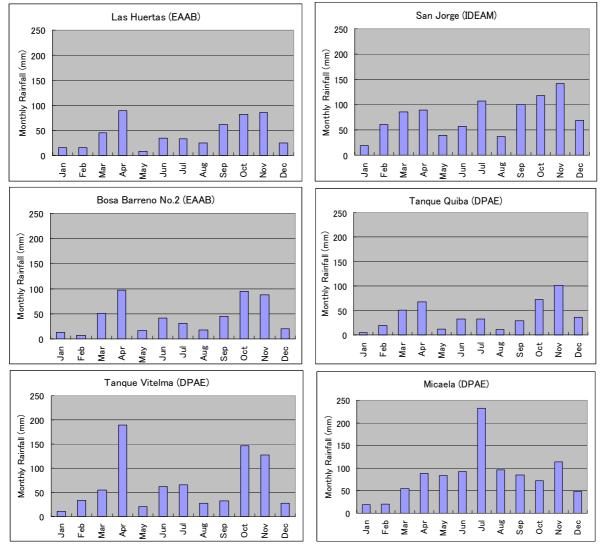
Figure S2-1-6 Monthly Rainfall Distribution (January - December, 2003) (2/3)



November

December







1.3.3 Number of Rainy Days in Month

Table S2-1-9 and Figure S2-1-8 shows the number of rainy days in month in 2003, when rainfall amount more than 0.1 mm was recorded, in the same stations as Figure S2-1-7. High numbers of Rainy days are recorded in April, July, October and November in all stations. The monthly variation among the stations is almost similar except Micaela station. The highest number of rainy days of 29 days is recorded in May in the Micaela station.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Las Huertas (EAAB)	1	6	14	16	6	11	19	13	13	19	20	9	147
San Jorge (IDEAM)	1	8	11	16	11	13	13	10	8	17	15	5	128
Bosa Barreno No.2 (EAAB)	1	8	13	14	7	12	15	11	14	19	21	7	142
Tanque Quiba (DPAE)	1	11	13	17	11	12	15	9	8	18	19	8	142
Tanque Vitelma (DPAE)	3	12	14	21	19	20	23	20	18	24	27	13	214
Micaela (DPAE)	2	11	15	21	29	21	26	24	21	21	20	15	226

Table S2-1-9 Number of Rainy Days in 2003

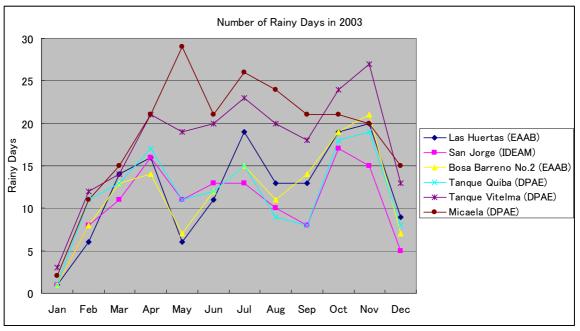


Figure S2-1-8 Rainy Days in Month in 2003

1.3.4 Daily Rainfall

Figure S2-1-9 and 2-1-10 show the monthly maximum daily rainfall in DPAE stations from October 2000 to August 2006. Figure S2-1-9 shows the value of eastern side of Rio Tunjuelo, and Figure S2-1-10 shows the value of western side. As a general trend, daily rainfall is bigger in eastern side than western side. In eastern side, daily rainfall is heavy in June and July as well as rainy season, although the daily rainfall in western side tends to be heavy in rainy season. Maximum value of 54.2 mm is recorded in May 3, 2005 in Tanque Vitelma station located in eastern side.

Table S2-1-10 shows the probable daily rainfall amount with several return periods in 5 (five) stations. It was analyzed by Gumbel method using collected data in this Study.

		-						
Station	Return Period (year)							
Station	3	5	10	25	50	100		
Las Huertas (EAAB)	29.19	32.03	35.60	40.12	43.47	46.79		
San Jorge (IDEAM)	35.38	38.74	42.96	48.30	52.26	56.19		
Bosa Barreno No.2 (EAAB)	33.56	37.23	41.83	47.65	51.97	56.25		
Juan Rey (EAAB)	47.74	52.98	59.56	67.88	74.06	80.18		
La Picota (CAR)	35.91	40.33	45.89	52.91	58.11	63.28		

Table S2-1-10 Probable Daily Rainfall (unit:mm)

Figure S2-1-11 shows the spatial distribution of daily rainfall from May 8 to May 12, 2006 in the Study Area. Heavy inundation occurred on May 11 in Soacha.

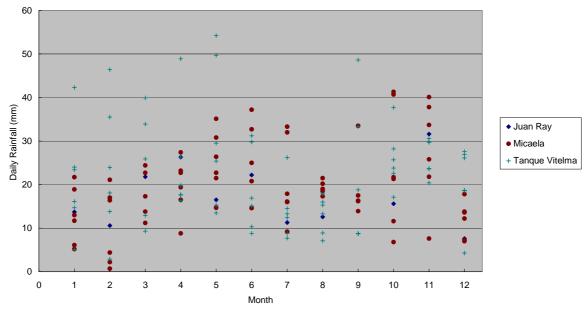


Figure S2-1-9 Maximum Daily Rainfall in DPAE Stations in Eastern Side of Rio Tunjuelo from 2000 to 2006

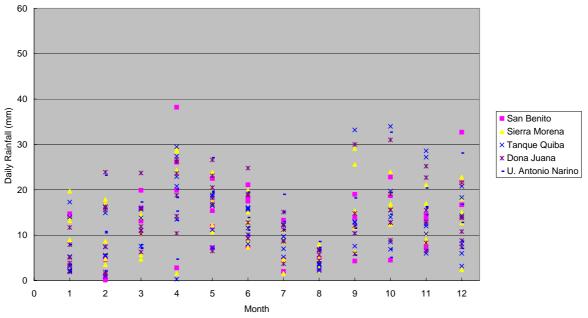
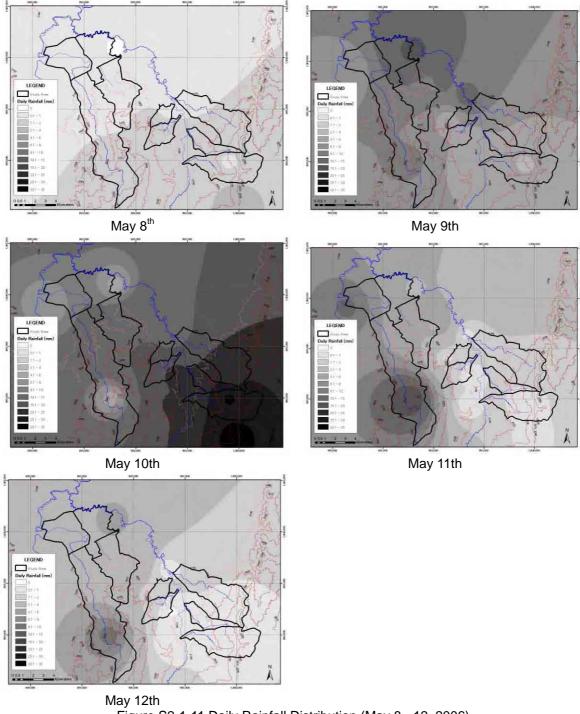


Figure S2-1-10 Maximum Daily Rainfall in DPAE Stations in Western Side of Rio Tunjuelo from 2000 to 2006





1.3.5 Hourly Rainfall

Figure S2-1-12 and S2-1-13 show the monthly maximum hourly rainfall in DPAE stations from October 2000 to August 2006. Figure S2-1-12 shows the value of eastern side of Rio Tunjuelo, and Figure S2-1-13 shows the value of western side. Hourly rainfall is bigger in eastern side than western side as is the case with daily rainfall. In both side, the value of maximum hourly rainfall is heavy in rainy season. Hourly rainfall of eastern side in June and July is comparatively low unlike with the tendency of the daily rainfall. It shows that rainfall intensity of eastern side in June and July is not strong whereas rainfall duration is long. Maximum value of 42.1 mm is recorded in September 25, 2005 in Tanque Vitelma stations.

Figure S2-1-14 shows the zoning of rainfall pattern by EAAB, 1995, with Study Area. Almost all the Study Area is included in zone of Z4, Z5 and Z7. Rainfall pattern varies by the zone. Rainfall intensities in several return periods in each zone by EAAB, 1995 are shown in Table S2-1-11.

Figure S2-1-15 shows the relation between daily rainfall and hourly rainfall in DPAE stations in 2000-2006. The daily rainfall is maximum value of each month from 2000 to 2006, and the hourly rainfall is also the maximum value of each month from 2000 to 2006. From the figure, the percentage of hourly rainfall amount to the daily rainfall amount is about 40-60%, which means the heavy rainfall finishes in short time. Figures S2-1-16 and S2-1-17 show rainfall distribution, in 1:00-24:00 for Tanque Quiba and Micaela stations, respectively. These 10 examples in each figure are top 10 of high daily rainfall amount from October 2000 to August 2006 in Tanque Quiba station, and from October 2000 to July 2006 in Micaela station. In Tanque Quiba station, rainfall distribution can classify two (2) patterns. One is comparatively moderate curve such as 2002/4/25 and 2003/4/12 and 2002, and other is very steep curve such as 2005/9/25 and 2006/4/30, which highest hourly rainfall almost equals daily rainfall amount. In Micaela station, rainfall distribution can classify also two (2) patterns. One is very moderate curve such as 2001/11/12 and 2002/6/22, and other is comparatively steep curve such as 2003/9/27 and 2005/10/23. Figure 2-1-18 shows the synthetic rainfall distributions for USA by USDA, 1986. When this classification of rainfall distributions is intended to apply in the Study Area for analysis, for example, I and II is regarded to fit in La Estrella basin near the Tanque Quiba station and IA and III to fit in Yomasa basin where Micaela station located.

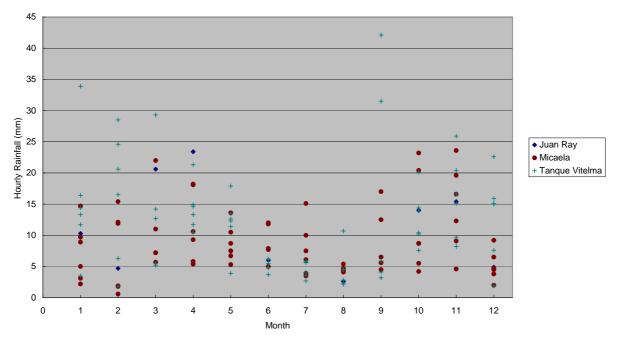


Figure S2-1-12 Maximum Hourly Rainfall in DPAE Stations in Eastern Side of Rio Tunjuelo from 2000 to 2006

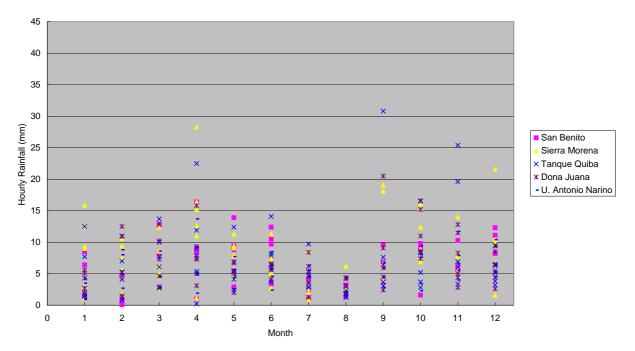
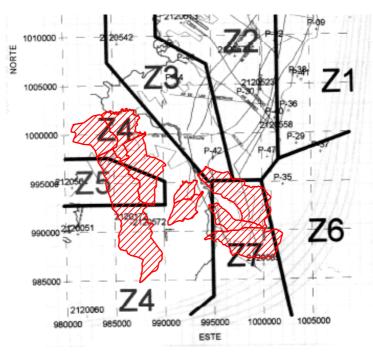


Figure S2-1-13 Maximum Hourly Rainfall in DPAE Stations in Western Side of Rio Tunjuelo from 2000 to 2006



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

Figure S2-1-14 Zoning of Rainfall Pattern

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

Table S2-1-11 Rainfall Intensity in each Zone (unit:mm/h)

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

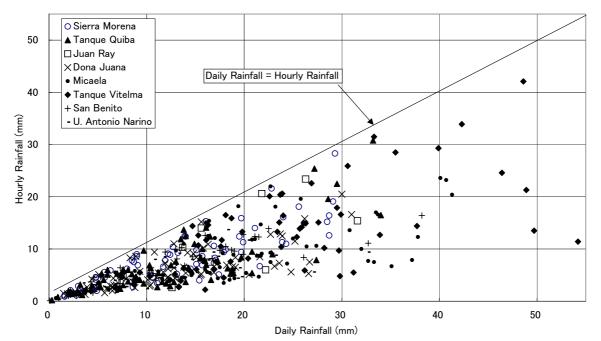


Figure S2-1-15 Relation between Daily Rainfall and Hourly Rainfall in DPAE Stations in 2000-2006

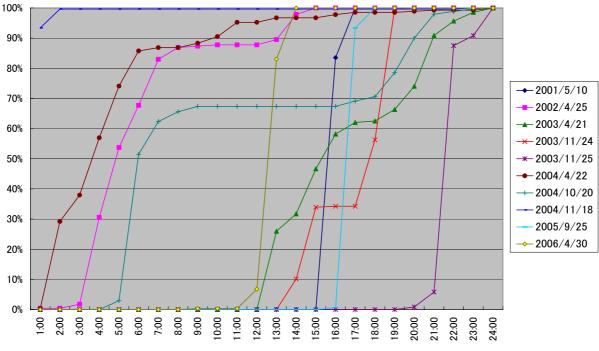


Figure S2-1-16 Rainfall Distribution in 1:00-24:00 in Tanque Quiba Station

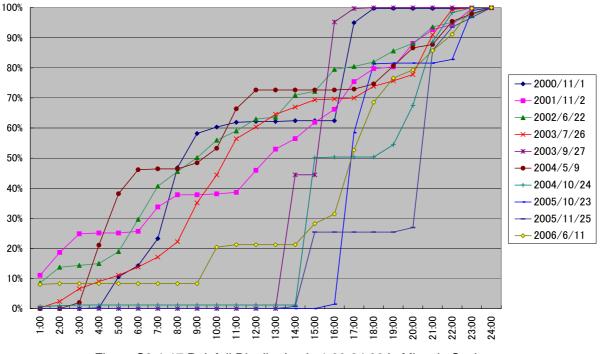
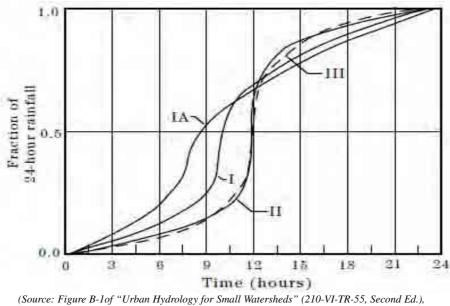


Figure S2-1-17 Rainfall Distribution in 1:00-24:00 in Micaela Station



USDA, June 1986)

Figure S2-1-18 SCS 24-hour Rainfall Distributions

1.4 Correlation of Rainfall Stations - Correlation of Rainfall Pattern -

1.4.1 Correlation of Rainfall Stations in and around the Study Area

In order to examine the correlation of stations and the rainfall pattern in and around the Study area, correlation coefficient of each station is calculated using the monthly rainfall data from 2000 to 2006 and daily rainfall data in 2003. It can be said that if correlation coefficient is high between two (2) stations, rainfall pattern is similar in relevant area. Figure S2-1-19 and S2-1-20 show the result of correlation calculation of monthly rainfall and daily rainfall in and around the Study Area, respectively. Values on the lines between stations designate the square value of correlation coefficient of each station.

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

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

1.4.2 Correlation of DPAE Rainfall Stations

Figures S2-1-21 and S2-1-22 shows the result of correlation calculation of monthly rainfall data from 2000 to 2006 and daily rainfall data in 2003 only in DPAE rainfall stations. However, data of Juan Rey station of EAAB is used for analysis instead of Juan Rey station of DPAE because operated period of Juan Rey of DPAE is very short. Numerical characters in the figures designate the square value of correlation coefficient of each station.

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

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

