3. DISASTER SCENARIO

3.1 Earthquake

1) Scenario Earthquakes

(1) Fault parameter

In the Study, three scenario earthquakes are selected as a specific and realistic approach explained as follows:

- Non-uniform distribution of bedrock acceleration is taken into account, due to the large spatial extension of the Study Area (1,949 km²);
- Taking most probable earthquake, fault with higher activity rate and higher magnitude into account for scenario earthquake;
- Base acceleration of 0.2g at the center of Bogotá;
- The closest distance from center of Bogotá to the ruptured segment of fault as 20 km due to the MZSB97.

Therefore, two faults are selected as scenario earthquakes in addition to the subduction event, which is not specified. Criteria of fault selection are as follows:

- Faults classified as "High Activity"
- Fault with largest "Maximum Probable Magnitude"
- Fault that satisfies the distance as specified in MZSB97

Regarding the fault parameters, magnitude is taken from MZSB97 estimated by fault characteristics such as fault type. Fault rupture length is taken as a segment length indicated as "longitude with neo-tectonic range" in MZSB97. The scenario earthquakes are shown as follows:

Table 26 Scenario Earthquakes for the Study

Case	Fault name	Type	Magnitude	Total fault length (km)	Fault rupture length (km)	Distance (km) *
1	La Cajita	Near	6.4	35	10	20
2	Guayuriba	Regional	7.0	60	29	60
3	Subduction	Subduction	8.3	--	--	400

* Closest distance from INGEOMINAS
Source: Microzonificacion sismica de Santa Fe de Bogotá, INGEOMINAS 1997

Case-1: Due to the existing study lists there are two active faults of No.6 and No.7, within the radius of 50 km from Bogotá. The two faults have almost same parameters as a whole, maximum probable magnitude, length and activity rate. However, the fault No. 6 contains a segment with higher activity rate than the fault No.7; therefore, the fault No.6 is selected as the scenario earthquake.

Case-2: There are faults with a higher magnitude than the fault No.27, which is selected as the scenario earthquake, but they are not selected for the scenario earthquake because of their lower base acceleration due to their longer distances.

(2) Acceleration distribution at basement

Using the magnitude and distance for each fault, acceleration at bedrock is calculated at the center of each microzone.

A. Case-1: La Cajita Fault

La Cajita Fault locates south of Soacha, thus base rock acceleration up to 0.5g in the southern part of the Study Area appears due to its short distance from the fault. At the southern part of the Bogotá Metropolitan Area, the base rock acceleration varies from 0.2g to 0.3g.

B. Case-2: Guayuriba Fault

In the major part of the Study Area, the base rock acceleration ranges from 0.1g to 0.2g. In northeastern part of the Study Area, basement acceleration is less than 0.1g due to the attenuation.

C. Case-3: Subduction

Basement acceleration is the same for the whole Study Area due to its long distance of 400 km from the epicenter.

(3) Surface geology

Based on aerial photograph interpretation and site visiting to verify the existing geological map, a geological zoning map (scale: 1/50,000) was prepared for the Study Area as a basis for the geotechnical-zoning map for the Study.

The geo-technical zoning map (1/50:000) was prepared based on collected boring data, topographic map, and geological zoning map.

The geotechnical classification defined in the Study is described in the following table:

Table 27 Geotechnical Classification Defined in the Study

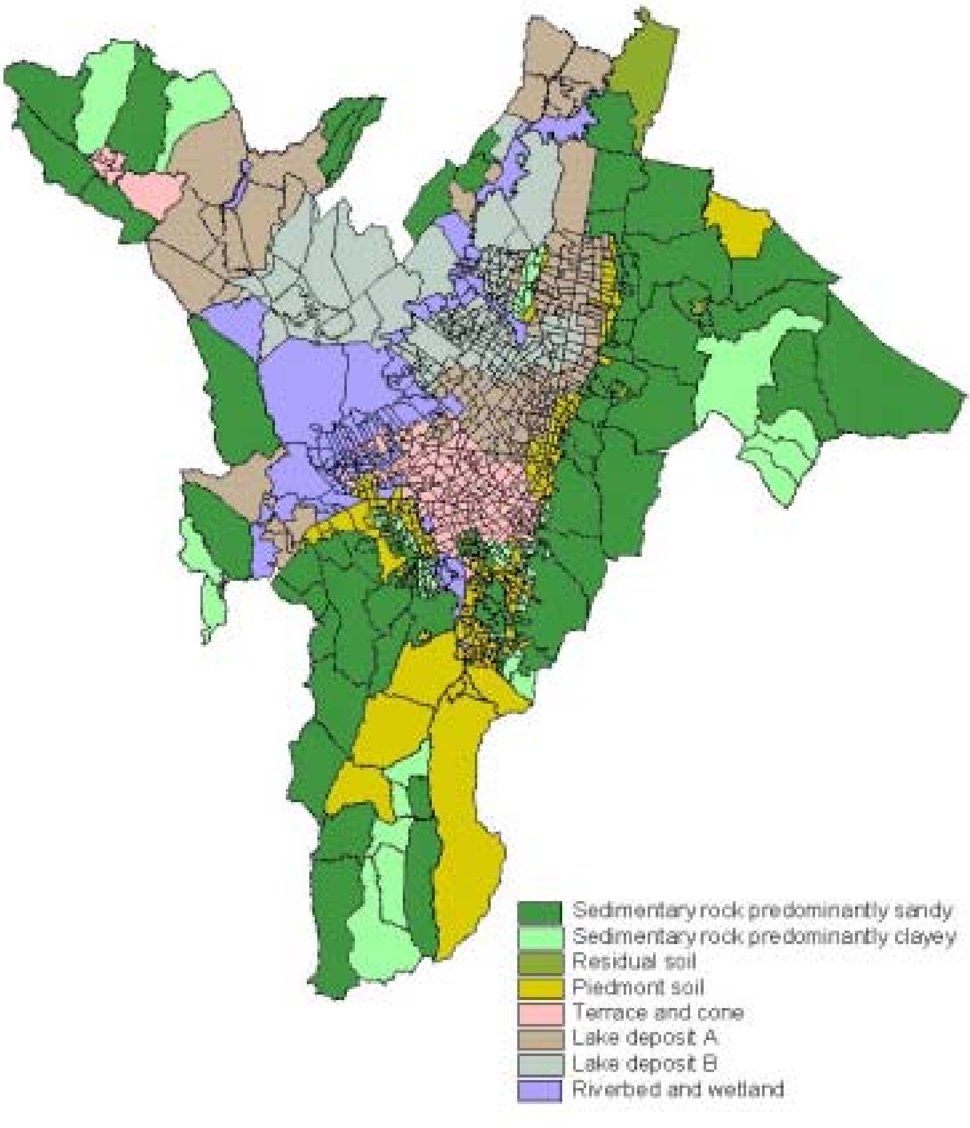
Zone	Zone in MZSB97	Name	Characteristics
1	1	Sedimentary rock predominantly sandy	Sandstone of Guadalupe group, sandstone formation of Regadera, Cachi formation
2	1	Sedimentary rock predominantly clayey	Chipaque, Guaduas and Bogota formation
3	2	Residual soil	Product of meteorization from parental material
4	2	Piedmont soil	Deposit of slope or pending (located preferencially in the base of the hills in the form of cone or fan) Slopes, coluvions, and fluviogracial deposit.
5	5, 5A	Terrace and cone	Preconsolidated clay with intercalation of sandy soils. It can contain layers of peat of thickness less than 4m in the depth deeper than 30m.
6	3	Lake deposit A	Soft clay of high compressibility with thickness more than 50m.
7	4	Lake deposit B	Soft clay of higher compressibility, with thickness from 200m to 400m or more.
8	--	Riverbed and wetland	Clayey deposit of lacustrine origin or of alluvial type innundation. In this zone also exist the body of water such as river, quebrada, wet zone, old lakes and innudation zone.
--	--	Garbage fill	Filled by garbage
--	--	Excavation	Filled excavation

Source: JICA Study Team

The motion at ground surface is calculated using three waveforms for scenario earthquake by three different input levels (0.05g, 0.10g, 0.20g) and the peak ground acceleration is calculated by multiplying base acceleration by averaged amplification factor, defined by geotechnical classification as follows:

Table 28 Averaged Amplification Factors by Geotechnical Zone

Geotechnical Zone	Name	Scenario earthquake and base acceleration level								
		Case-1			Case-2			Case-3		
		0.05g	0.10g	0.20g	0.05g	0.10g	0.20g	0.05g	0.10g	0.20g
1	Sedimentary rocks	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	Residual, piedmont	2.60	2.38	2.12	2.49	2.40	2.25	2.42	2.37	2.29
3	Lake deposit A	1.69	1.27	0.81	3.17	2.69	2.05	3.28	2.84	2.26
4	Lake deposit B	1.32	0.99	0.66	2.54	2.18	1.67	2.84	2.46	2.00
5	Terrace and cone	2.05	1.73	1.34	2.71	2.58	2.27	2.85	2.58	2.32
6	Riverbed and wetland	1.33	1.01	0.62	1.81	1.67	1.44	2.26	1.89	1.45



Source: JICA Study Team

Figure 5 Geotechnical Classification by Microzone

(4) Peak ground acceleration and seismic intensity

	Peak Ground Acceleration (g)	Seismic Intensity (MMI)
Case-1: La Cajita Fault	0.1- 1.0	VII- X
Case-2: Guayuriba Fault	0.1- 0.5	V - IX
Case-3: Subduction	0.1- 0.2	V - VII

Note: MMI=(Log(PGA)-0.014)/0.3

Seismic Intensities are shown in Figure 6.

Case-1: La Cajita Fault

In the southern part of the Study Area, which is close to the fault, MMI ranges from IX to X. While in most part of the Study Area MMI is VII, and at some distant zones from the fault MMI is VIII due to the amplification by site condition.

Case-2: Guayuriba Fault

In the majority of the Study Area, most part of Bogotá and northwestern part of the Study Area, MMI is VIII. For the rest of the area, MMI is VII, with the exception of northwestern end of the Study Area, which has an MMI of V, and one micro zone in southeastern edge appears to experience an MMI of IX.

Case-3: Subduction

Microzones with MMI VII appears in the center of Bogotá and northwestern part of the Study Area, due to the amplification by thick lake deposit. MMI for mountainous area in the suburb of the Study Area remains V.

(5) Liquefaction area

In general, liquefaction occurs at where loose fine sand and high water table is found, together with an intensive ground motion, and liquefaction is known to repeat at the same site with different earthquakes.

The area which has liquefaction potential was mentioned in the previous study based on the description in historical records. The deposits of the Rio Tunjuelito contain fine sand, while the deposits of the Rio Bogotá are composed of mostly clayey materials, which have a less possibility of liquefaction.

In the Study, new data of boreholes in Bogotá have been collected and used to review the liquefiable area from geotechnical point aspects. The liquefaction possibility is evaluated as follows:

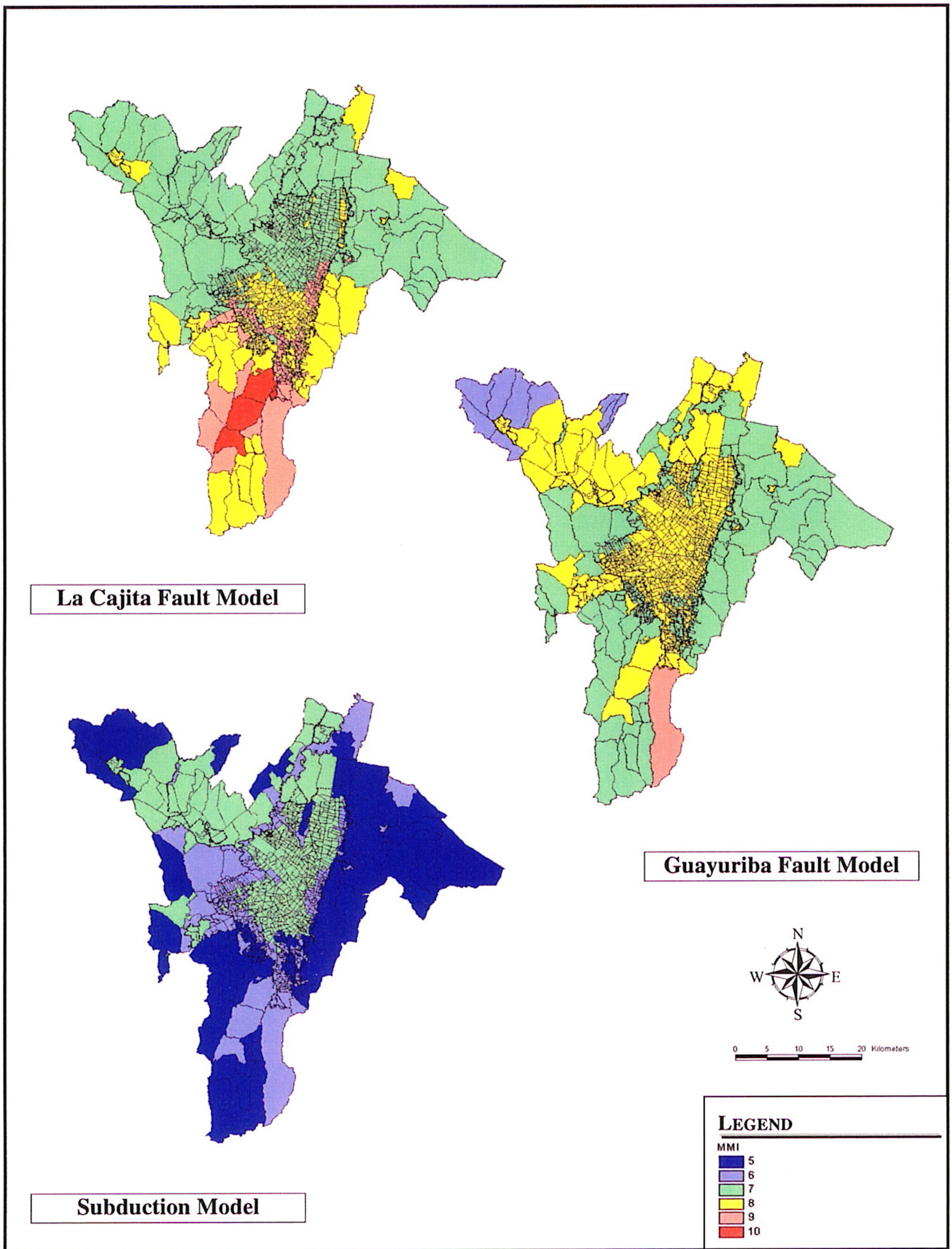


Figure 6	Modified Mercalli Intensity (MMI)

Table 29 Criteria for Liquefaction Evaluation Used in this Study

	Area		
Seismic Intensity (MMI)	Liquefiable area defined by boring data	Zone 5	Others
Less than VII	None	None	None
VII	Possible	Possible	None
VIII or more	Probable	Possible	None

Source: JICA Study Team

However, the detailed evaluation of liquefaction area is not possible, because of insufficient data such as soil grain size destitution, standard penetration testing N-values and water table. Therefore, a rough evaluation method is employed using the existing information.

The identified liquefiable area is shown in the next page.

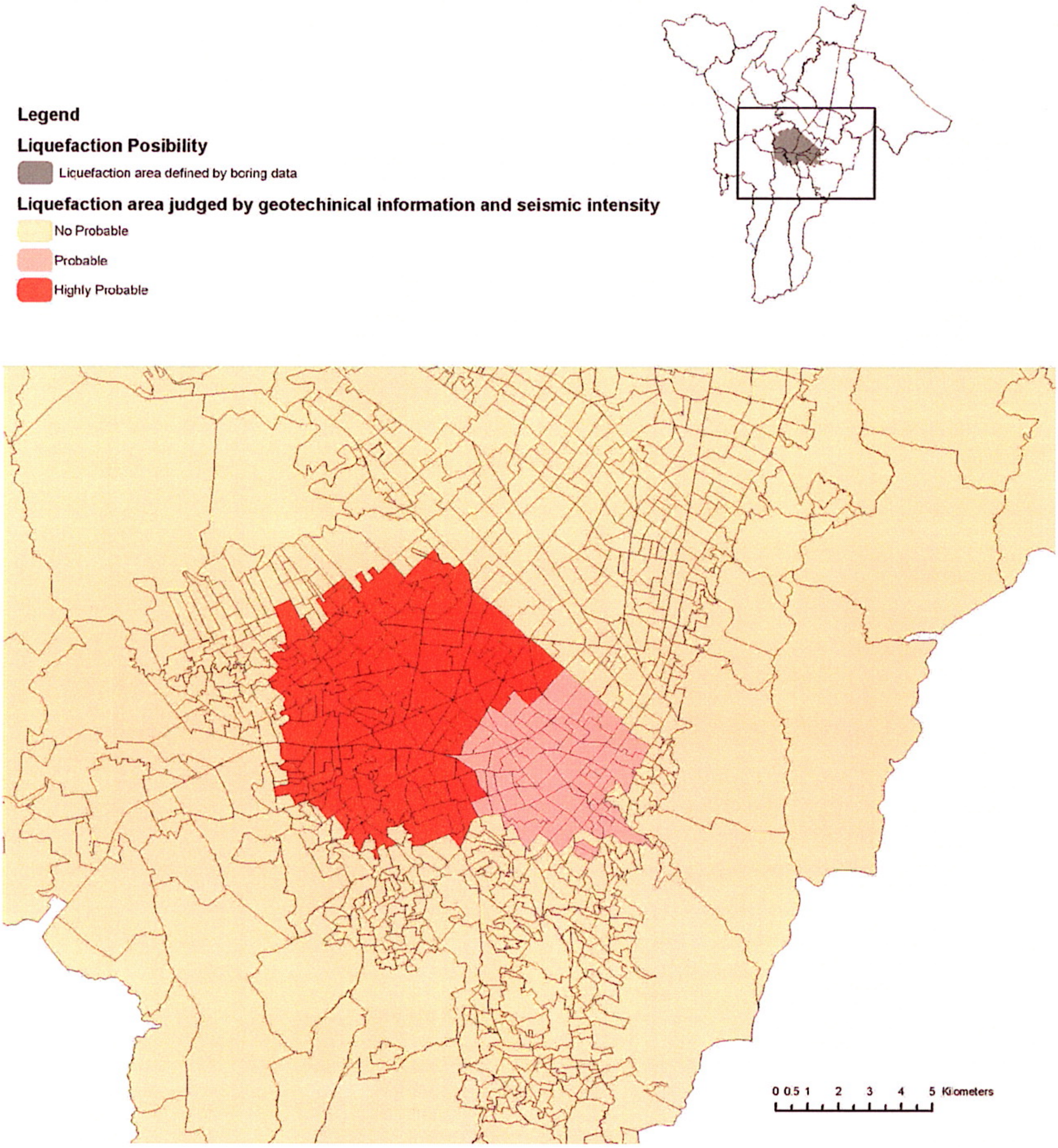


Figure 7 Liquefaction Potential Area

3.2 Damage Estimation

1) Building

(1) Building type

For estimation of seismic damages, the buildings are classified based on the following conditions:

- Type of building
- Number of stories
- Class of estrato

A site investigation was conducted during the Study in order to check the discrepancies between the cadastral data and the actual conditions, by sampling, and thereafter, the existing buildings were classified into the following types:

Table 30 Building Classification in the Study

Type	Structure Type	Estrato
1	Wood, Prefablicated	1,2,3,4,5,6
2	Masonry	1,2
3	Masonry	3,4
4	Masonry	5,6
5	Reinforced Concrete Frame less than 3 floors	1,2,3,4,5,6
6	Reinforced Concrete Frame more than 4 floors	1,2,3,4,5,6

Source: JICA Study Team

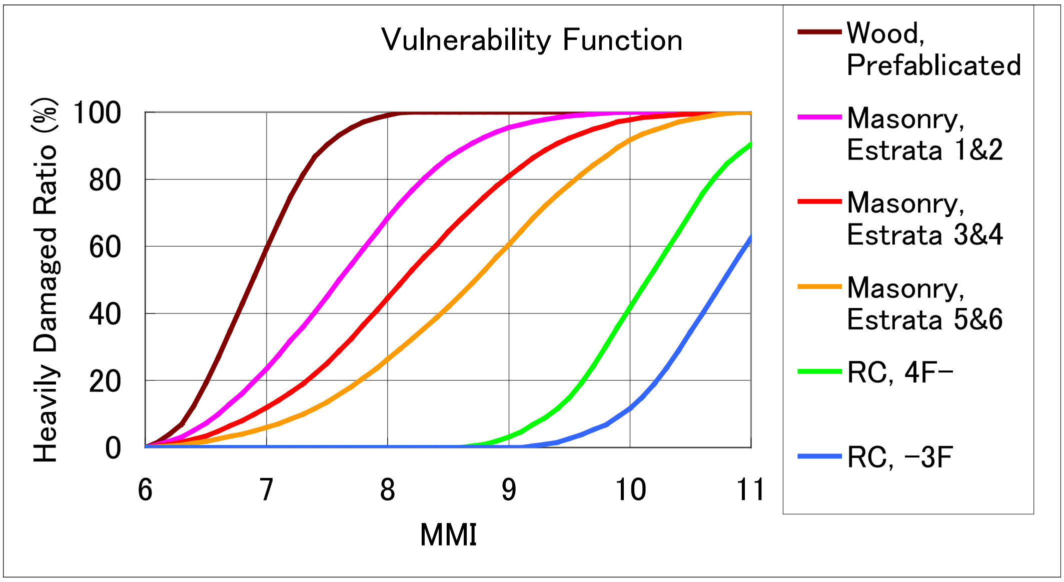
Table 31 Distribution of Masonry Buildings by Estrato

	B	C	D
Type 2	80%	20%	0%
Type 3	40%	50%	10%
Type 4	20%	40%	40%

(2) Damage functions for buildings

In order to establish damage functions for estimation of seismic damages corresponding to the scenario earthquakes, the studies on the building damages of the 1999 Quindio earthquake were referred to.

Damage function defined for each MMI as a discrete value is finally smoothed as shown in the following figure:



Source: JICA Study Team

Figure 8 Estimated Ratio of Heavily Damaged Buildings

(3) Results of estimation of building damage

Table 32 Number of Heavily Damaged Buildings

Location	Case-1 La Cajita		Case-2 Guayuriba		Case-3 Subduction	
	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Bogotá City	362,072	90.7	377,585	89.5	51,908	84.0
Eight Municipalities	37,312	9.3	44,404	10.5	9,921	16.0
Total	399,384	100.0	421,989	100.0	61,829	100.0

The results of heavily damaged buildings are shown in Figure 9(1) and (2).

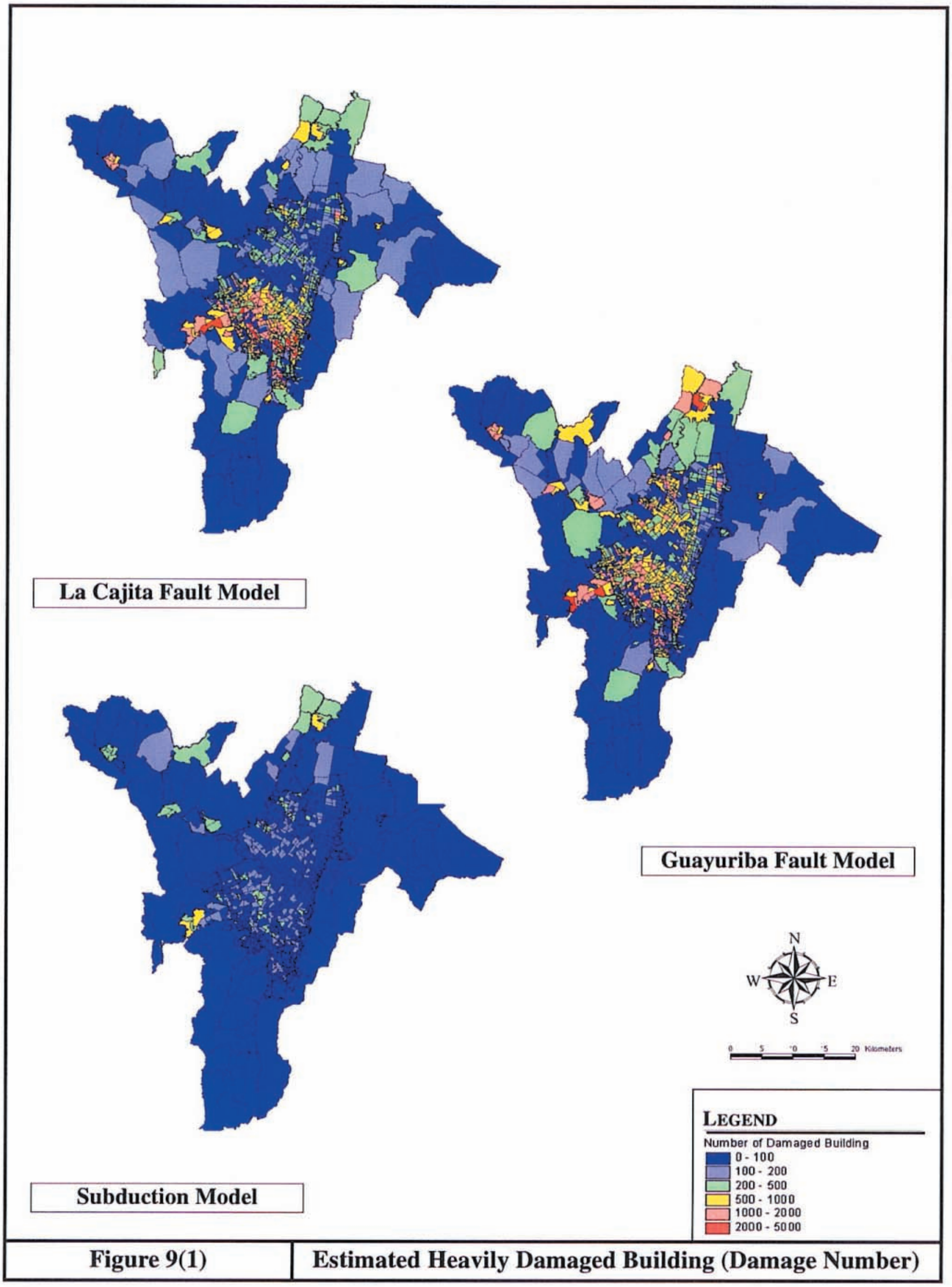


Figure 9(1) | **Estimated Heavily Damaged Building (Damage Number)**