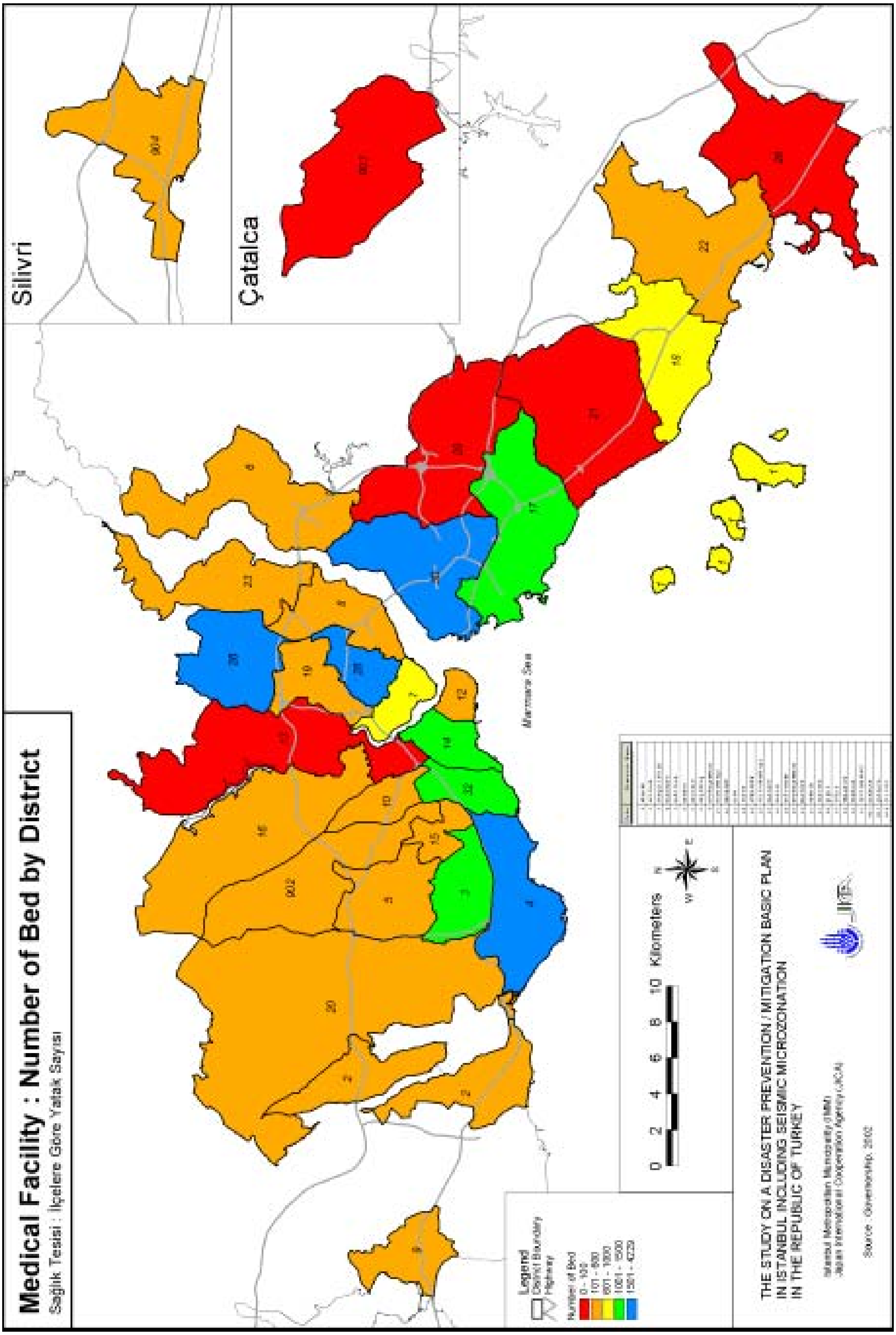


Figure 6.2.34 Medical Facility : Number of Bed by District

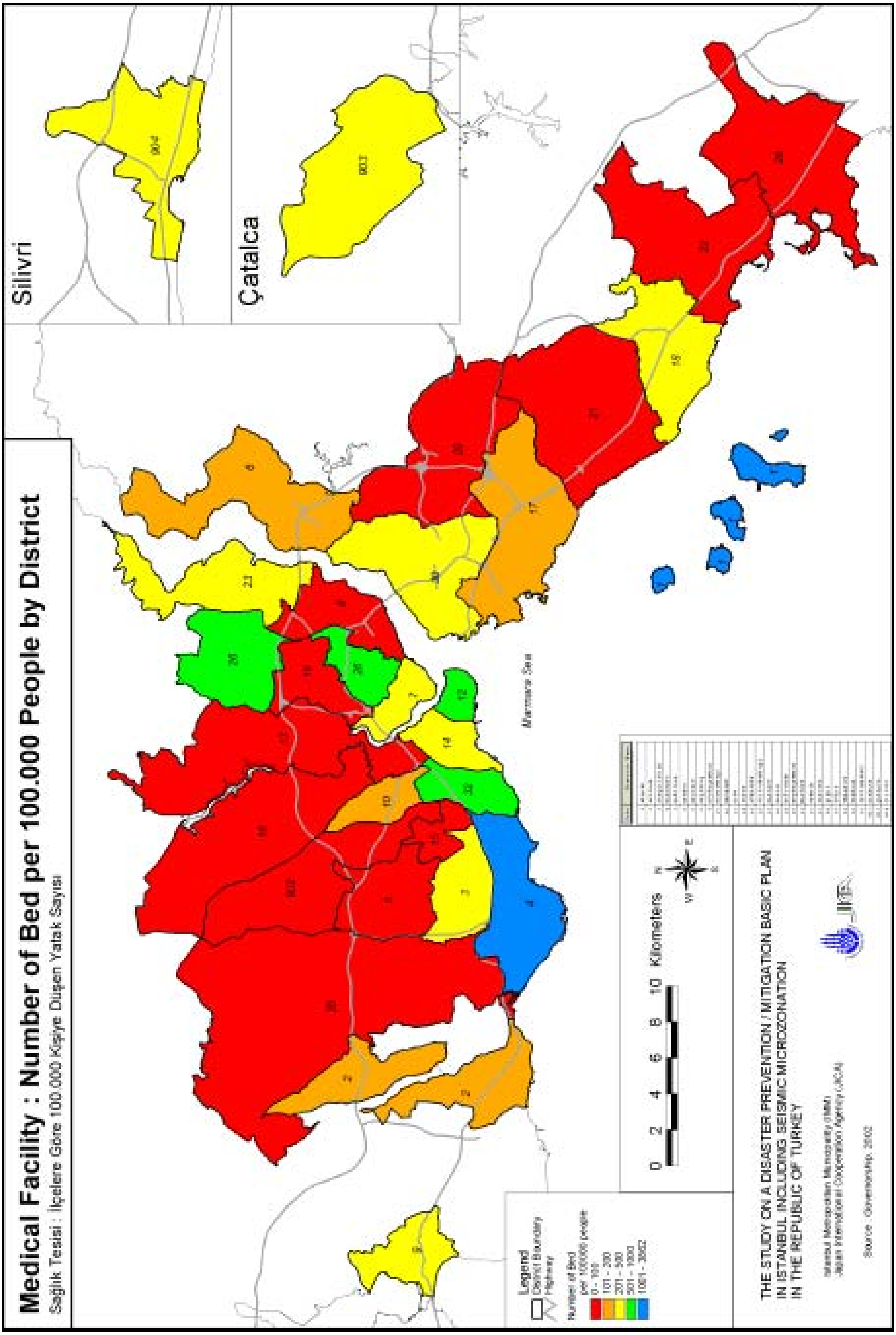


Figure 6.2.35 Medical Facility : Number of Bed per 100,000 People by District

(3) Fire Fighting Facilities

Current situation for the fire fighting facilities is examined based on the data obtained from the IMM Fire Department in May 2002. Table 6.2.14 shows numbers of facilities for each district. Figure 6.2.36 shows locations of fire fighting facilities. There is more than 1 fire fighting facility in most of the districts. According to the figure, many fire-fighting facilities are located close to the first-degree road designated by the IMM.

Table 6.2.14 Numbers of Fire Fighting Facilities for Each District

Code	District	Fire Fighting
1	ADALAR	4
2	AVCILAR	1
3	BAHÇELİ EVLER	1
4	BAKIRKÖY	1
5	BAĞCILAR	1
6	BEYKOZ	2
7	BEYOĞLU	0
8	BEŞİ KTAŞ	1
9	BÜYÜKÇEKMECE	1
10	BAYRAMPAŞA	2
12	EMİ NÖNÜ	0
13	EYÜP	2
14	FATİ H	1
15	GÜNGÖREN	1
16	GAZİ OSMANPAŞA	1
17	KADIKÖY	2
18	KARTAL	1
19	KAĞITHANE	2
20	KÜÇÜKÇKMECE	2
21	MALTEPE	1
22	PENDİ K	1
23	SARIYER	2
26	Şİ ŞLİ	2
28	TUZLA	2
29	ÜMRANİ YE	1
30	ÜSKÜDAR	2
32	ZEYTİ NBURUNU	1
902	ESENLER	0
903	ÇATALCA	1
904	Sİ Lİ VRİ	1
Total		40

Source: IMM Fire Department

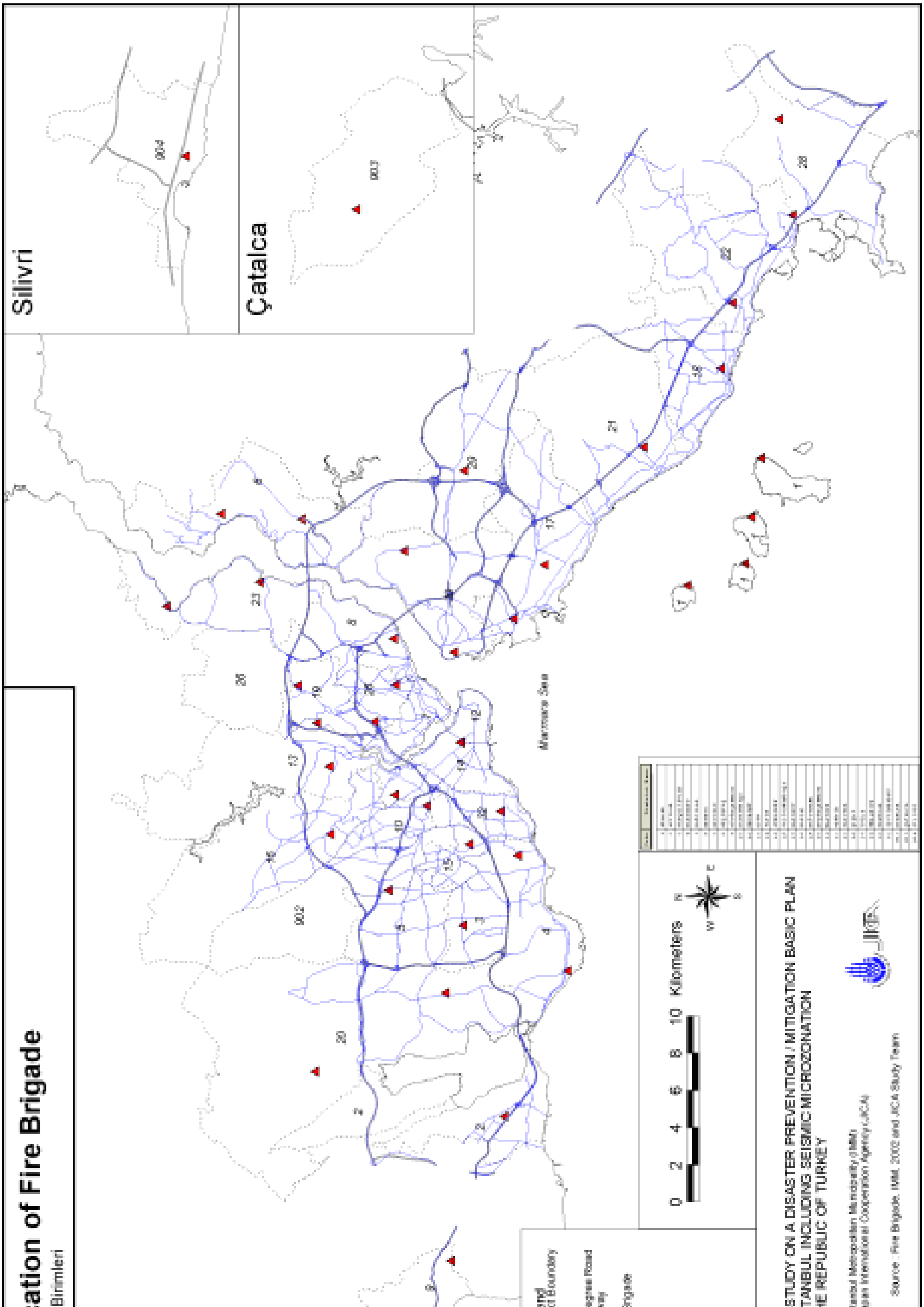


Figure 6.2.36 Location of Fire Brigade

(4) Security Facilities

Current situation for the security facilities is examined based on the data obtained from the province in May 2002. Table 6.2.15 shows the numbers of district polices (İlçe emniyet), polices, gendarmes (Jandarma), and other relating facilities for each district.

Table 6.2.15 Numbers of District Polices(İlçe Emniyet), Polices, Gendarmes(Jandalma) and Other Relating Facilities for Each District

Code	District	District Police	Police	Gendarme	Other	Total
1	ADALAR	1	0	0	0	1
2	AVCILAR	1	3	0	0	4
3	BAHÇELİ EVLER	1	3	0	0	4
4	BAKIRKÖY	1	6	2	1	10
5	BAĞCILAR	1	2	0	0	3
6	BEYKOZ	1	5	1	0	7
7	BEYOĞLU	1	5	0	0	6
8	BEŞİ KTAŞ	1	7	0	0	8
9	BÜYÜKÇEKMECE	1	1	1	0	3
10	BAYRAMPAŞA	1	2	1	0	4
12	EMİ NÖNÜ	1	6	0	0	7
13	EYÜP	1	5	1	0	7
14	FATİ H	1	13	0	1	15
15	GÜNGÖREN	1	3	0	0	4
16	GAZİ OSMANPAŞA	1	6	1	1	9
17	KADIKÖY	1	0	0	0	1
18	KARTAL	1	5	1	0	7
19	KAĞITHANE	1	4	0	0	5
20	KÜÇÜKÇKMECE	1	5	0	1	7
21	MALTEPE	1	4	0	0	5
22	PENDİ K	1	2	1	0	4
23	SARIYER	1	7	1	1	10
26	Şİ ŞLİ	1	7	1	0	9
28	TUZLA	1	1	0	1	3
29	ÜMRANİ YE	1	1	2	0	4
30	ÜSKÜDAR	1	9	1	0	11
32	ZEYTİ NBURUNU	1	2	0	1	4
902	ESENLER	1	1	0	0	2
903	ÇATALCA	1	0	0	0	1
904	Sİ Lİ VRİ	1	0	0	0	1
Total		30	115	14	7	166
Average		-	-	-	-	6

Source: Provincial Disaster Management Center

More than 10 buildings of security facilities are located in Fatih (15 buildings) and Üsküdar (11 buildings). In an average 6 security related buildings are located in each district. Figure 6.2.37 shows numbers of buildings of security facilities for each district and locations of the district police (İlçe emniyet). According to the figure, the district police(İlçe emniyet) buildings are locating close the first degree road designated by IMM.

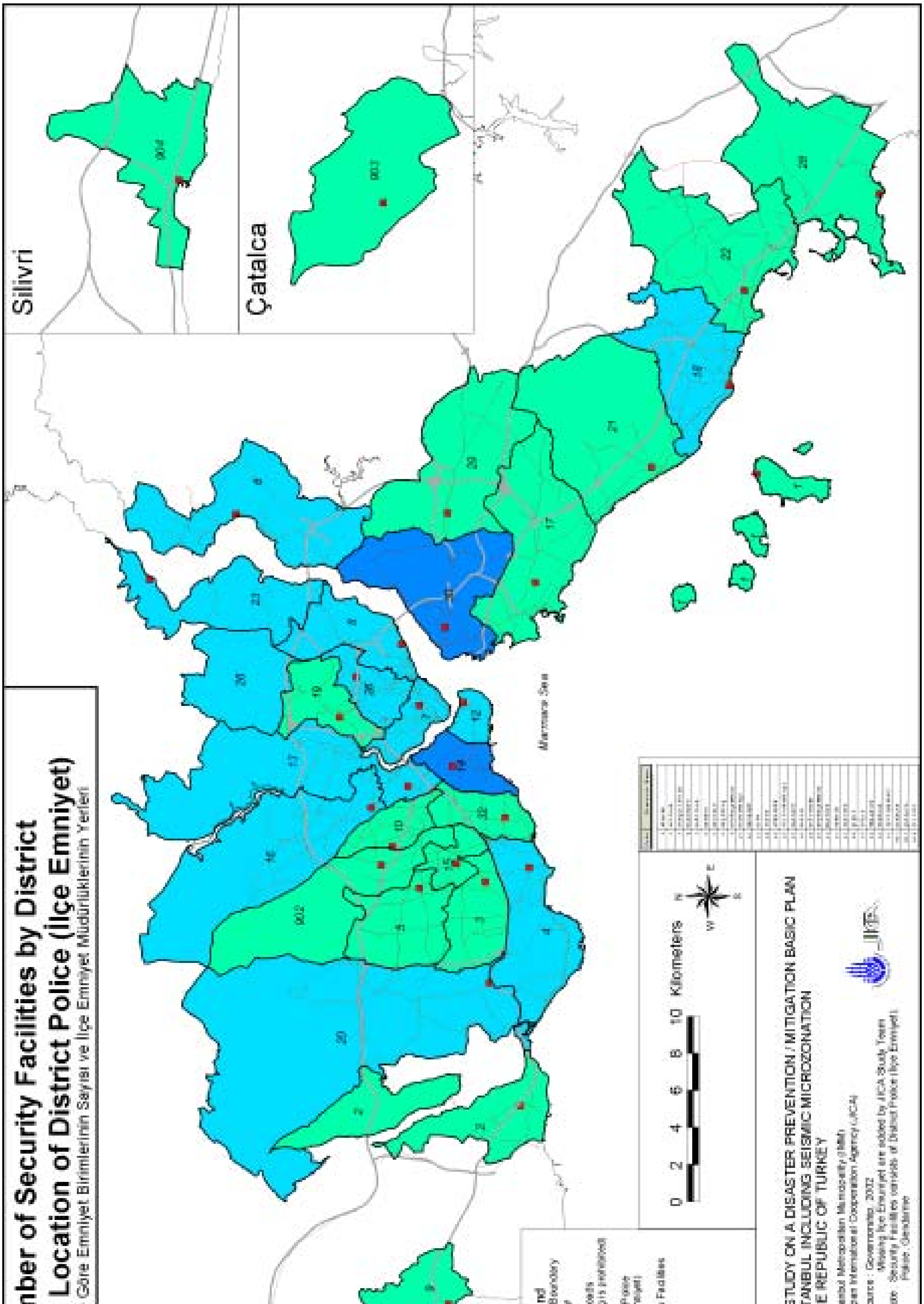


Figure 6.2.37 Number of Security Facilities by District and Location of District Police

(5) Governmental Facilities

Current situation for the governmental facilities is examined based on the data obtained from the province in May 2002. Table 6.2.16 shows numbers of ministerial, provincial, and municipal buildings for each district.

Table 6.2.16 Numbers of Buildings Belong to Ministry, Province, and Municipality for Each District

Code	District	Ministry	Province	Municipality	Total
1	ADALAR	0	1	1	2
2	AVCILAR	2	1	12	15
3	BAHÇELİ EVLER	7	1	11	19
4	BAKIRKÖY	21	1	11	33
5	BAĞCILAR	0	1	1	2
6	BEYKOZ	8	1	11	20
7	BEYOĞLU	26	1	8	35
8	BEŞİ KTAŞ	21	1	14	36
9	BÜYÜKÇEKMECE	1	1	8	10
10	BAYRAMPAŞA	3	1	6	10
12	EMİ NÖNÜ	10	2	5	17
13	EYÜP	19	1	14	34
14	FATİ H	11	1	28	40
15	GÜNGÖREN	1	1	3	5
16	GAZİ OSMANPAŞA	3	1	8	12
17	KADIKÖY	27	1	10	38
18	KARTAL	21	1	13	35
19	KAĞITHANE	3	1	4	8
20	KÜÇÜKÇKMECE	3	2	16	21
21	MALTEPE	3	1	3	7
22	PENDİ K	7	1	7	15
23	SARIYER	5	1	9	15
26	Şİ ŞLİ	10	1	4	15
28	TUZLA	7	1	8	16
29	ÜMRANİ YE	0	1	2	3
30	ÜSKÜDAR	0	1	1	2
32	ZEYTİ NBURUNU	8	1	2	11
902	ESENLER	2	1	8	11
903	ÇATALCA	0	1	1	2
904	Sİ Lİ VRİ	0	1	1	2
Total		229	32	230	491
Average		-	-	-	16

Source: Provincial Disaster Management Center

More than 35 buildings of governmental facilities are located in Fatih (40 buildings), Kadıköy (38 buildings), and Beşiktaş (36 buildings). In an average 16 buildings are located in each district. Figure 6.2.38 shows numbers of buildings of governmental facilities and the locations of the central provincial offices (Kaymakamılık) and the municipality offices (Belediye) for each district. According to the figure, the central provincial offices (Kaymakamılık) and the municipality offices (Belediye) tend to be located close to the first degree road designated by IMM.

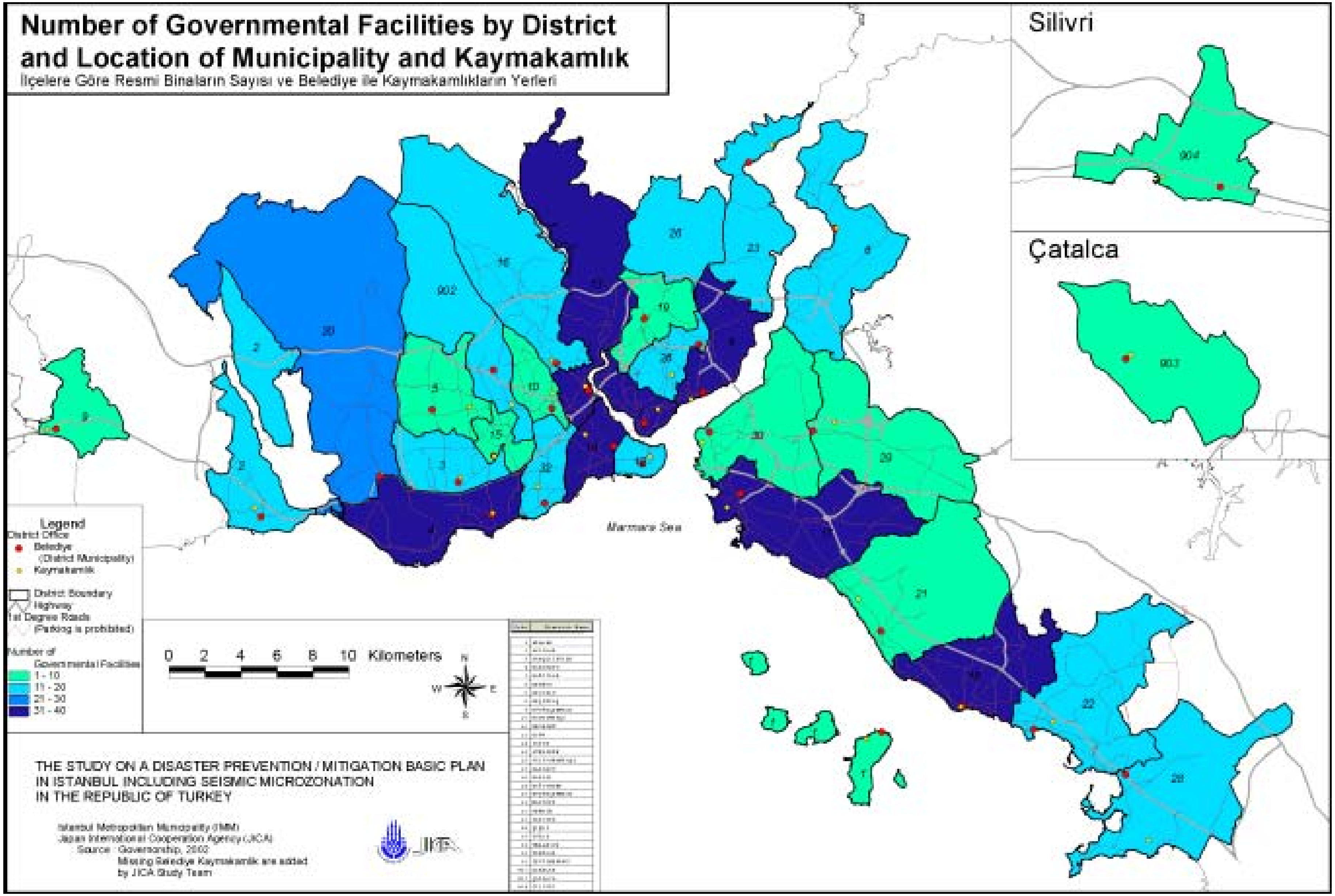


Figure 6.2.38 Number of Governmental Facilities by District and Location of Municipality and kaymakamlik

6.2.7. Hazardous Facility Data

During an earthquake, hazardous facilities may cause secondary disasters. It is imperative, therefore, to have a database to understand not only the distribution of hazardous facilities, but also to understand which critical facilities have high danger rates. The list of the 882 registered hazardous facilities (which are categorised as 1) large LPG storage, 2) paint/polish products factories, 3) Chemical Warehouses, 4) fuel/LPG filling stations, 5) fuel filling stations) was compiled by the Licensing Directorate of IMM. This data does not contain building information. In the Study, critical areas for fire outbreak were to be identified. Distribution based on Districts are summarized and shown in Table 6.2.17 and Figure 6.2.39.

Table 6.2.17 Distribution of Hazardous Facility

District Code	District Name	Big LPG Storage	Factory of Paint/Polish Products	Warehouse of Chemical Products	Fuel/LPG Filling Facility	Fuel Filling Station	TOTAL
1	ADALAR	0	0	0	0	0	0
2	AVCILAR	3	0	10	4	0	17
3	BAHÇELİEVLER	7	0	11	16	2	36
4	BAKIRKÖY	0	0	17	2	0	19
5	BAĞCILAR	17	0	28	16	0	61
6	BEYKOZ	0	0	11	2	0	13
7	BEYOĞLU	4	1	14	1	2	22
8	BEŞİKTAŞ	7	0	10	1	0	18
9	BÜYÜKÇEKMECE	N/A	N/A	N/A	N/A	N/A	N/A
10	BAYRAMPAŞA	2	1	8	5	5	21
12	EMİNÖNÜ	4	0	3	0	0	7
13	EYÜP	6	7	10	4	2	29
14	FATİH	13	0	12	4	0	29
15	GÜNGÖREN	4	1	8	4	1	18
16	GAZİOSMANPAŞA	14	12	30	1	2	59
17	KADIKÖY	6	0	35	5	0	46
18	KARTAL	9	9	22	5	1	46
19	KAĞITHANE	15	7	10	7	5	44
20	KÜÇÜKÇEKMECE	9	10	16	6	2	43
21	MALTEPE	6	3	12	4	1	26
22	PENDİK	5	29	25	3	5	67
23	SARIYER	6	0	11	3	0	20
26	ŞİŞLİ	9	2	18	3	1	33
28	TUZLA	1	0	5	0	0	6
29	ÜMRANİYE	8	6	29	8	3	54
30	ÜSKÜDAR	2	0	20	11	0	33
32	ZEYTİNBURNU	6	3	19	6	1	35
902	ESENLER	0	0	10	2	0	12
903	ÇATALCA	N/A	N/A	N/A	N/A	N/A	N/A
904	SİLİVRİ	N/A	N/A	N/A	N/A	N/A	N/A
Total		163	91	404	123	33	814

Source: Licensing Directorate of IMM (2002)

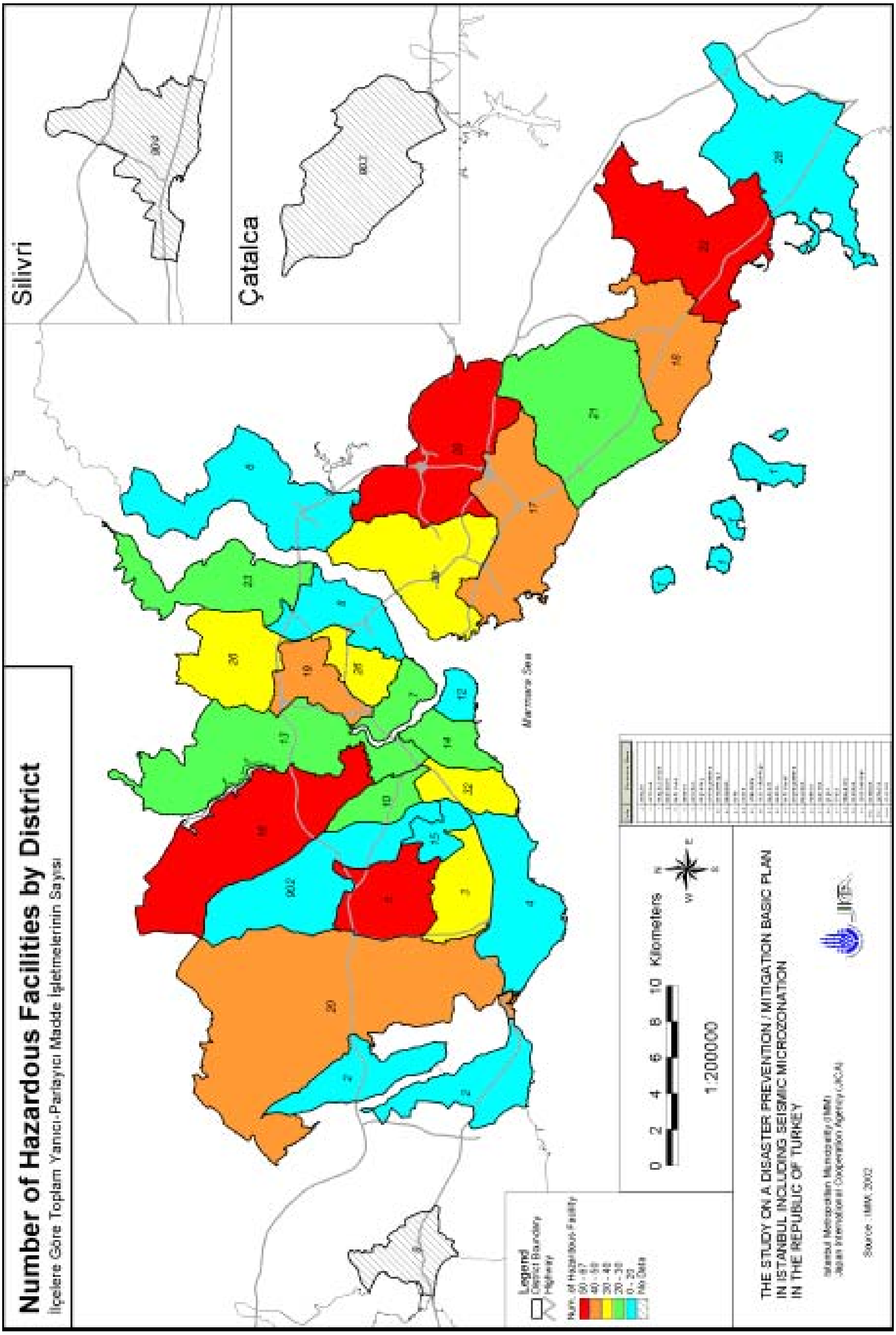


Figure 6.2.39 Number of Hazardous Facilities by District

Chapter 7.
Earthquake Analysis

Chapter 7. Earthquake Analysis

7.1. Scenario Earthquake

From the beginning of the study, many extensive discussions have occurred with relevant institutes/researchers in order to determine the scenario earthquakes. Based on these discussions and the recent amount of research work on the North Anatolian Fault (NAF), the scenario earthquakes were identified so that the appropriate damage estimation is taken into consideration in disaster prevention planning. The location of the NAF, in the Marmara Sea, was determined based on the most recent study result by CNRS-INSU, ITU, TÜBİTAK.

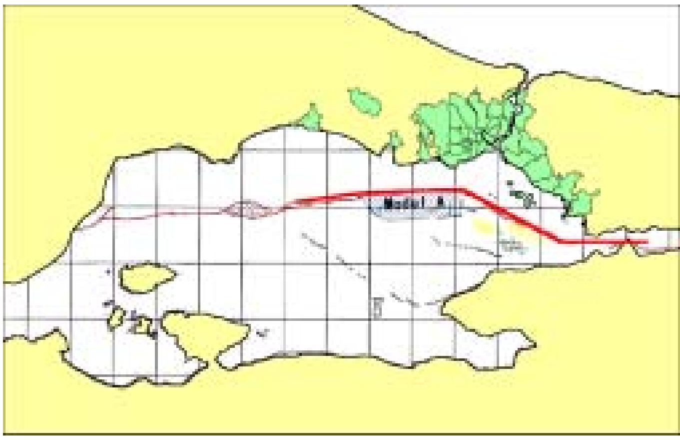
The following the four scenario earthquakes models were determined as show inFigure 7.1.1:

Model A: This section is about 120 km long from west of 1999 Izmit earthquake fault to Silivli. This model is the most probable model of these four scenario earthquakes because the seismic activity is progressing to the west. The moment magnitude (Mw) is assumed to be 7.5.

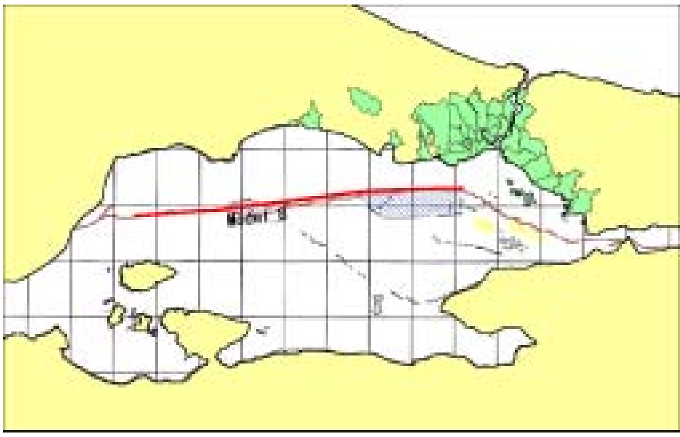
Model B: This section is about 110 km long from the eastern end of 1912 Murefte-Sarkoy earthquake fault to Bakılköy. The moment magnitude is assumed to be 7.4.

Model C: This model supposes a simultaneous break of the entire 170 km section of the NAF in the Marmara Sea. The moment magnitude is assumed to be 7.7. This is the largest magnitude that this area has ever experienced, as the maximum magnitude of historical earthquakes in the Marmara Sea area is 7.6. There is no evidence of a simultaneous break of the entire section in the past, though the eastern one-third did rupture on May 1766 and the rest on August 1766. If a rupture of the maximum length of the faults is assumed, this is the worst case within reason.

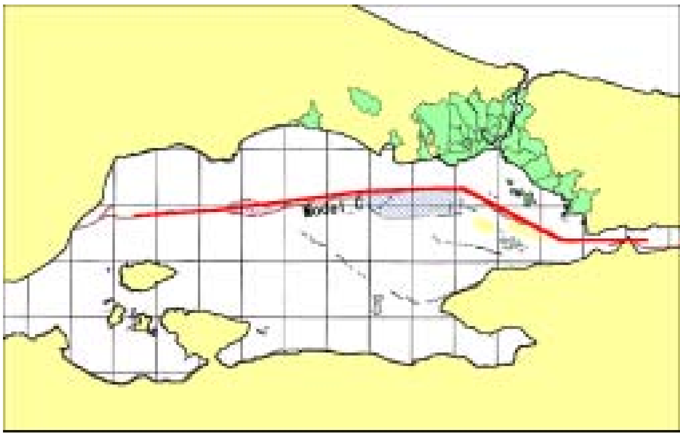
Model D: The continuous fault that was found in the north of the Marmara Sea follows the base of the northern steep slope of the Çinarcık Basin. A normal fault model was developed, which follows the northern slope of the Çinarcık Basin with reference to many recent researched works. The moment magnitude (Mw) was assumed to be 6.9 with the empirical formula for a normal fault.



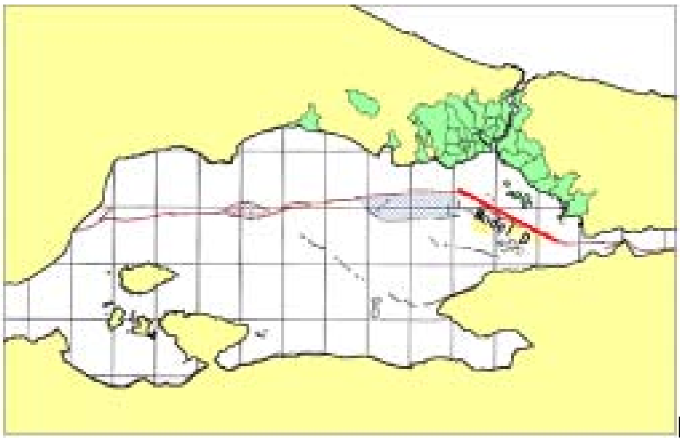
Model A



Model B



Model C



Model D

Figure 7.1.1 Scenario Earthquakes

The fault model scenario earthquake parameters were decided as shown in Table 7.1.1.

Table 7.1.1 Fault Model Parameters

	Model A	Model B	Model C	Model D
Length (km)	119	108	174	37
Moment magnitude (Mw)	7.5	7.4	7.7	6.9
Dip angle (degree)	90	90	90	90
Depth of upper edge (km)	0	0	0	0
Type	Strike-slip	Strike-slip	Strike-slip	Normal fault

7.2. Ground Motion

A flowchart of the earthquake analysis is shown in Figure 7.2.1. Based on the fault model, peak acceleration, peak velocity, and acceleration response spectrum are calculated with the selected empirical attenuation formula. Next, the amplification factor is multiplied to get the peak ground acceleration (PGA), peak ground velocity (PGV), and acceleration response spectrum (Sa) at the ground surface.

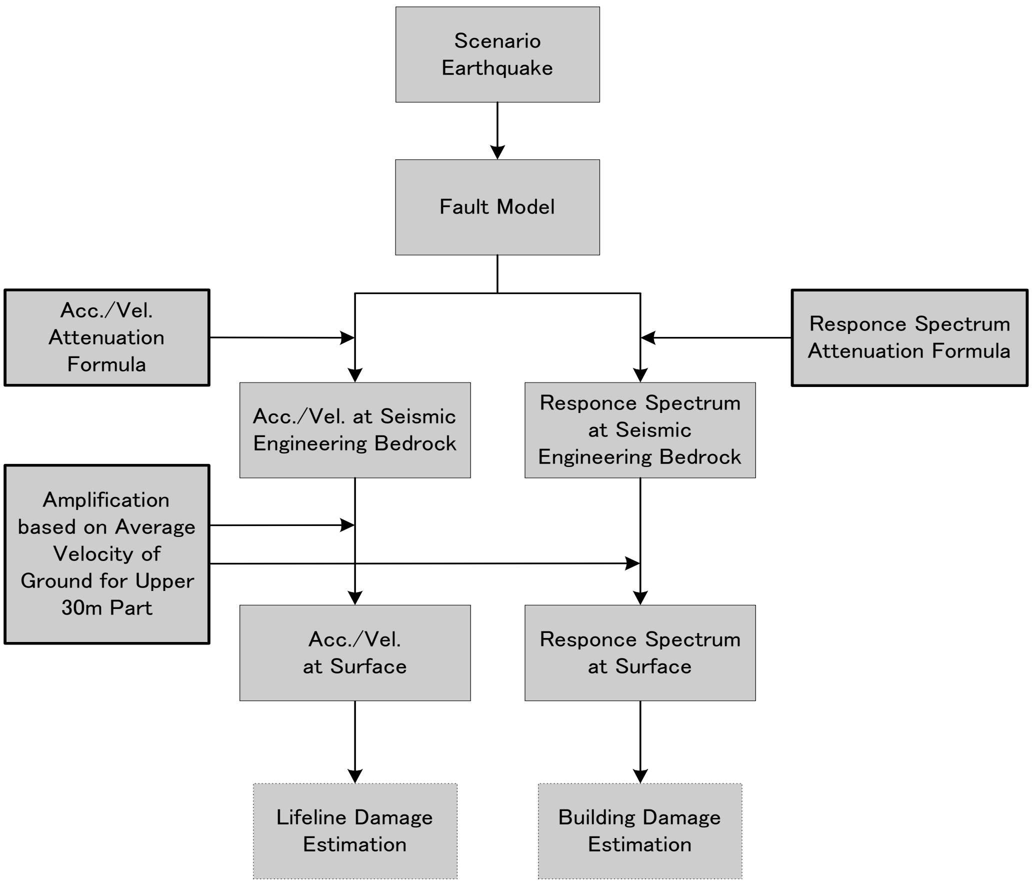


Figure 7.2.1 Flowchart of Earthquake Ground Motion Analysis

7.2.1. Bedrock Motion

Many researchers have proposed different empirical attenuation functions. The selection of the attenuation formula was conducted separately for the acceleration, velocity, and acceleration response spectrum. Formulae that explain the observed data during the August 17, 1999 Izmit Earthquake were selected. This decision was based on similarities between the Izmit Earthquake and the scenario earthquakes: namely, magnitude of the Izmit Earthquake is 7.4 and those of the scenario earthquakes are 6.9 to 7.7. The types of faults of all earthquakes are strike-slip, except that of Model D.

(1) Acceleration

Seven (7) attenuation formulae were studied and the formula by Boore *et al*. (1997) was selected for PGA analysis for Model A, B and C. Spudich *et al*. (1999) is used for Model D, which has a normal fault mechanism.

(2) Velocity

Four (4) attenuation formulae were studied, and the formula by Campbell (1997) was selected for PGV analysis. 200% of the estimated value obtained by this formula was used. For normal fault, there was no adequate attenuation function of PGV. Therefore, the PGV of Scenario Earthquake D could not be estimated.

(3) Acceleration Responce Spectrum (Sa, h=5%)

Four (4) attenuation formulae were studied, and the formula by Boore *et al*. (1997) was selected for the Sa analysis. 130% of estimated value obtained by this formula was used.

7.2.2. Subsurface Amplification

Subsurface amplification was evaluated by an amplification factor assigned to each site class. Classifications ranged from class A to E according to the average S wave velocity over the upper 30 m (AVS30) of the surface soil. This policy is based on the NEHRP (National Earthquake Hazards Reduction Program) “Recommended Provisions for Seismic Regulations for New Buildings and Other Structures,” (1997 edition, FEMA-302, 303; BSSC, 1997. This method takes the difference of ground class into consideration, as well as that of nonlinear effects during strong motion.

The amplification factor of acceleration response spectrum was defined at 0.2 seconds and 1.0 seconds. The amplification factor of site class B (760m/s $<$ AVS30 $\leq$ 1500 m/s) was defined to be 1.0 at the seismic engineering bedrock.

The difference between amplification factors of site class D and E was large. Therefore, in this study, site class D was divided into 5 sub-classes (D1 to D5). If enough data to decide on the subclasses was not available, the single site class D was used. Site classification and amplification factors are shown in Table 7.2.1 and Figure 7.2.2, respectively. The amplification of PGA and PGV were assumed to be identical to the amplification of Sa (h = 5%) at 0.2 seconds and Sa (h = 5%) at 1.0 second, respectively, according to Wald *et al.* (1999).

Table 7.2.1 Site Classification Applied in the Study

Site Class	Average S Wave Velocity Over Upper 30m
A	>1500m/sec
B	760 - 1500m/sec
C	360 - 760m/sec
D	180 - 360m/sec
D1	300 - 360m/sec
D2	250 - 300m/sec
D3	220 - 250m/sec
D4	200 - 220m/sec
D5	180 - 200m/sec
E	<180m/sec

Source: NEHRP

Note: AVS30 = Average S wave Velocity over the upper 30 m

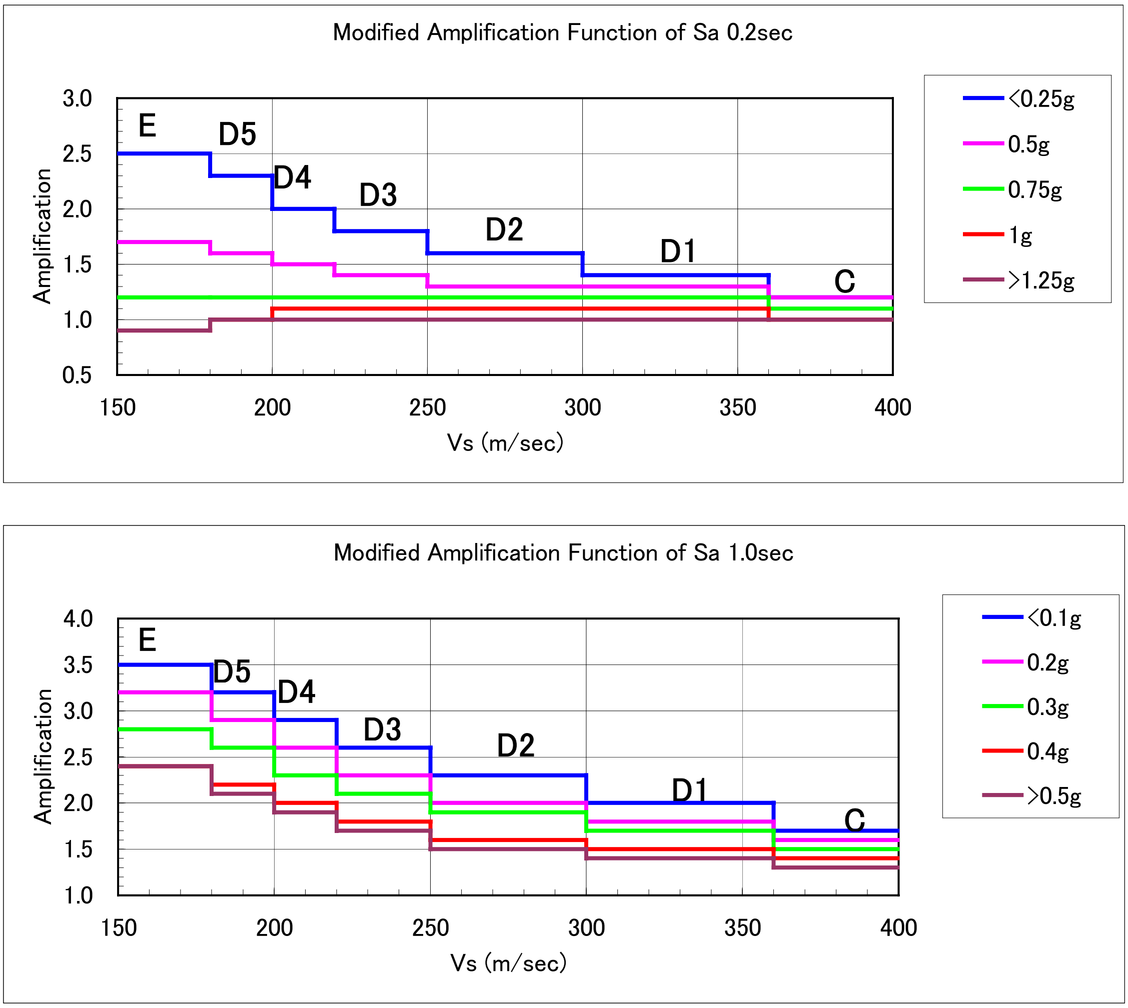


Figure 7.2.2 Modified Amplification Function

7.2.3. Ground Model

A square grid system of 500 m by 500 m dimensions was adopted for the ground motion calculation. Geological models were defined for each grid using geological maps, geological cross-sections, boring logs, and shear wave velocities. The ground-modeling flowchart is shown in Figure 7.2.3.

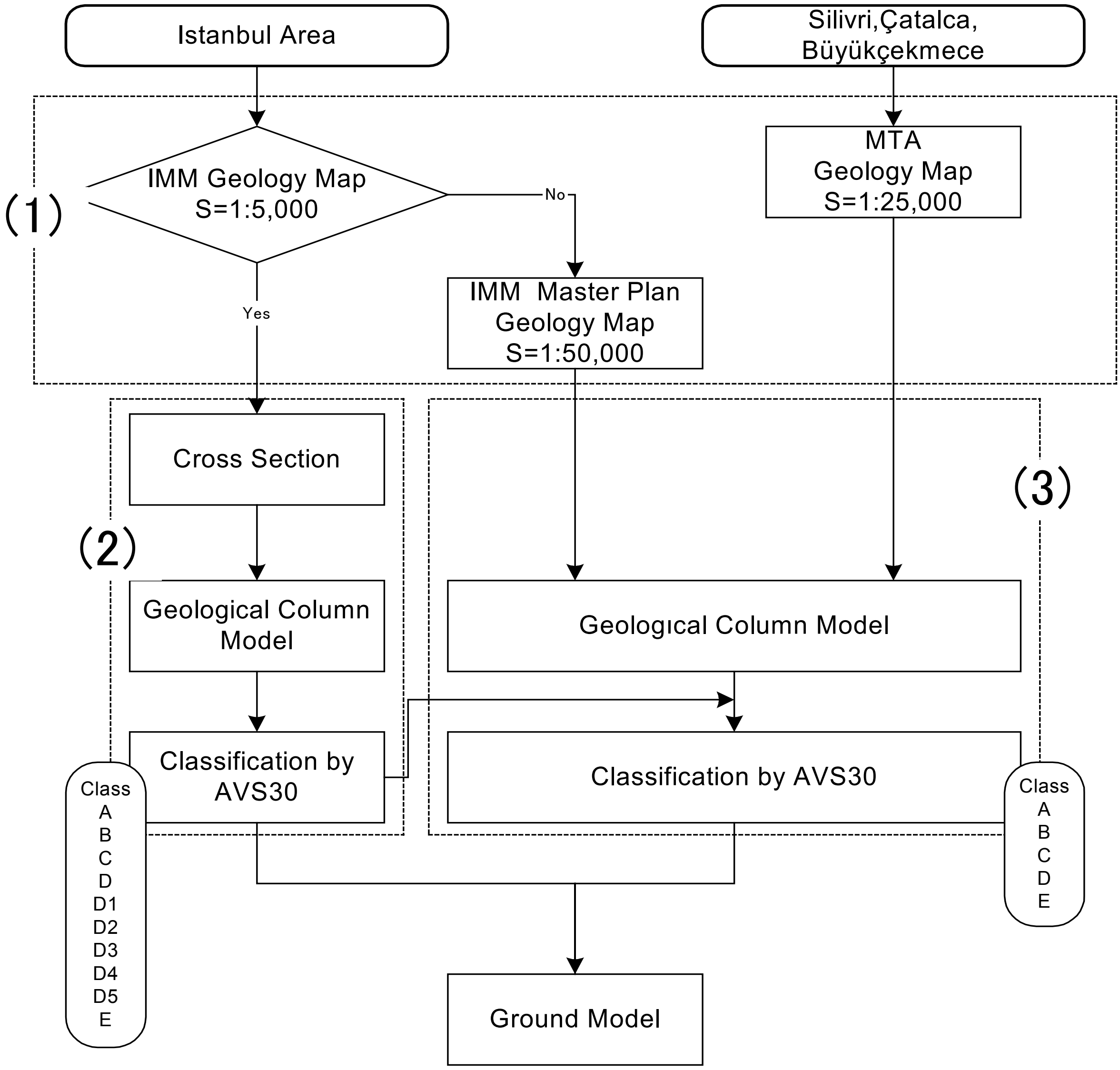


Figure 7.2.3 Flowchart of Ground Classification

Geological cross sections were prepared at1 km interval in areas for which 1:5000 geological maps were available. Geological models of the upper 30 meters of each 500 m grid were compiled. In other areas, only surface geology was used.

Shear wave velocities were measured comprehensively by suspension PS logging. Ground shear wave velocities for every 1 m-pitch of the boreholes were directly correlated to most of the geological units in the Study Area. Shear wave velocities for each geological unit were examined statistically in detail, considering 1) correlation to standard penetration test N value and 2) variation by measured depth or elevation. Determined shear wave velocities for each geological formation are tabulated in Table 7.2.2.

Table 7.2.2 Shear Wave Velocity of Geological Formation Applied in Earthquake Analysis

Geological Formation and sub-category			Average Shear Wave Velocity (m/sec)	Applied Shear Wave Velocity (m/sec)
Yd/Sd			280	150
Qal			240	220
Kşf			190	150
Ym			-	150
Baf	All data		430	-
	105m < Elevation		260	260
	51m < Elevation < 105m		470	470
	7m < Elevation < 51m		330	330
	Elevation <7m		600	600
Gnf	All data		340	-
	0m < Depth < 15m		260	260
	15m < Depth		360	360
Çf/Sbf			410	410
Çmlf			460	460
Güf	All data		440	-
	West of Küçükçekmece Gölü	All data	380	-
		-76m <Elevation	330	330
		-131m < Elevation < -76m	410	410
		Elevation < -131m	550	550
	East of Küçükçekmece Gölü	All data	480	-
		60m < Elevation	300	300
		-10m < Elevation < 60m	600	600
		-45m < Elevation < -10m	390	390
		Elevation < -45m	510	510
Cef			-	850
Sf			850	850
Trf			1310	1310
Kf			1360	1310
Df			2620	1310
Other Rock formations			-	1310

Using these values, average shear wave velocities of the upper 30 m of every 500 m grid model are calculated. Ground classification of each grid model was determined according to Table 7.2.1. In the area where 1:5,000 geological maps were not available, the classification shown in Table 7.2.3 was adopted. The compiled ground classification map is shown in Figure 7.2.4.

Table 7.2.3 Site Class Definition for Areas of IMM 1:50,000 Geological Maps and MTA 25,000 Geological Maps

Surface Geology	Site Class
Alluvium deposit layer	D
Tertiary layer	C
Rock formation	B

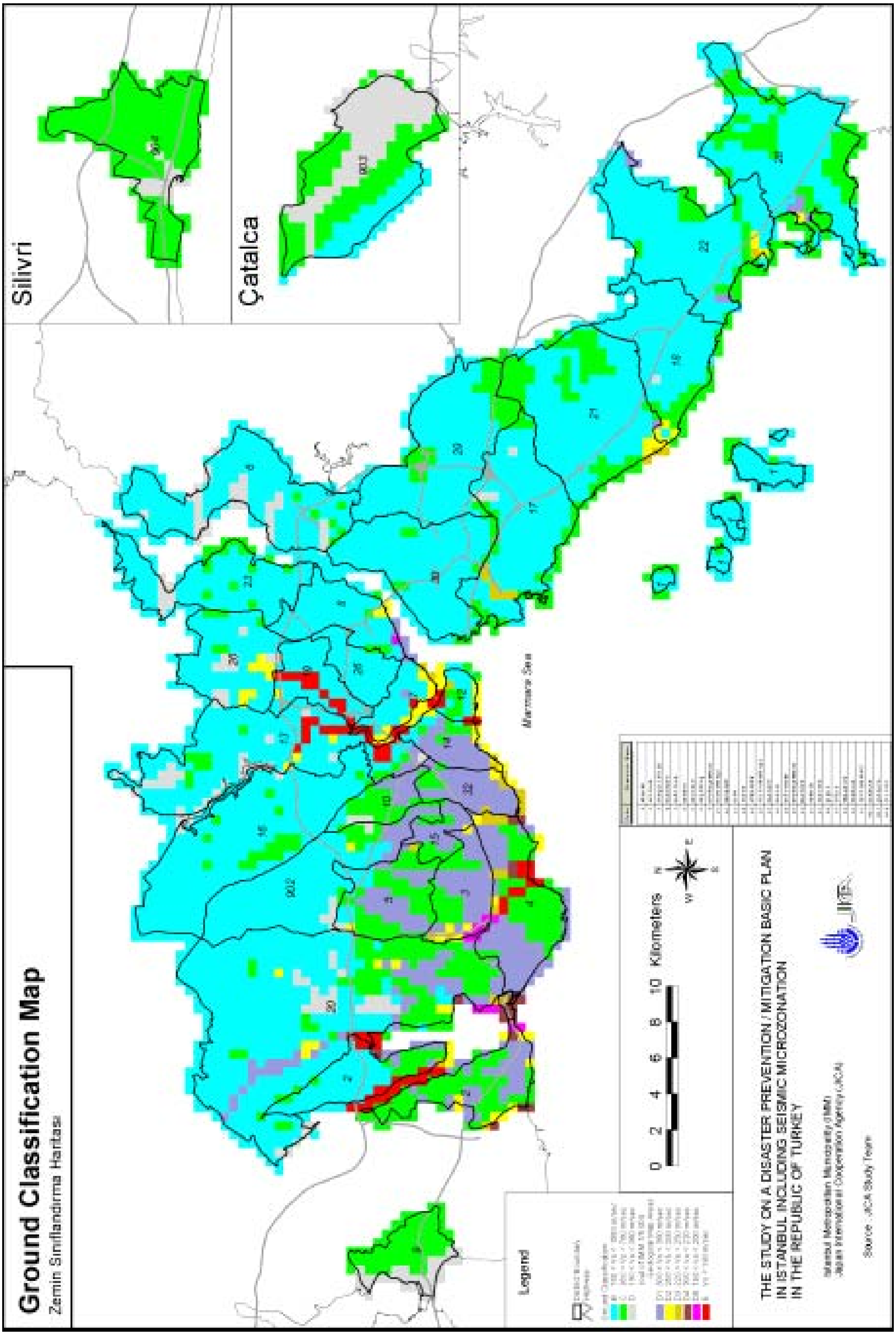


Figure 7.2.4 Ground Classification Map

7.2.4. Ground Motion by Scenario Earthquakes

(1) Peak Ground Acceleration (PGA)

The PGA distribution maps are shown in Figure 7.2.5 to Figure 7.2.8.

a. Model A

Acceleration exceeds over 400 gals on the seashore of the European side and in Adalar. The valley following north from Haliç also experiences accelerations of over 400 gals. Acceleration in Eminönü to Büyükçekmece ranges from 300 to 400 gals. In the majority of areas of the New City, Çatalca, and Silivri, acceleration ranges from 200 to 300 gals. The Asian side suffers less than 300 gals, except for the seaside areas.

b. Model B

The PGA distribution of the European side is similar to Model A. The majority of the Asian side area experiences accelerations of less than 200 gals, except Adalar, Kadıköy, and Üsküdar.

c. Model C

The seaside area of Bakırköy and part of Adalar experiences accelerations of more than 500 gals. Accelerations of over 400 gals are estimated in Tuzla, Fatih to Avcılar, and the valley extending to the north from Haliç. The area with accelerations of 400 to 500 gals is a little wider to the north, compared to Model A. Every grid in this model experiences the largest observed PGA of the four scenario earthquakes.

d. Model D

A part of Adalar and Bakırköy experience accelerations of over 400gals. Bakırköy and part of Tuzla experience accelerations of 300 to 400 gals. Accelerations of 200 to 300 gals are experienced from Eminönü to Avcılar and on the Asian seashore.

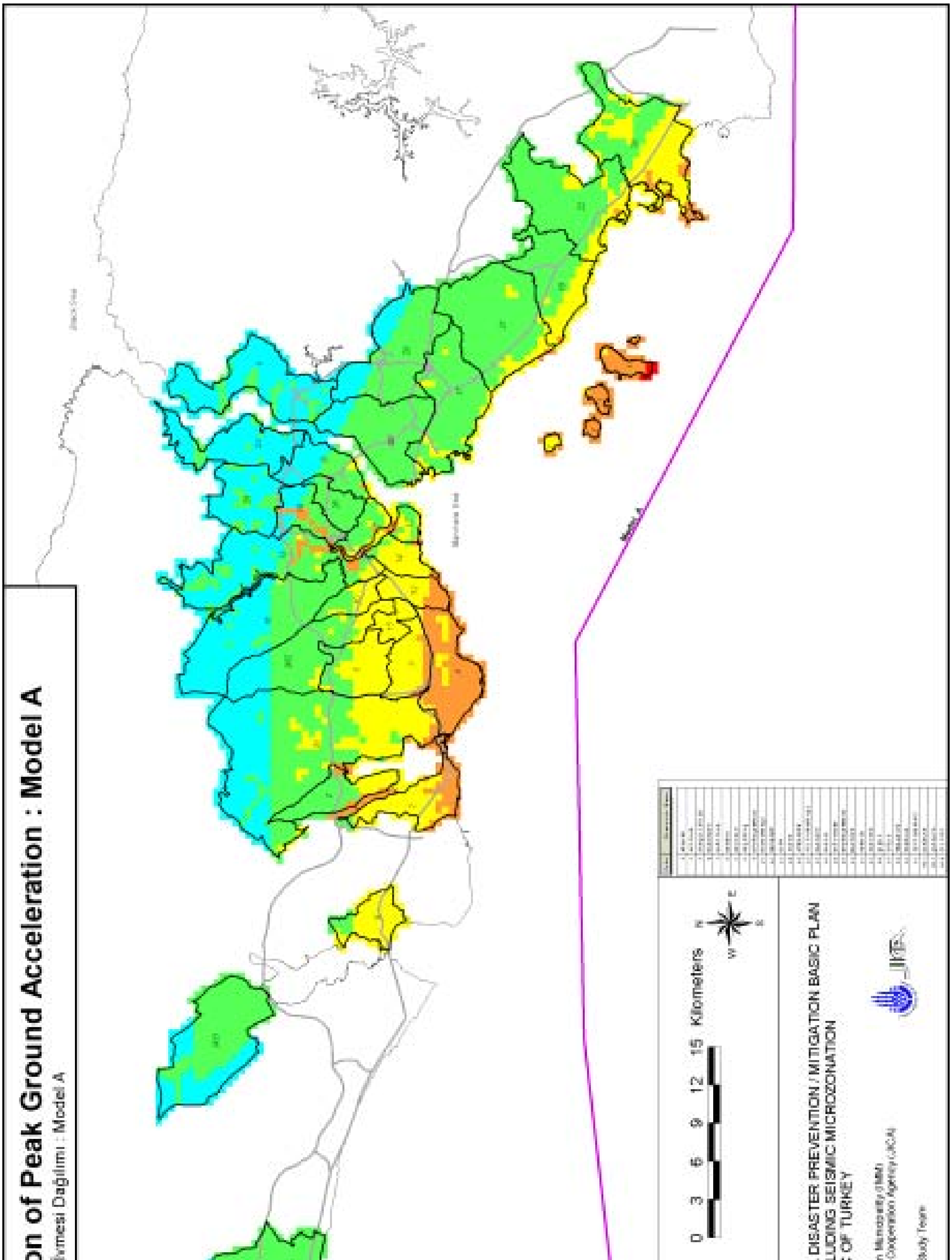


Figure 7.2.5 Distribution of Peak Ground Acceleration: Model A

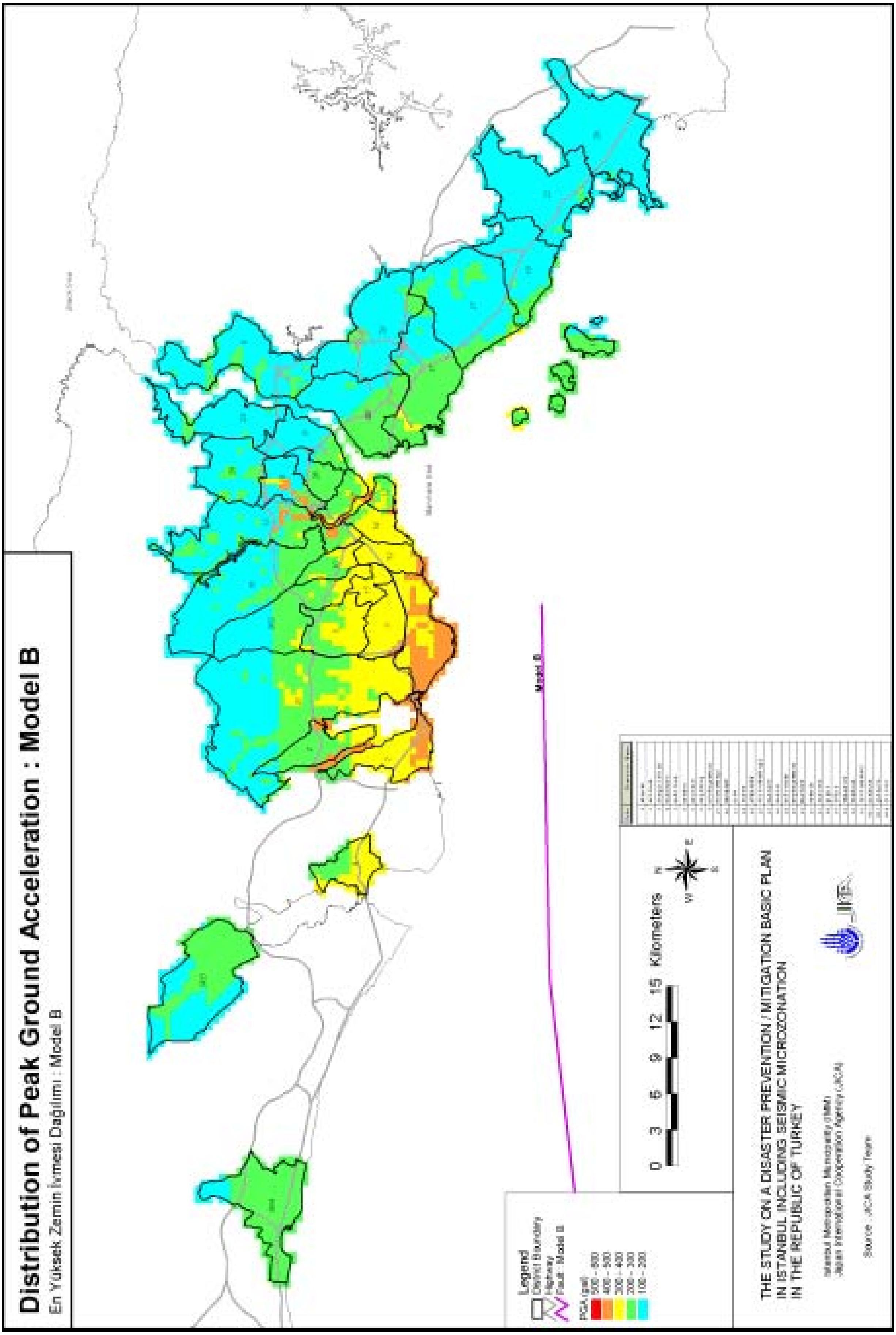


Figure 7.2.6 Distribution of Peak Ground Acceleration: Model B

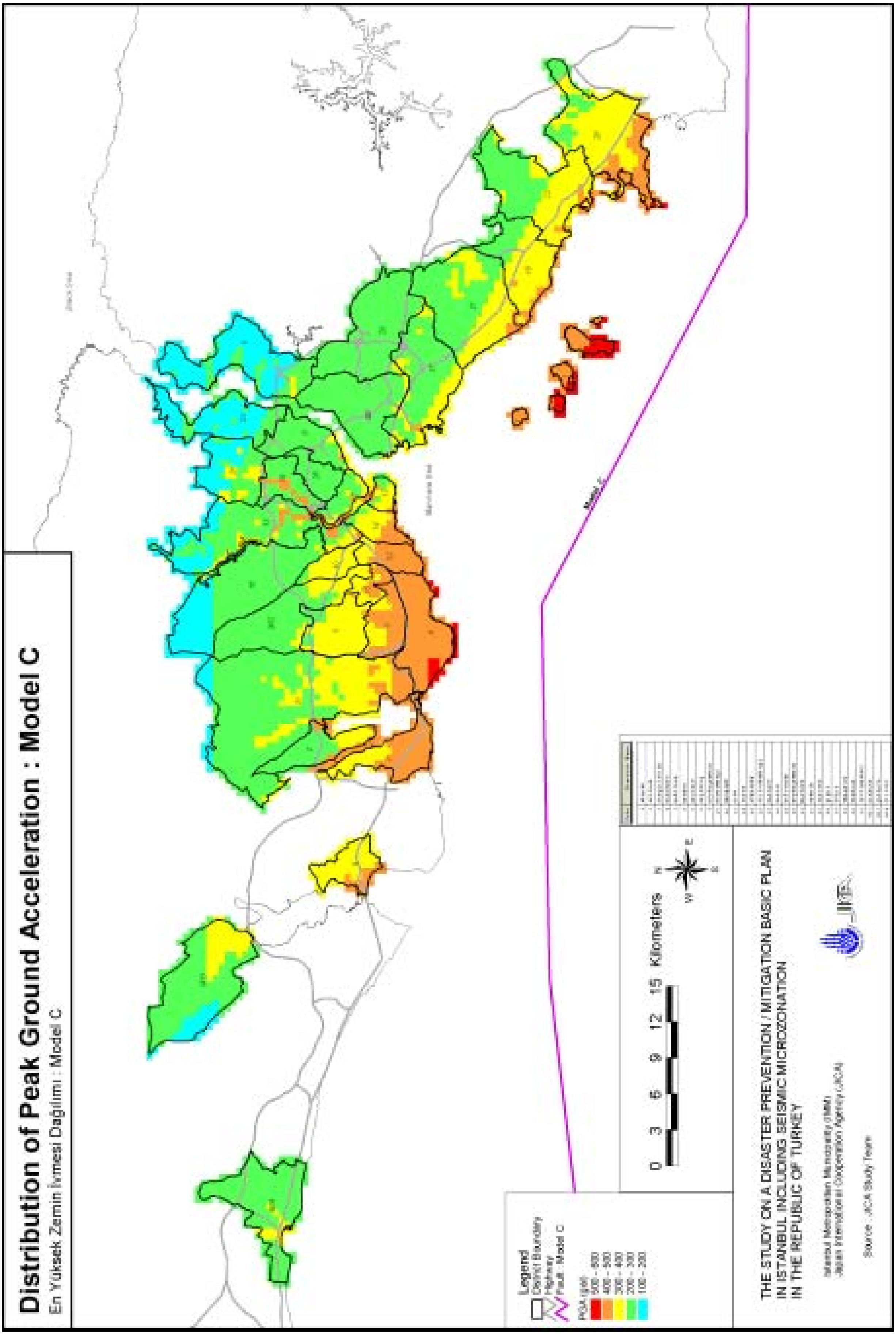


Figure 7.2.7 Distribution of Peak Ground Acceleration: Model C

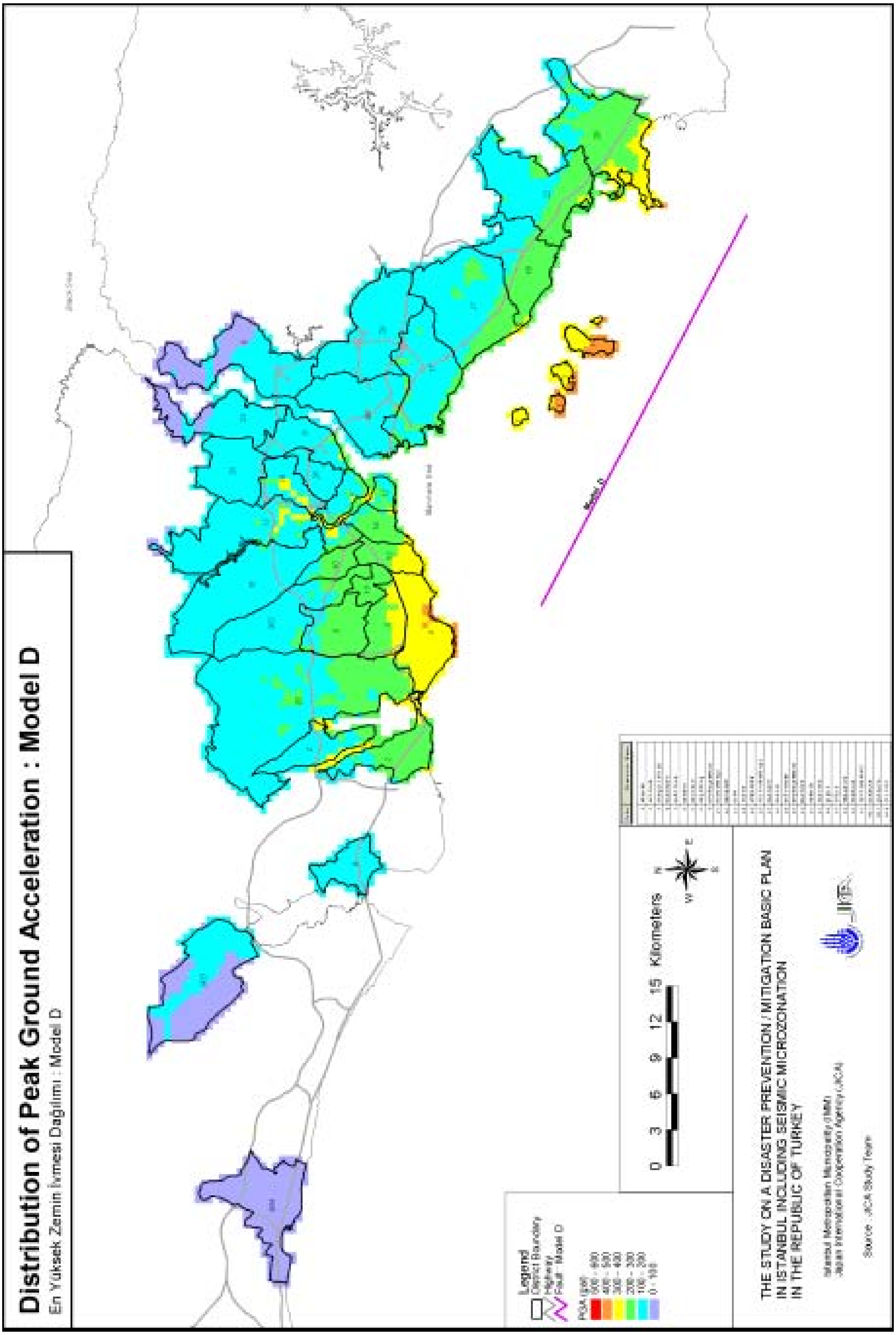


Figure 7.2.8 Distribution of Peak Ground Acceleration: Model D

(2) Peak Ground Velocity (PGV)

The PGV distribution maps are shown in Figure 7.2.9 to Figure 7.2.11. PGV of Model D was not estimated because an adequate attenuation function was not available for the normal fault.

Ground conditions (grid class site) influence PGV distribution more than they do PGA distribution. This difference is explained as follows:

- Short period, seismic motion components more strongly reflect PGA values, and long period seismic motion components more strongly reflect PGV values.
- The short period seismic motion is strongly affected by the non-linearity effect of soil because the scenario earthquake is large.
- The long period seismic motion (PGV) is not affected very much.

a. Model A

Grid classes D4, D5, and E on the European side experience velocities of over 80 kine. Grid classes D1, D2, and D3 in Fatih, Bayrampaşa, Bağcılar, Avcılar, and the southern districts on the European side experience velocities of 60 to 80 kine. The class C grid on the Asian seashore experience velocities of 40 to 60 kine.

b. Model B

The PGV distribution on the European side of Model B is somewhat similar to Model A. The majority of the Asian side, except the seaside from Maltepe to Tuzla and along the valley, experience velocities of less than 40 kine.

c. Model C

The area that experiences velocities of 40 kine is wider than that of Model A on the Asian side.

Every grid experiences the largest PGV among the three scenario earthquakes.

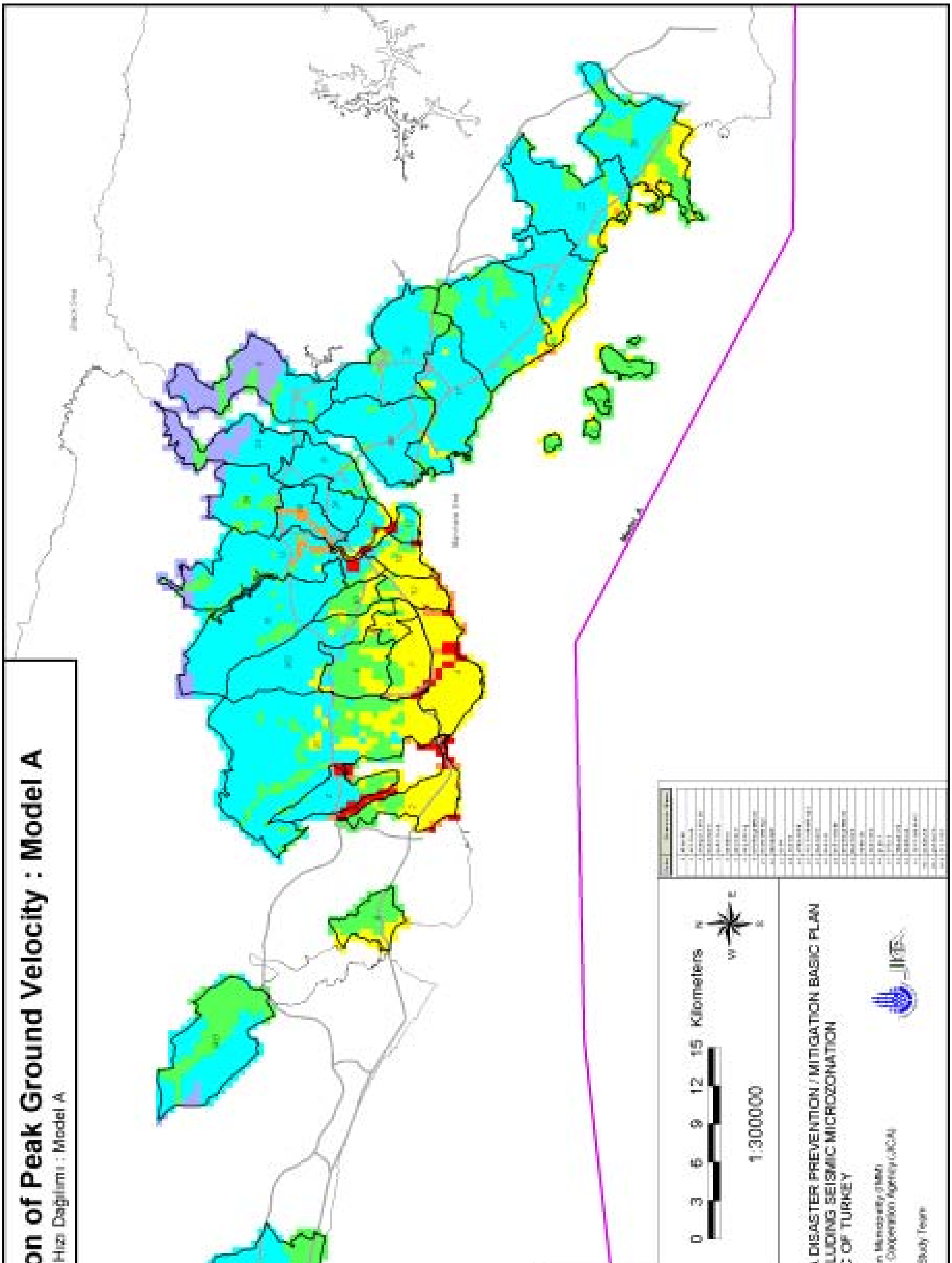


Figure 7.2.9 Distribution of Peak Ground Velocity: Model A

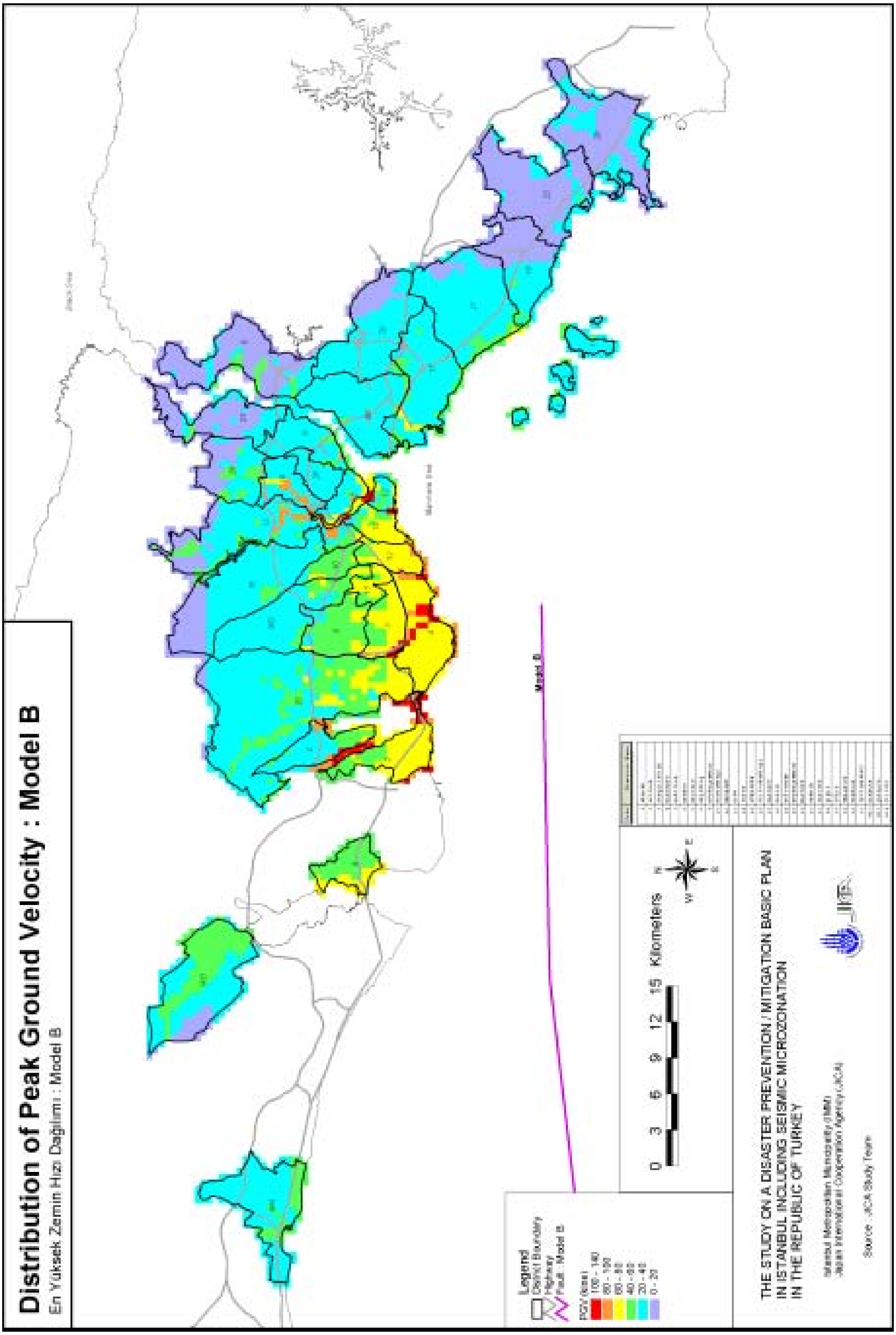


Figure 7.2.10 Distribution of Peak Ground Velocity: Model B

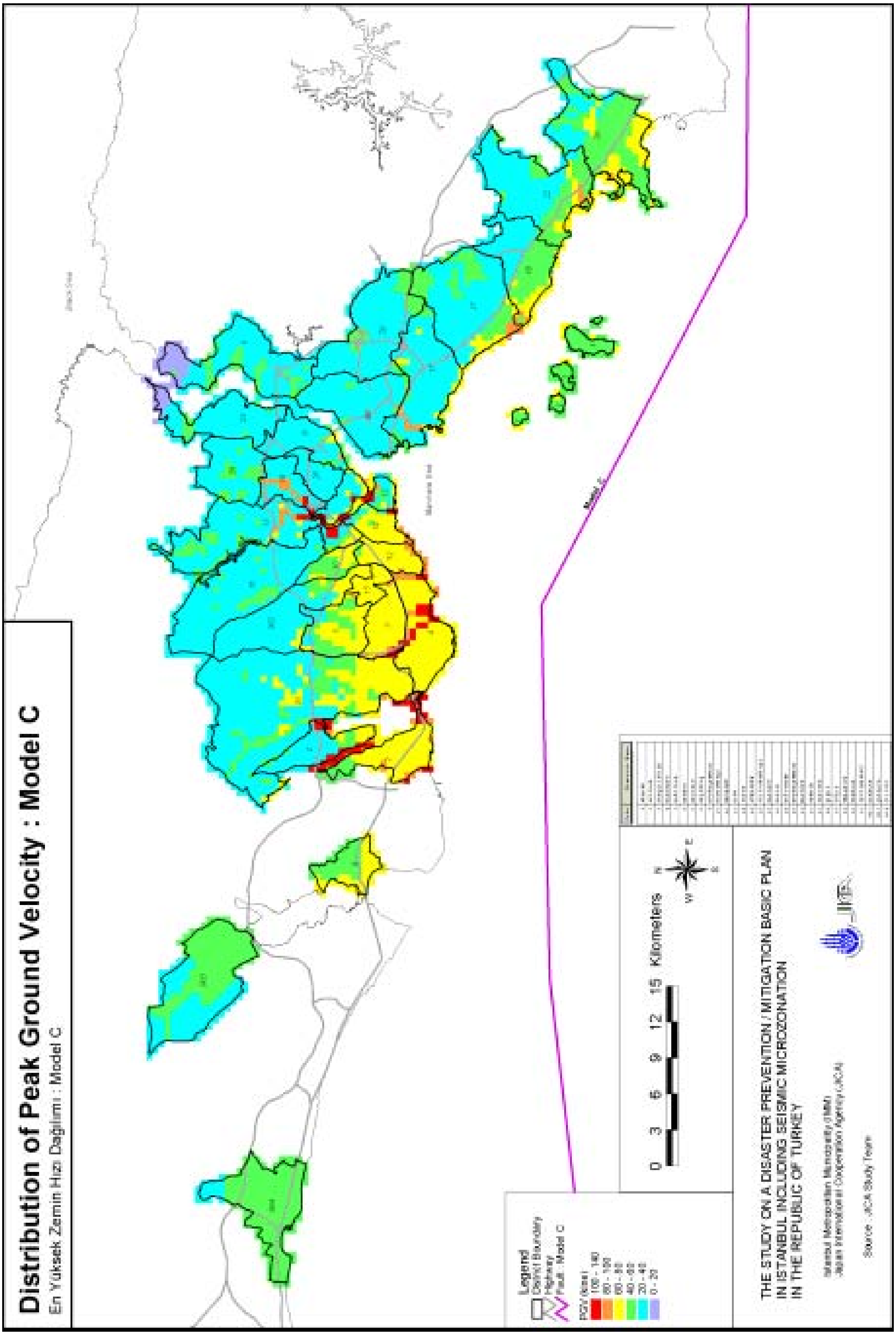


Figure 7.2.11 Distribution of Peak Ground Velocity: Model C

(3) Acceleration Response Spectrum (Sa, h=5%)

The 5% damped Sa values for the period of 0.1 to 2.0 seconds were calculated. The distribution maps of Sa at 0.2 sec and 1.0 sec are shown in Figure 7.2.12 to Figure 7.2.19.

a. Model A

0.2 sec: Sa values of 500 to 1000 gals are experienced from Eminönü to Büyükçekmece on the European side and on the seaside of the Asian side. Other areas experience 200 to 500 gals.

1.0 sec: Grid classes D and E at the seaside of Bakırköy experience over 500 gal. Eminönü to Büyükçekmece and the Asian seashore experience 200 to 500 gals.

b. Model B

The Sa distribution of the European side for Model B is similar to that for Model A. Almost the entire area on the Asian side experiences accelerations of 200 to 500 gals at 0.2 sec, and less than 200 gals at 1.0 sec.

c. Model C

0.2 sec: The Sa distribution for Model C is very similar to that of Model A.

1.0 sec: Almost all of Bakırköy experiences accelerations of over 500 gals, and the area with 200 to 500 gals is wider than that of Model A.

d. Model D

0.2 sec: The Sa distribution of Model D on the European side is similar to Model A. The majority of the Asian side experiences accelerations of 200 to 500 gals, except for the seaside.

1.0 sec: A part of Bakılköy experiences accelerations of over 500 gals. Bahçelievler and the southern district of the European side and seashore of the Asian side experience 200 to 500 gals. The majority of the study areas suffer less than 200 gals.