CHAPTER 6

EARTHQUAKE DAMAGE AND LOSSES

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6.1. Earthquake Intensity Zonation of Industrial Facilities

The element at risk assessed in Chapter 3 will be illustrated on the intensity distribution map that would result from the occurrence of the Marmara Earthquake. These maps are provided Figure 6.1.1 through Figure 6.1.8 respectively for industrial facilities in sectors1 to sector 8 obtained on the basis of the Turk-Telekom maps. The pie-chart of the distribution of these sectors overlaid on the intensity map are provided in Figure 6.1.9. The numbers of industrial facilities for each sector located in different intensity zones are given in Table 6.1.1

The distribution of small to medium size industrial facilities overlaid on the intensity map is shown in Figure 6.1.10. The data base is obtained from the Istanbul Metropolitan Municipality. The quantity of industrial facilities in each intensity zone is provided in Table 6.1.2

The location of the large size industrial park, where helicopter and, other surveys have been carried out, are indicated in Figure 6.1.11 on the intensity distribution map. Enlarged detail of this figure is provided in Figure 6.1.12.

Table 6.1.1. Numbers of Industrial Sectors in Each Intensity Zone.

INTENSITY ZONE	Sect.1	Sect.2	Sect.3	Sect.4	Sect.5	Sect.6	Sect.7	Sect.8
VI – VII	188	357	70	72	159	87	81	11
VII – VIII	393	339	148	113	184	147	196	43
VIII – IX	656	490	517	204	296	202	259	69
IX	160	113	110	72	75	47	48	17

Table 6.1.2. Numbers of small to medium size industrial facilities from municipality data in each intensity zone.

Intensity Zone	VI – VII	VII – VIII	VIII – IX	IX
Industrial Facilities	294	1044	1874	234

On the basis information provided in Chapter 4 and Chapter 5 and with reference to figure 4.3.8, figure 4.3.9, figure 5.2.1 and figure 5.2.6 .The mean damage ratio for buildings in industrial facilities can be given as in Table 6.1.3

Table 6.1.3 Mean Damage Ratios for Buildings in Industrial Facilities

EMS-98 I or MMI	VII	VIII	IX
Mean Damage Ratio	3%	8%	20%

The following average losses can be predicted in reference to the factual loss information presented in Chapter 4 and earthquake vulnerability information presented in Chapter 5 for ”Equipment and Machinery” and “Stock” losses in EMS-98 I (MMI) IX intensity zones for each industrial sector, originally defined by Table 6.1.4

Table 6.1.4. Mean Loss Ratios for ”Equipment and Machinery” and “Stock” for MMI IX

Sector No	Description	Equipment and Machinery Loss	Stock Loss
1	Mining, Construction, Ceramics, Glass Min	10%	10%
2	Commercial Facilities, Food and Beverage	10%	10%
3	Textile, Leather	10%	30%
4	Wood products and furniture, Agriculture	10%	10%
5	Chemical and Petroleum Products	30%	35%
6	Iron- steel and the other metals	2%	2%
7	Machinery and automotive	2%	2%
8	Transportation and telecommunication	10%	2%

It should be noted that these loss ratios are associated large variations depending on the physical properties of the industrial facility and the possibility of consequential hazard related losses.

Although very limited empirical data exists at intensity level VIII for losses at industrial facilities, Figure 4.5.1 indicate that the ”Equipment and Machinery” and “Stock” losses would be realized at about 1/3 to 1/4 of the average losses associated with intensity level IX.

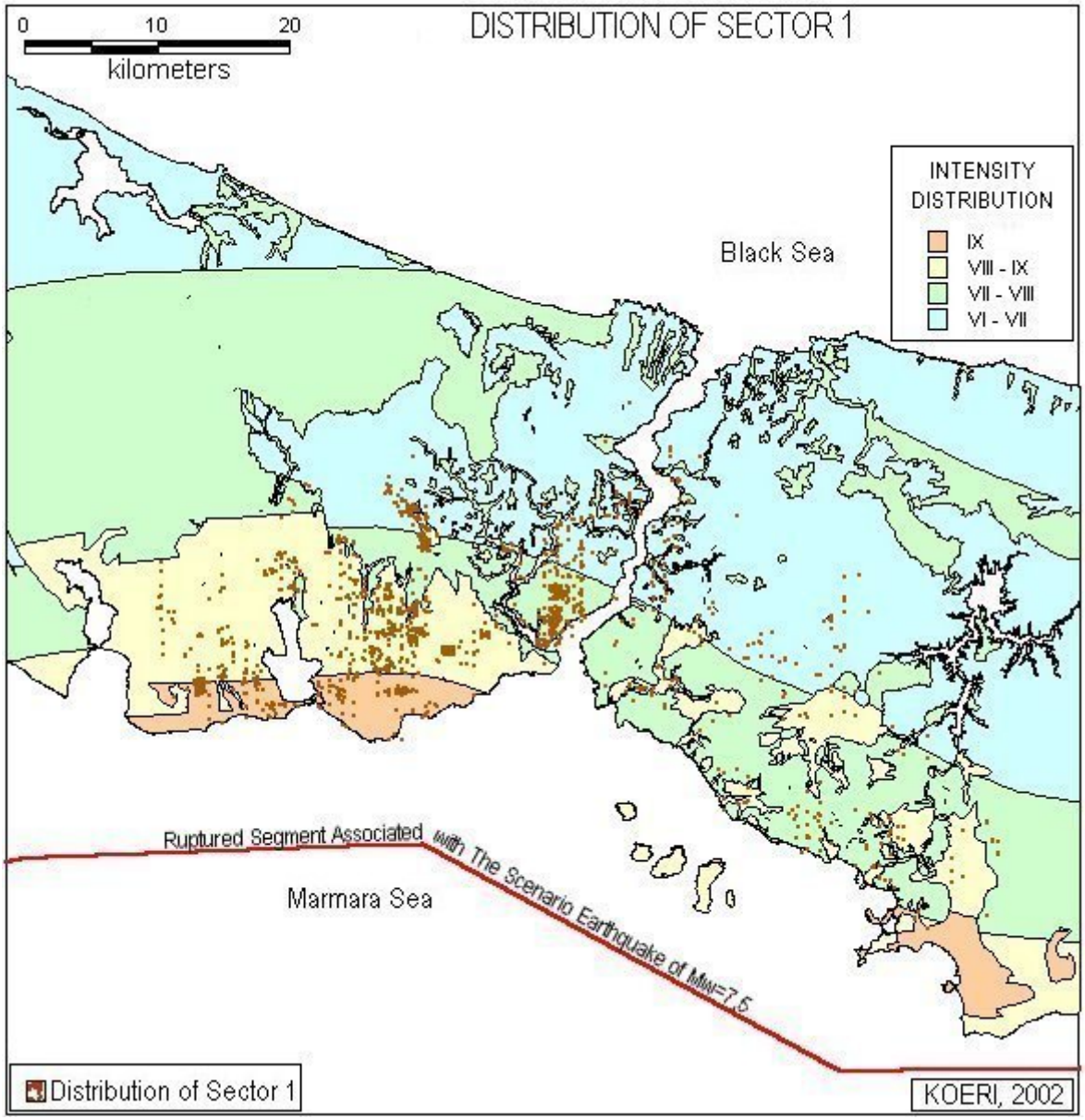

Figure 6.1.1. The distribution of industrial facilities in Sector 1 overlaid on the intensity map (each dot represents one facility).

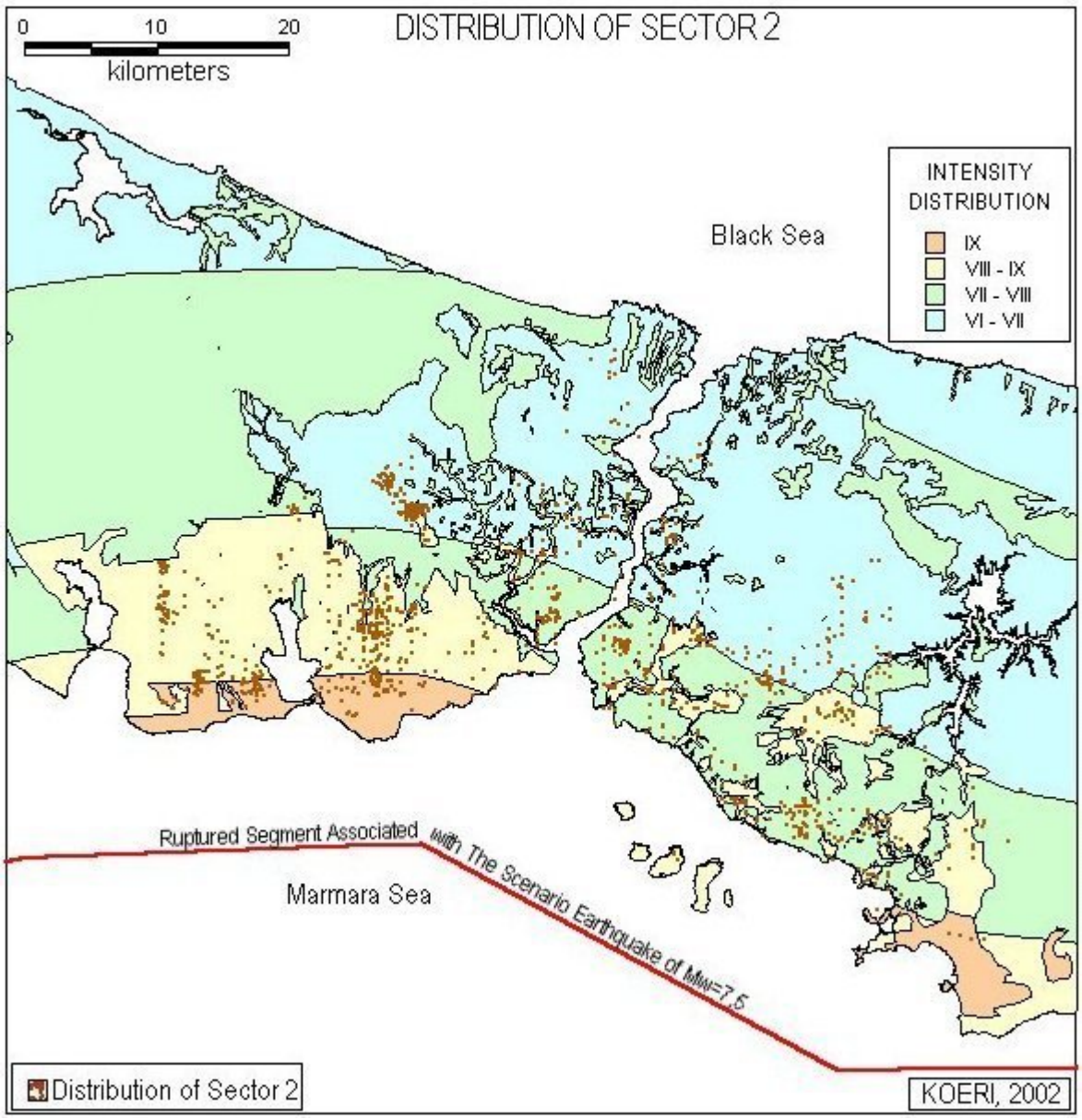

Figure 6.1.2. The distribution of industrial facilities in Sector 2 overlaid on the intensity map (each dot represents one facility).

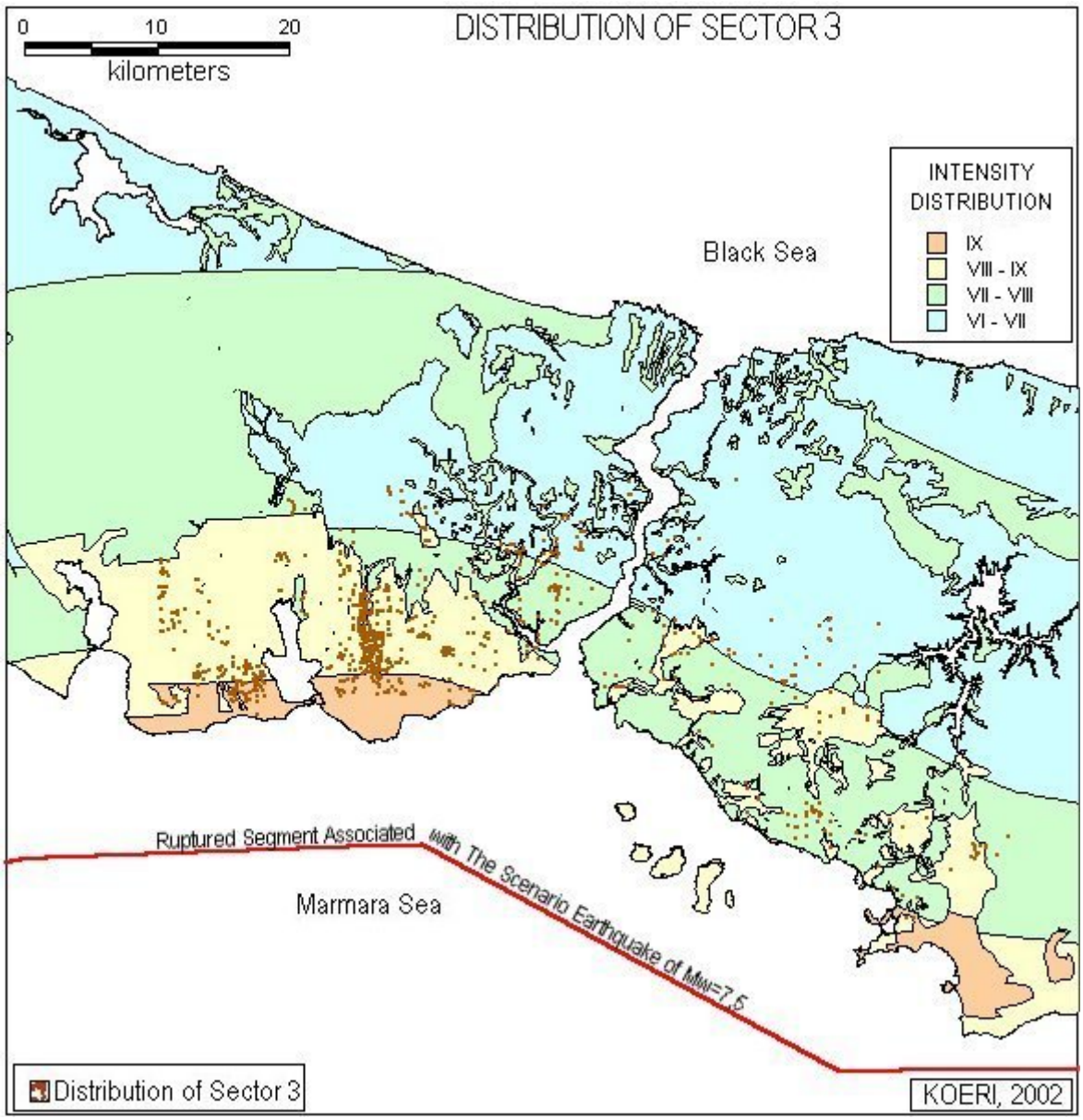

Figure 6.1.3. The distribution of industrial facilities in Sector 3 overlaid on the intensity map (each dot represents one facility).

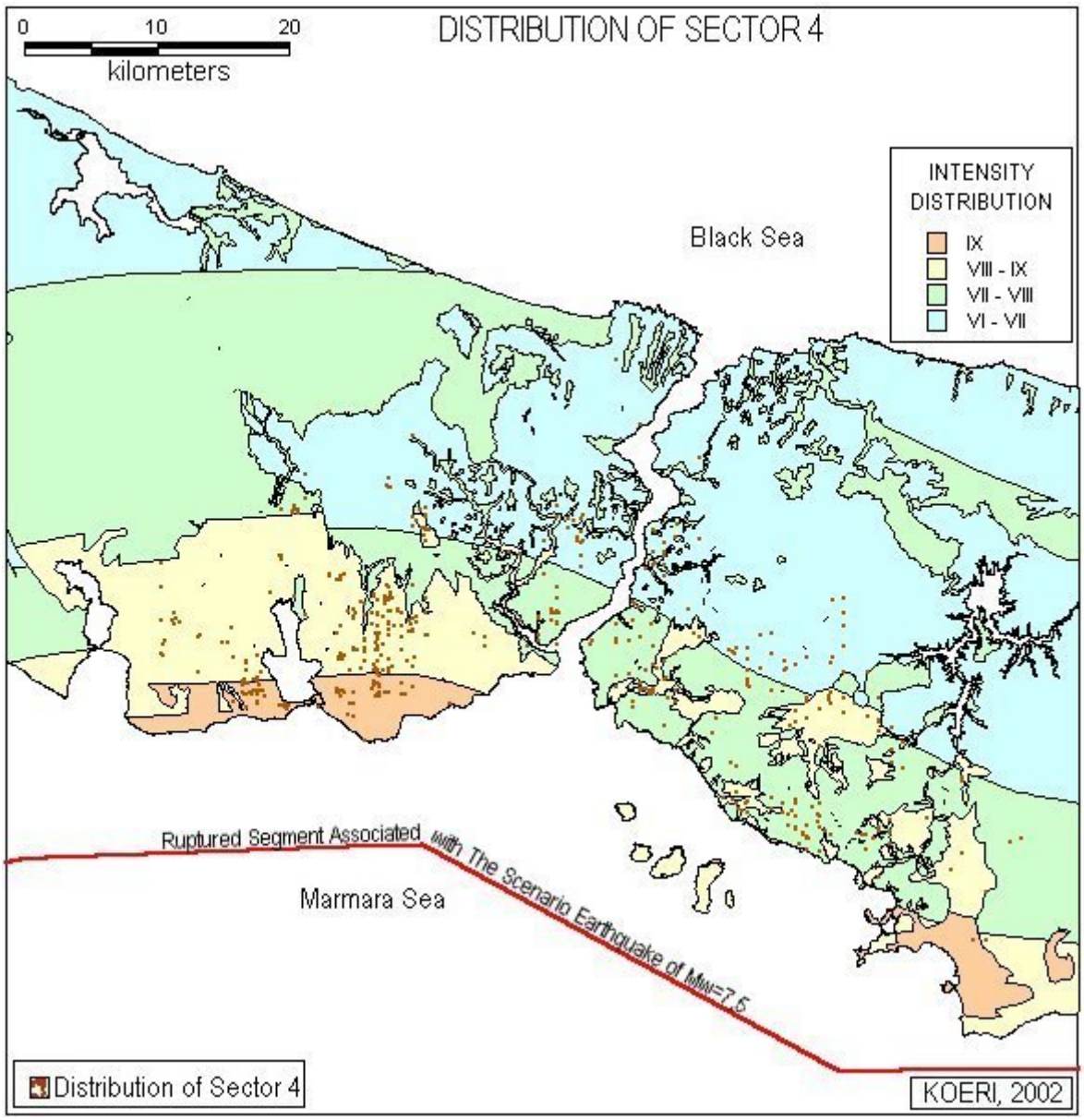

Figure 6.1.4. The distribution of industrial facilities in Sector 4 overlaid on the intensity map (each dot represents one facility).

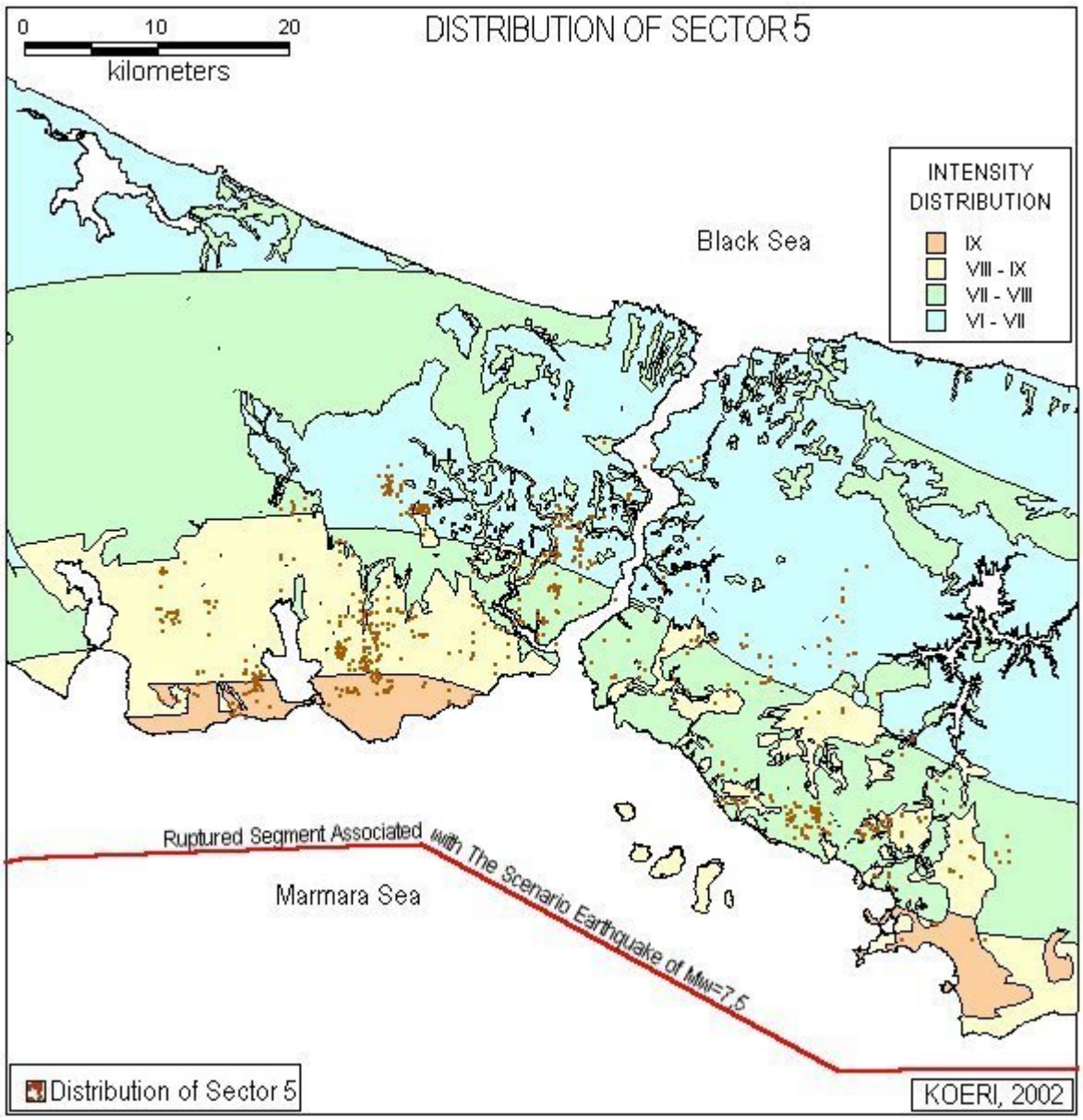

Figure 6.1.5. The distribution of industrial facilities in Sector 5 overlaid on the intensity map (each dot represents one facility).

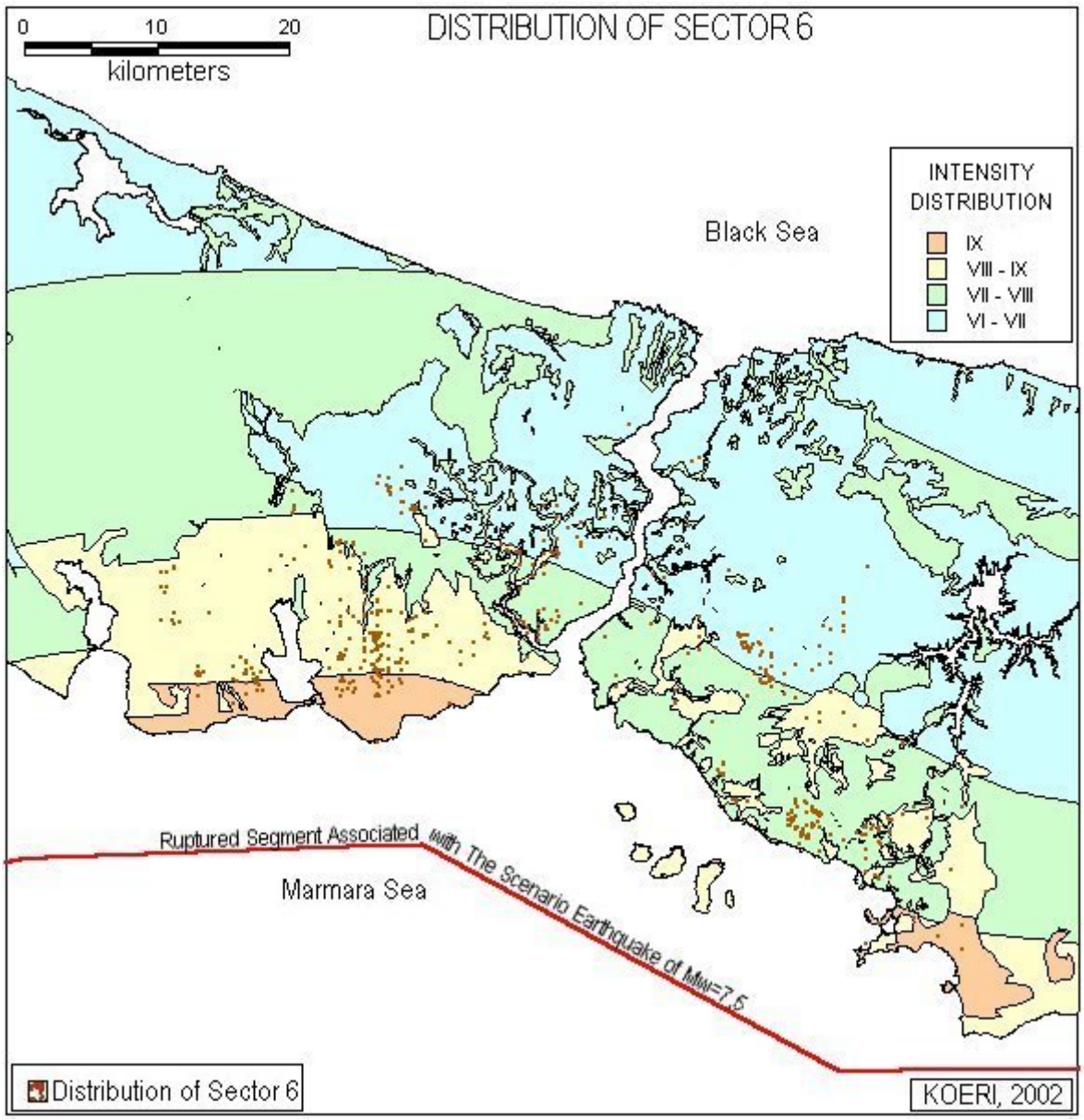

Figure 6.1.6. The distribution of industrial facilities in Sector 6 overlaid on the intensity map (each dot represents one facility).

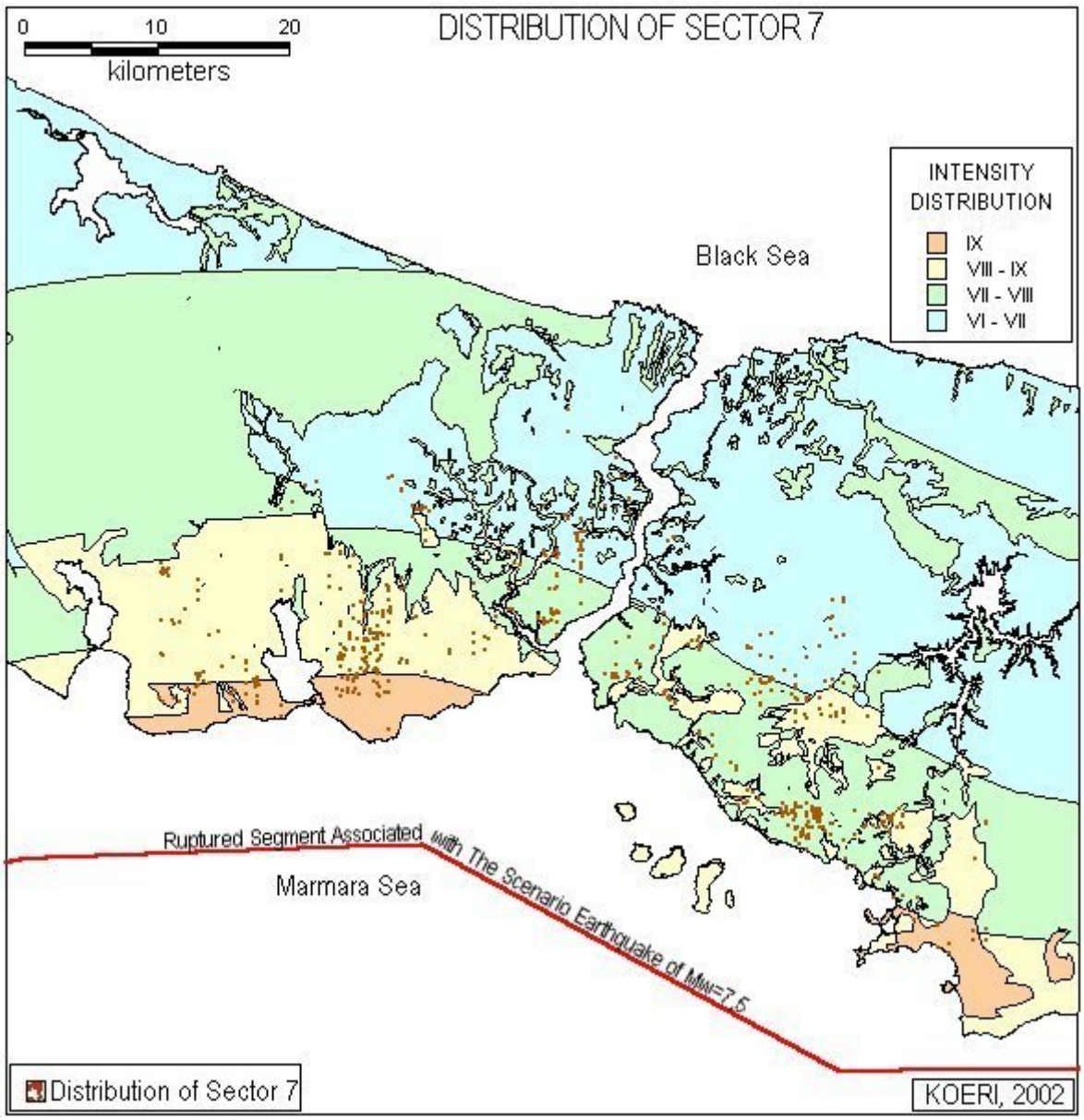

Figure 6.1.7. The distribution of industrial facilities in Sector 7 overlaid on the intensity map (each dot represents one facility).

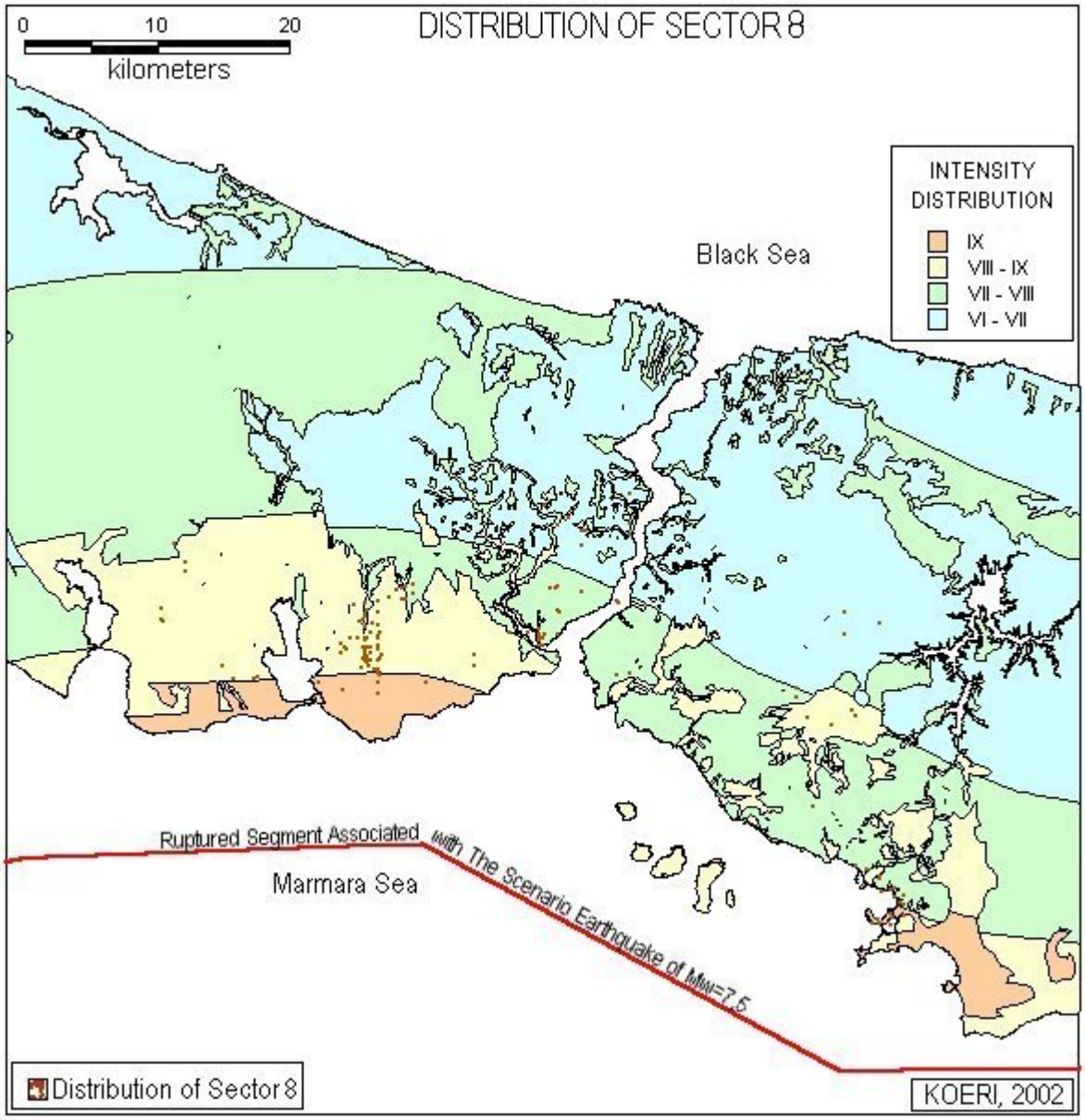

Figure 6.1.8. The distribution of industrial facilities in Sector 8 overlaid on the intensity map (each dot represents one facility).

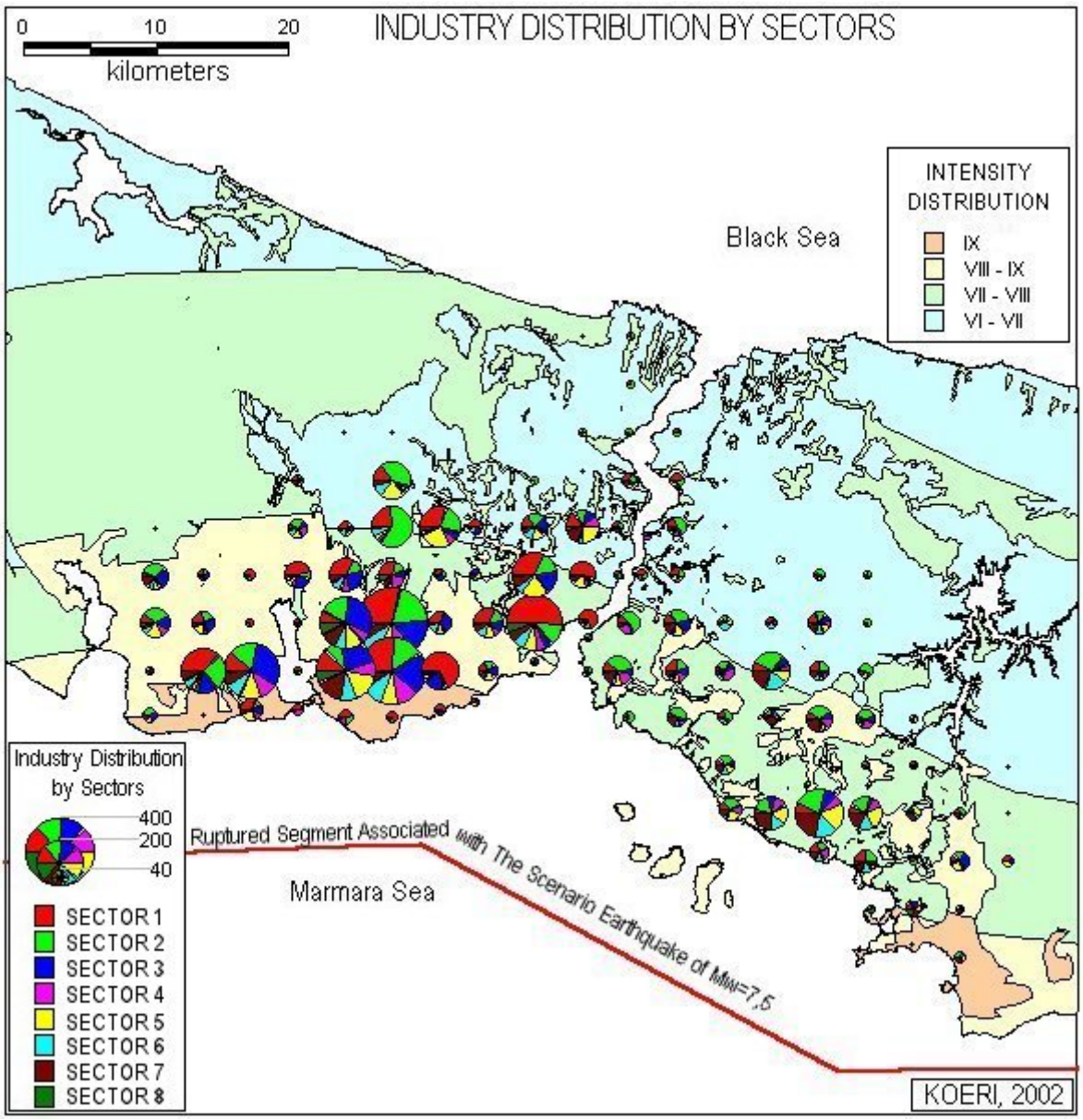

Figure 6.1.9. The pie chart distribution of the eight sector groups for each cell, the size of the pie chart indicating the total number of the industrial facilities in the cell.

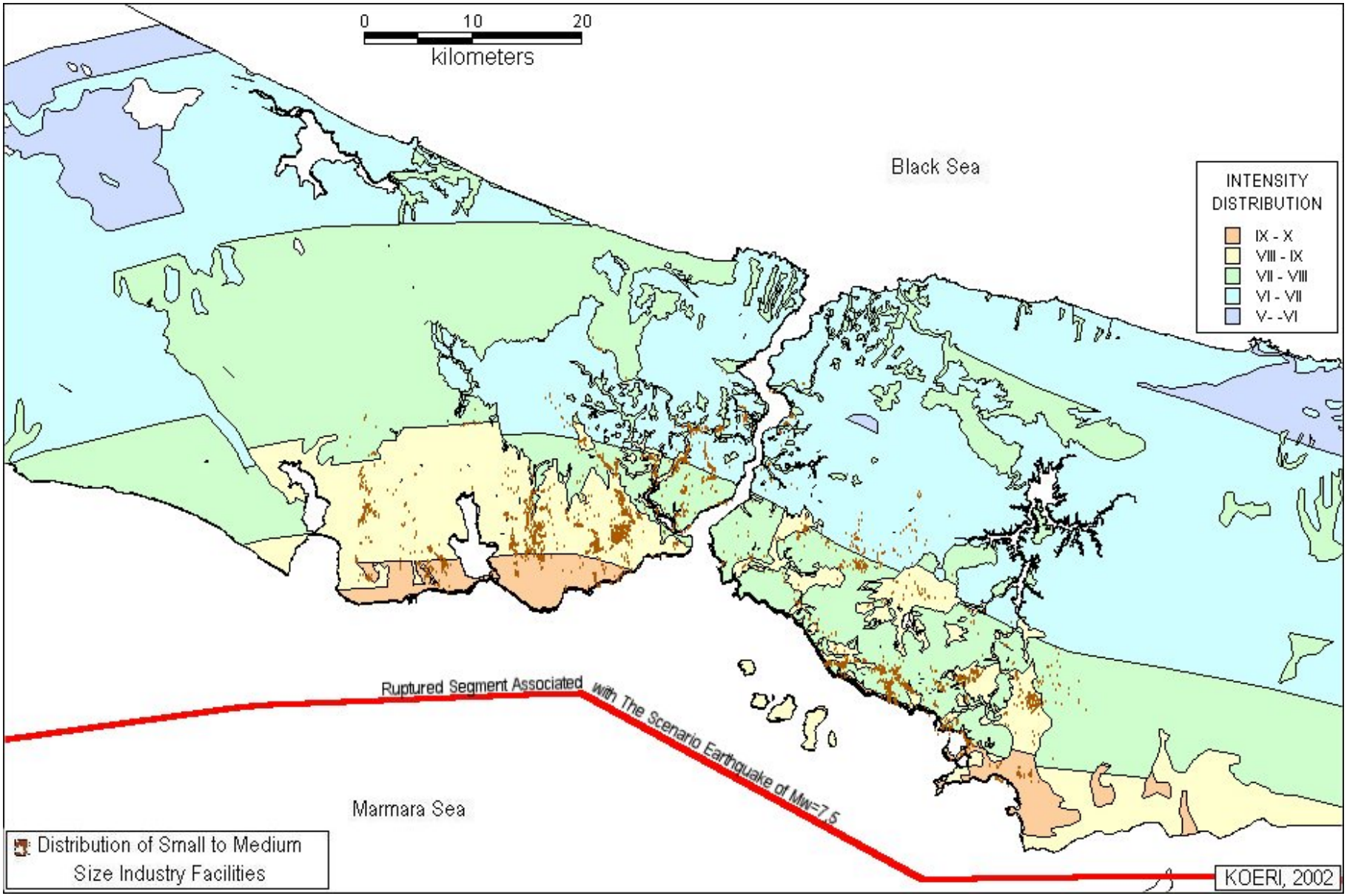

Figure 6.1.10. The distribution of small to medium size industry facilities overlain with the intensity map (from Municipality data)

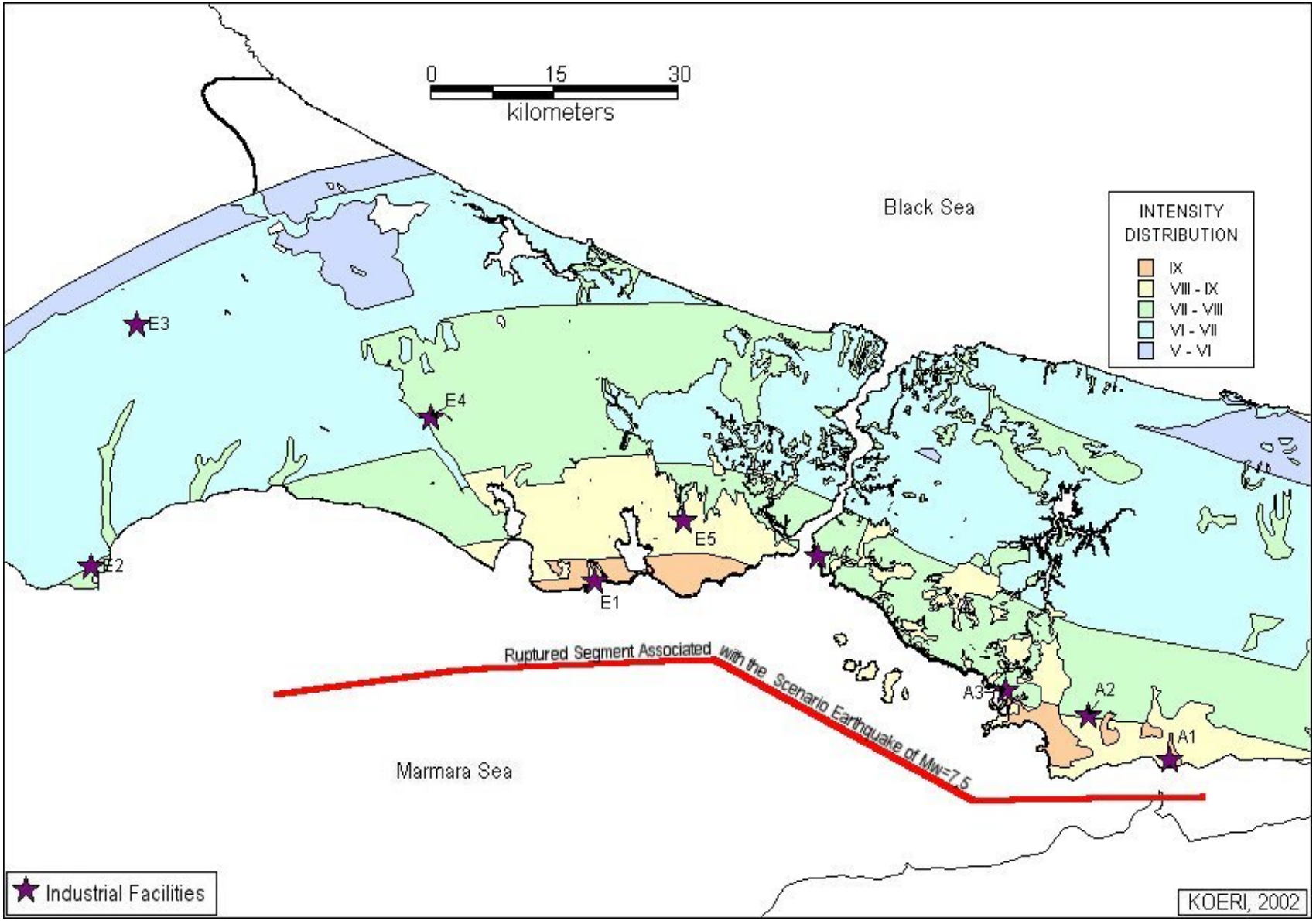

Figure 6.1.11. Locations of essential industrial facilities (industrial parks and large size facilities) overlain with the intensity map

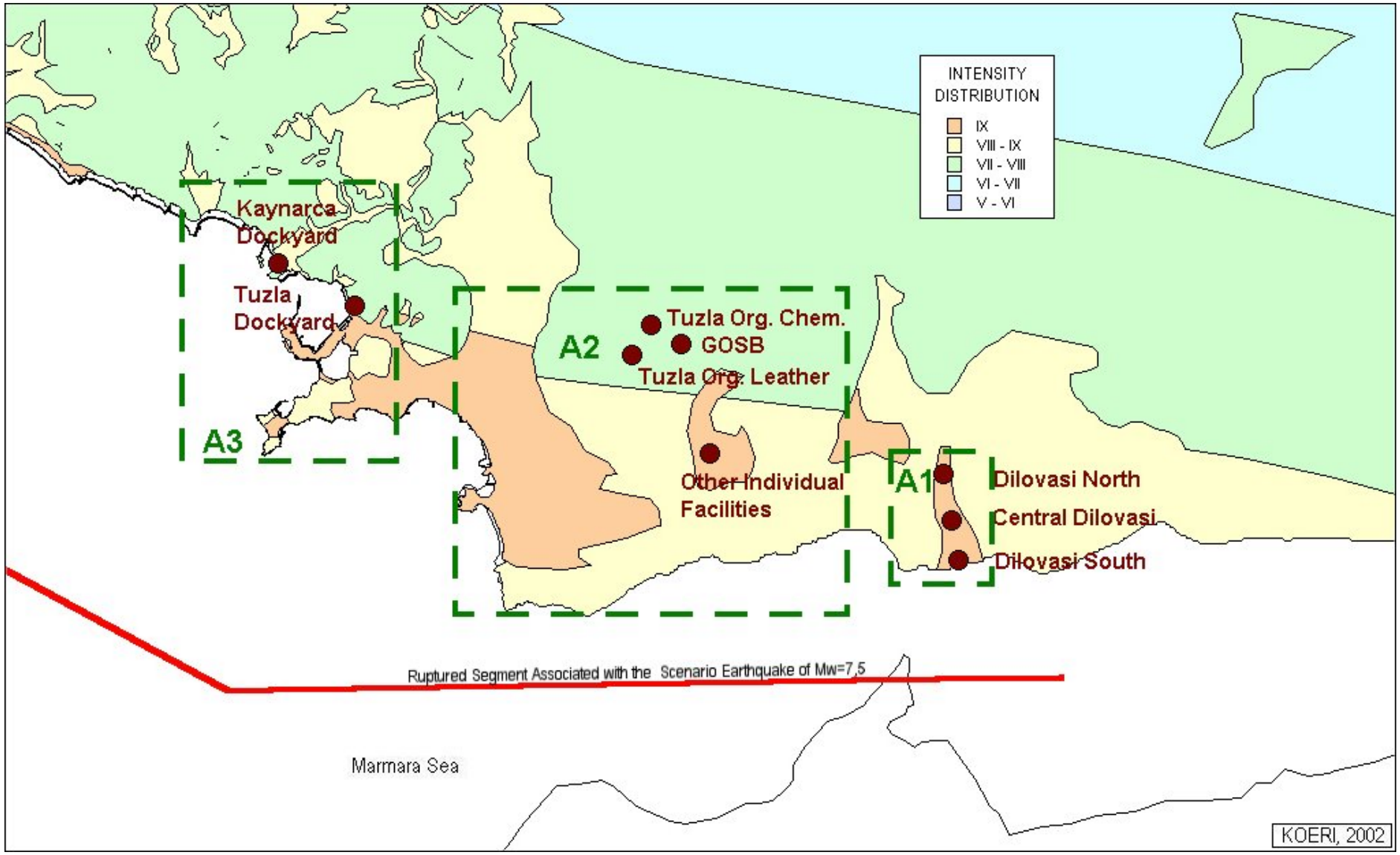

Figure 6.1.12. Enlarged view of the intensity map for the Tuzla, Gebze and Dilovasi region

6.2. Expected General Losses and Conclusions

In both Table 6.1.1 and Table 6.1.2 the percentage of industrial facilities in intensity zones IX and VIII are about respectively 7%-12% and 40%-60%. By considering this distribution with the mean damage ratios for buildings given in Table 6.1.3, the overall loss for all industrial buildings in Istanbul and immediate vicinity can be assessed to be between %6 and %8 as a result of the scenario earthquake Table 6.2.1 provides the total Equipment-Machinery and Stock losses to be expected in occurrence of the scenario earthquake in intensity zones IX and VIII for different industrial sectors. The approximate overall losses for all sectors will be about 2.5% for Equipment-Machinery and about 3% for Stocks.

Table 6.2.1. Total Losses for ”Equipment and Machinery” and “Stock” in Intensity Regions

Sector No	Description	Equipment and Machinery Loss		Stock Loss	
		IX	VIII	IX	VIII
1	Mining, Construction, Ceramics, Glass Min	0.011	0.013	0.011	0.013
2	Commercial Facilities, Food and Beverage	0.009	0.011	0.009	0.011
3	Textile, Leather	0.013	0.017	0.039	0.050
4	Wood products and furniture, Agriculture	0.016	0.012	0.016	0.012
5	Chemical and Petroleum Products	0.033	0.035	0.033	0.035
6	Iron- steel and the other metals	0.002	0.002	0.002	0.002
7	Machinery and automotive	0.002	0.002	0.002	0.002
8	Transportation and telecommunication	0.012	0.014	0.002	0.003

In intensity IX zones the empirical data from Turkey indicates that the Business Interruption losses, expressed as a ratio of annual turnover, varies between 5%-10% for almost all industrial sectors. In intensity VIII regions the Business Interruption losses varies between 2-3% for almost all sectors. For both intensity regions, anomalous exceptions exist for of “Chemical”, “Textile” and “Automotive” sectors where the Business Interruption losses have respectively reached 50%, 30% and 15%. These figures indicate that the average Business Interruption loss for all industrial sectors in Istanbul will vary between 2% and 3% in relation to their total annual turnover.

These loss ratios can be converted to monetary losses if the value of the portfolio is known.

It should be noted that these loss figures obtained just to provide an indication of the order of losses to be experienced by the industrial facilities in Istanbul after the occurrence of the scenario earthquake. They are based on gross assumptions and across the table generalizations.

The earthquake damage to industrial facilities observed in Turkey is elaborated in Chapter 4. It can be said in general that the earthquake damage observed in Turkey are not really different from industrial damage observed in worldwide earthquakes. Large storage tanks, pipelines, transmission lines and precision machinery seem to be particularly susceptible to damage through earthquakes. Due to the high relative value of contents, their vulnerability and dependence on structural

performance are key to assessing loss potential especially for Heavy Manufacturing Facilities. Port and Harbor facilities are particularly susceptible to submarine landslide or ground settlement due to liquefaction that may occur during earthquakes. In addition, all processes that involve a substantial risk of explosion, for example processes in the petrochemical industry and processes involving molten metal, should be examined particularly.

An industrial facility consists of many integrated components and processes. As such, the operation of the facility depends on the performance of its critical components.

Earthquake vulnerabilities of the buildings and main components and functions of the industrial facilities are encompassed in Chapter 5 of this report.

The greatest risk from an earthquake is that to life safety. Building code requirements in most counties, including Turkey, are set with the intent of protecting the life of the occupants. The building is allowed to experience damage but without any collapse thereby allowing for the safe evacuation of occupants with minimum risk of casualties. However, in large earthquakes, the damage to the industrial buildings and other structures may cause costly to repairs to the machinery and equipment they house and may also lead to consequential damages such as fire and chemical spills. Since most of the revenue generated by industrial facilities is related to the products and services they provide, rather than the physical assets of the company, any significant interruption to the production of these goods and services because of this damage will also have an adverse affect on the business. The risk of business interruption is an important economic reason for controlling the damage from and following earthquakes. As such, the design (or seismic retrofit) of industrial facilities should preferably be based on performance-based methodologies with the intent on controlling the structural and non-structural damage.

Economic growth and the broadening role of globalization and multinationals has created a class of high-value industrial facilities worth tens of billions Dollars in the Marmara Region waiting to be exposed to a large earthquake. Large earthquakes have an ability to find holes in the technology and weak points in the structural design and equipment. To detect these weak spots in a given industrial facility mandates a through investigation of the vulnerability to earthquakes and particularly its expected performance under exposure to the Marmara Earthquake. A first order assessment can be conducted by using the hazard and vulnerability information contained in this report. However, it should be noted that, the vulnerability relationships are essentially intended for a large number of inventories. For individual elements at risk the vulnerabilities encompass large uncertainties. For a rigorous assessment of the performance engage professionals and have your facility inspected by an earthquake engineer. The next steps should be the development, prioritization and implementation of strengthening measures for buildings, storage tanks, silos, stacks, electrical equipment and other critical components of the facility.

Inspection of the facility for entities or equipment that can move, fall, topple or spill during an earthquake is an important task. Appropriate measures needs to be taken to secure them and to have incompatible chemicals stored separately.

Installation of fire protection systems and earthquake early warning/alarm systems to automatically shutoff critical processes in the facility is an important measure to avoid fire, explosion and/or damages during strong earthquakes.

Preparation of a contingency plan to be followed in the event of earthquake is essential in order to minimize damage and restore operations as soon as possible. Among other issues that relate to the continued operation, the contingency plan should encompass: Restoration of the supply of power if

the normal supply systems are not functioning; Supply of raw materials if the suppliers are affected; Repair and/or replacement of damaged equipment and machinery in an timely manner.