ANALYSIS OF PREPAREDNESS AND RESPONSE TO EARTHQUAKE RISK OF BEŞİKTAŞ DISTRICT USING GIS

by
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ABSTRACT

ANALYSIS OF PREPAREDNESS AND RESPONSE TO EARTHQUAKE RISK OF BEŞİKTAŞ DISTRICT USING GIS

For years Turkey is placed in a higher position among the countries that have been struck with loss of life and property due to earthquakes. Location of Turkey is the most important reason for this situation, since it is located on an active seismic belt. Being the economical, cultural and industrial centre of the country, Istanbul has a considerably high earthquake risk since the North Anatolian Fault Zone extents through the Marmara Sea.

Considering the historical earthquakes especially Kocaeli Mw:7.4 in 1999, and the structure of the North Anatolian Fault Zone, it is estimated that the occurrence probability of an earthquake, bigger than Mw: 7.0 in the next 30 years is approximately 70 per cent. Furthermore the earthquake risk increases due to the rapid, unplanned urbanization and building construction that damages the specifications in Istanbul. Considering urban structuring in Istanbul, it has been concluded that connected districts have different characteristics. That is why the need of a comprehensive damage mitigation plan which is based on detailed earthquake hazard analysis emerged.

The aim of this study is to investigate the preparedness and response levels of Beşiktaş district for a possible earthquake using the Geographic Information Systems and carrying out the analyses that will form a base for extensive damage mitigation plans.

Within this concept, the earthquake risk for houses and business units located on Beşiktaş district is determined using a scenario earthquake which is obtained from Kandilli Observatory and Earthquake Research Institute Earthquake Engineering Department and a hazard assessment was determined by using the geological formation and seismic activity evaluations of the field. Additionally, estimation of the casualties in terms of damage probabilities by determining the building stocks, structural characteristics of these buildings (wood, steel, reinforced concrete *etc.*) and number of stories has been performed.

A data infrastructure has been prepared for the planning activities which will be produced by using these analyses. In this way, the determination of the most appropriate meeting and tenting areas after an earthquake and the determination of the closest health care centers for injured people were practiced in this study.

ÖZET

BEŞİKTAŞ İLÇESİNİN DEPREM RİSKİNE HAZIRLIĞININ COĞRAFİ BİLGİ SİSTEMLERİ KULLANILARAK ANALİZİ

Türkiye yüzyıllardır depremler nedeniyle can ve mal kayıplarına uğrayan ülkeler arasında üst sıralarda yer almaktadır. Bunun en önemli nedeni Türkiye'nin aktif deprem kuşağında bulunmasıdır. Kuzey Anadolu Fay zonunun Marmara denizindeki uzantısından dolayı ekonomik, kültürel ve sanayi merkezi olan İstanbul'da deprem tehlikesi oldukça yüksektir.

Tarihsel depremlere ve Kuzey Anadolu Fay zonunun yapısına bakıldığında İstanbul'da 1999 yılından sonra 30 yıl içerisinde büyüklüğü yedi ve üzerinde bir depremin gerçekleşmesi olasılığı yüzde 70 olarak hesaplanmaktadır. Ayrıca, İstanbul gibi büyük bir metropol alanın çok hızlı ve plansız kentleşmesi ve şartnamelere uymayan inşaat uygulamaları nedeniyle deprem riski oldukça artmaktadır. İstanbul'un kentsel yapılaşmasına bakıldığında bağlı ilçelerin birbirinden çok farklı özellikler gösterdiği görülmektedir. Bu nedenle ilçelerin detaylı deprem tehlike analizlerine dayanan kapsamlı zarar azaltma planlarının hazırlanması ihtiyacı ortaya çıkmıştır.

Bu çalışmanın amacı, Coğrafi Bilgi Sistemleri kullanılarak Beşiktaş ilçesinin deprem riskine karşı hazır olup olmadığının ve cevap verebilme potansiyelinin araştırılması ve kapsamlı zarar azaltma planlarına altlık oluşturacak analizlerin yapılmasıdır.

Bu kapsamda Kandilli Rasathanesi ve Deprem Arştırma Enstitüsü Deprem Mühendisliği tarafından hazırlanan senaryo depremi kullanılarak, Beşiktaş ilçesi içerisindeki konut ve işyerleri için deprem riski belirlenmiştir. Çalışma alanının jeolojik

yapısı ve sismik aktivitesi değerlendirilerek tehlike analizi; bina stokları, bunların yapısal karakteristikleri (betonarme, ahşap *vs.*) ve kat adetleri göz önünde bulundurularak hasar olasılıkları bağlamında kayıp tahminleri yapılmıştır.

Bu analizlerden yola çıkarak üretilecek planlama çalışmaları için bir veri altyapısı sağlanmıştır. Böylece deprem sonrası söz konusu ilçede yaşayanlara toplanma ve çadır alanları gösterilmesi, yaralılar için en yakın ilk yardım ve acil müdahale merkezlerinin belirlenmesi çalışmaları gerçekleştirilmiştir.

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LIST OF SYMBOLS / ABBREVIATIONS

Yd	Filling / Manmade fill
Qa	Alluvium
Kşf	Kuşdili formations
Tf	Tuzla formations
Df	Dalayoba formations
Blf	Baltalimanı formations
Trf	Trakya formations
Kf	Kartal formations
σ	Standard deviation of the normal distribution
μ	Mean of the normal distribution
D	Ductility parameter
S	Strength parameter
k	Damage level
P	Probability changing between zero and one
m	The number of average damage
n	Number of damage level
NAFZ	North Anatolian Fault Zone
TCA	The Turkish Court of Accounts
UN ISDR	United Nations, International Strategy for Disaster Reduction
AYM	Istanbul Governorship Provincial Disaster Management Center Directorate
TABIS	Hazard Information System of Turkey
GIS	Geographic Information System

WHO	World Health Organization
IPENZ	The Institution of Professional Engineers New Zealand
EMA	Emergency Management Australia
USGS	United States Geological Survey
FEMA	Federal Emergency Management Agency
JICA	Japan International Cooperation Agency
IMM	İstanbul Metropolitan Municipality
NIBS	National Institute of Building Sciences
NIMS	National Incidence Management System
FEMA	Federal Emergency Management Agency
TIN	Triangulated Irregular Network
Turk Stat	The Prime Ministry Turkish Statistical Institute
RC	Reinforced Concrete
MM	Modified Mercalli scale
EMS-98	The European Macroseismic Scale
MBiD	Modified Binomial Distribution
MBeD	Modified Beta Distribution
PDF	Probability Distribution Function
ED50	European Datum 1950
UTM	Universal Transverse Mercator

1 . GENERAL

1.1. Introduction

Turkey is remarkably vulnerable to hazards and disaster risks because of unrestrained urbanization and rapid population growth. Earthquake is the most deadly and destructive natural hazard occurred in Turkey. This is due to the seismo-tectonic structure of the country. İstanbul has always been the centre of the country's economic life because of its location. The rich historical and cultural background of İstanbul attracts a lot of people worldwide. Taking into account historical earthquakes and the structure of North Anatolian Fault Zone (NAFZ), a catastrophic earthquake with a magnitude larger than seven is expected to occur in İstanbul in the next 30 years at a probability of 70 per cent. It is essential to develop a disaster mitigation plan to reduce the damages of the possible earthquake hazard in İstanbul.

Vulnerability is defined as the degree of damage on people, buildings and environment. With the help of vulnerability assessment, damaging building stock and the planning areas towards disaster preparedness and prevention can be modeled before the earthquake hazard.

There are some multidisciplinary projects performed by The Turkish Court of Accounts (TCA) and United nations - International Strategy for Disaster Reduction (UN/ ISDR). These are Disaster management report (2002) and Desk Study Review Risk Assessment in South Eastern Europe (2007). The former project includes only natural disaster and demonstrates the casualties and economic loss in Turkey in the last century. The latter project, UN ISDR, contains both natural and technology related hazards.

According to The Turkish Court of Accounts report the distribution of earthquake hazard in Turkey is 61 per cent that is displayed in Figure 1.1. UN ISDR projects, on the other hand, shows that the rate of earthquakes recorded during the last 33 years is 19 per cent. UN ISDR has classified hazards into natural and technology related hazard based on their origins. According to the UN ISDR database the country has recorded almost all kinds of hazards; earthquake, extreme temperature, flood, landslides, epidemics, wind storms, wild fires and technology related hazards (Figure 1.2).

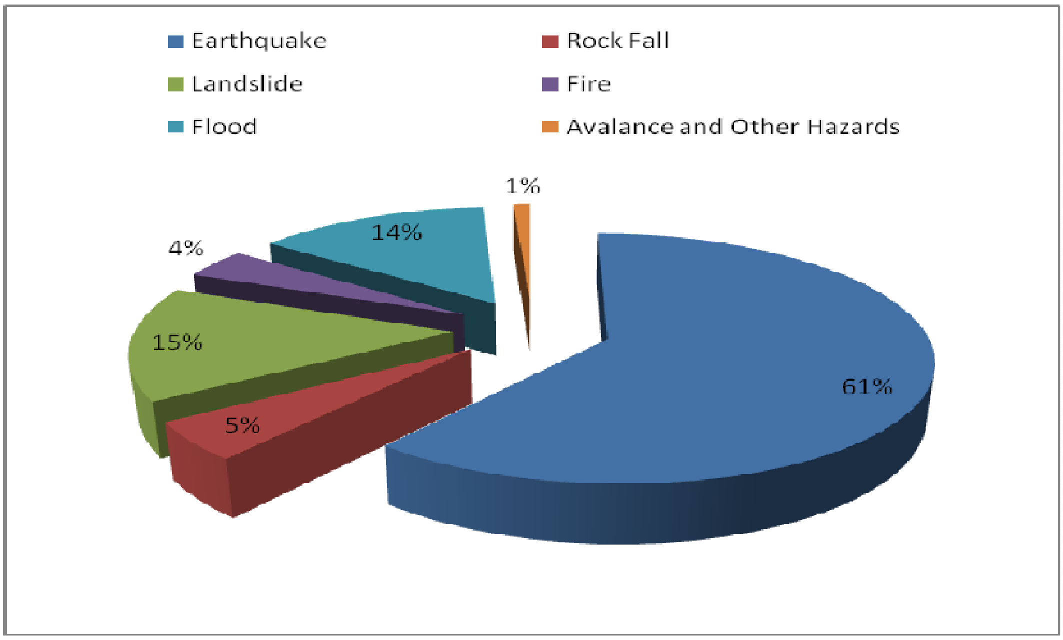


Figure 1.1. Distrubion of natural hazards in Turkey
(TCA, 2002)

Furthermore, this report claims that approximately 64 major earthquakes (Mw: 6 and over) hit the Turkey in the last century, cause the deaths of 100,000 people and destroy 500,000 homes. These results show that about 70 per cent of the country's population and 75 per cent of industrial facilities are vulnerable to earthquake and 66 per cent of the country is located in the active fault zone. It is estimated that 64 per cent of the total disaster losses in the last century are due to earthquakes.

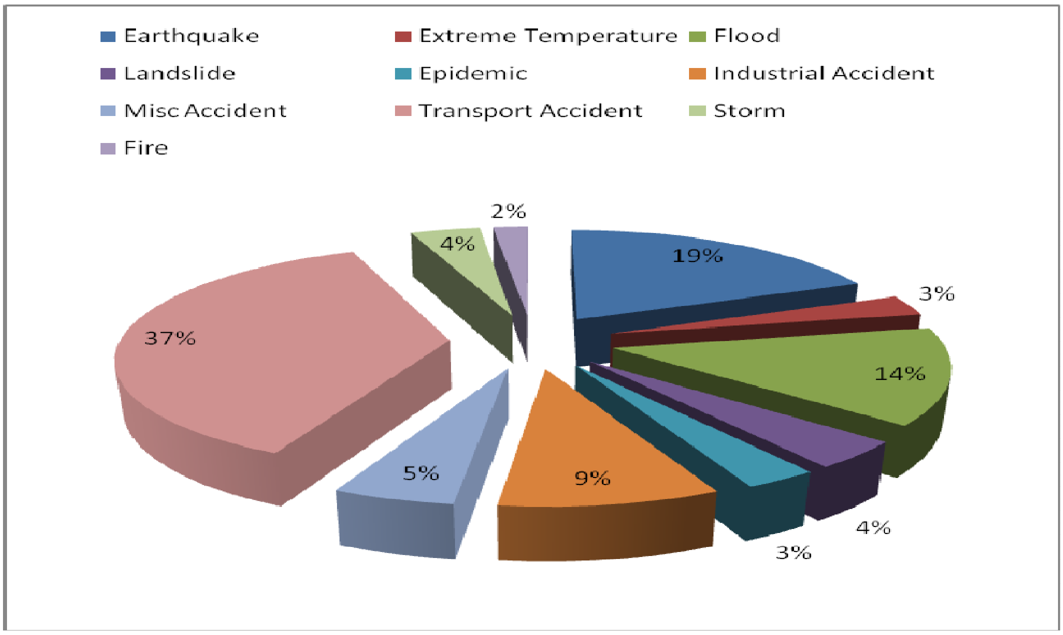


Figure 1.2. Distribution of different hazards in Turkey (1974-2006) (UN ISDR)

Number of death; number of victims and economic losses reports due to each hazard in Turkey are demonstrated below in Figure 1.3, Figure 1.4 and Figure 1.5 respectively.

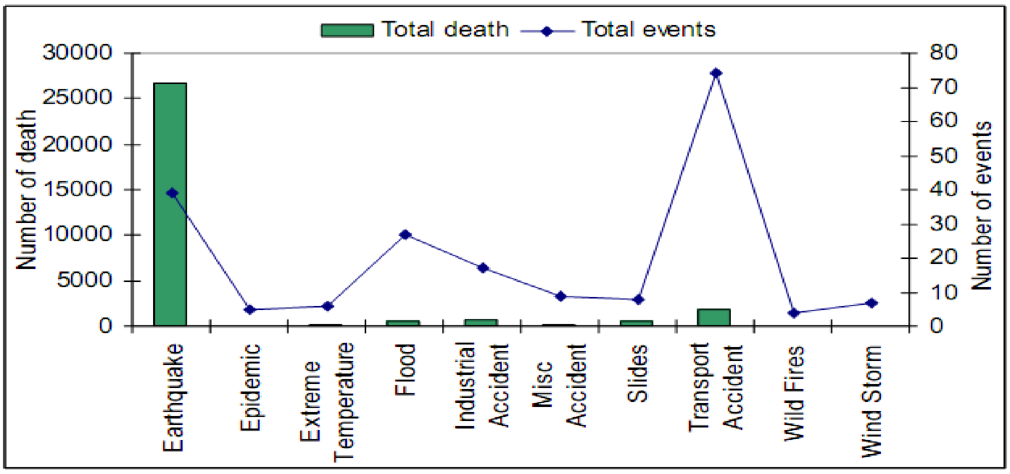


Figure 1.3. Hazard wise incidence and number of death due to each hazard in Turkey (1974-2006) (UN ISDR)

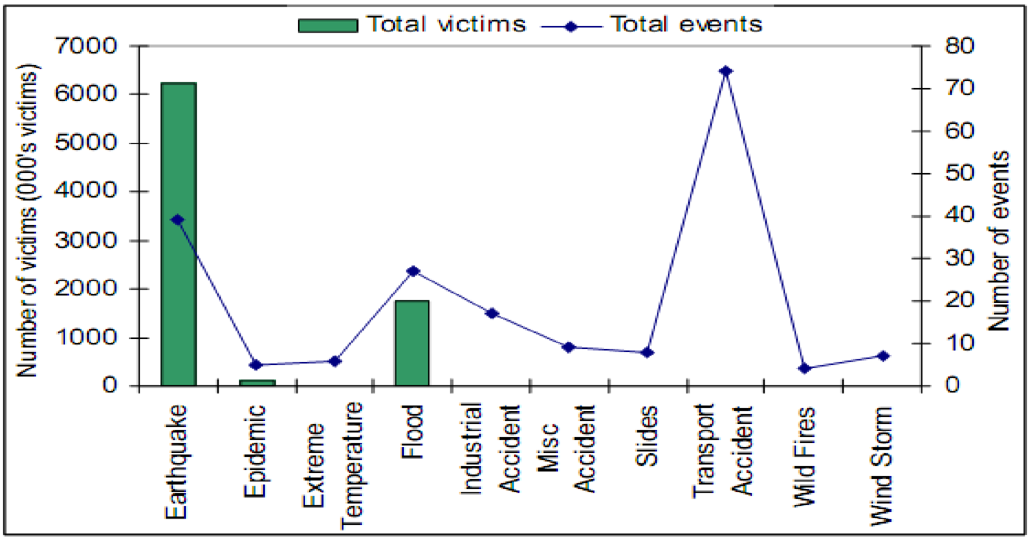


Figure 1.4. Hazard wise incidence and number of victims due to each hazard in Turkey (1974-2006) (UN ISDR)

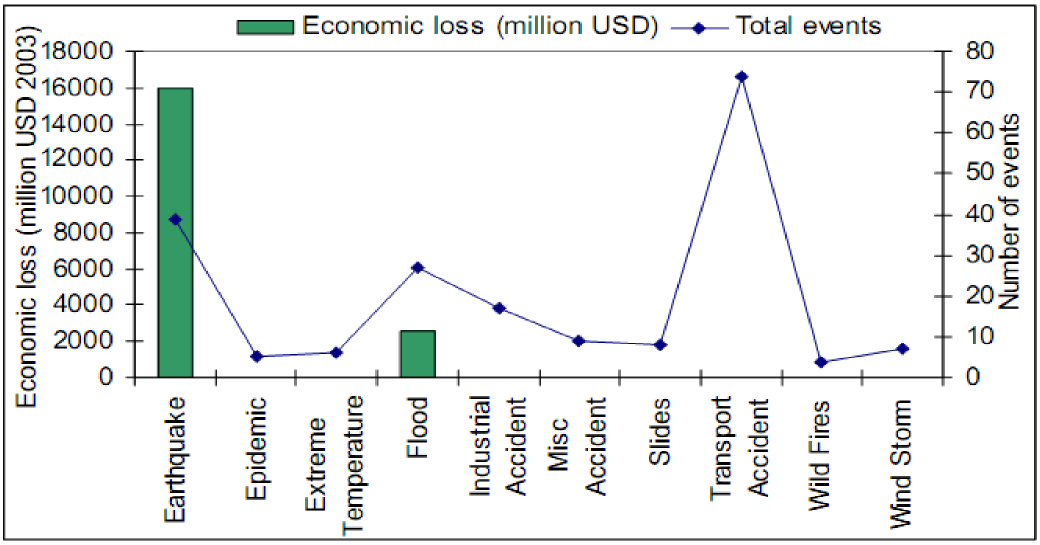


Figure 1.5. Hazards wise incidence and economic losses report due to each hazard in Turkey (1974-2006) (UN ISDR)

This figure emphasizes that 90 per cent of losses are caused by earthquakes in the content of loss of life and injury. Average annual direct economic loss due to earthquake exceeded USD one billion in the last decade. About 950 people per year are killed due to earthquake in the country making it in the 3rd position in the world in terms of death risk due to earthquakes. The physical exposure per year is 2.75 million population and stands 8th in the world.

In brief, rapid and uncontrolled urbanization, increasing population and seismicity for the area of interest have increased the level of vulnerability to earthquakes of Istanbul and caused economic loss.

In this study, Beşiktaş district of Istanbul is analyzed in order to assess the earthquake risks. Summaries of each chapter are stated below.

The second chapter gives some definitions used in this study about the study area in terms of the tectonics. Historical earthquake information and earthquake fault segment information were obtained to estimate the expected destructive earthquake and understand the scenario earthquake.

The third chapter of this study establishes topographic, demographic and socio-economic data presentation and analysis by using ArcGIS software and its extensions.

The last chapter assigns the comments of analyses in a perspective of planning.

1.2. Scope of the Study

1.2.1. Study Objective

This study comprises two main stages. The aim of the first step is to assess risk which is defined as estimating expected losses. This step is based on two components; one is hazard assessment which covers mapping and monitoring of geological and seismological structures of the study area. The second one is vulnerability assessment obtained by analyses of vulnerable components such as building stock and infrastructures. In the second stage general building stocks, their acts on stable and unstable soils and number of stories are analyzed in detail. However, urban structures, transportation and underground infrastructures are not considered because of the lack of data.

The aim of the second step is to build an infrastructure for developing a mitigation program based on both hazard and vulnerability assessments. The second step embodies testing of getting ready against earthquake risk of urban areas and analyzing of parks in a sufficient amount.

In this study, a scenario earthquake is obtained from the project of Earthquake Risk Assessment for İstanbul Metropolitan Area realized by Boğaziçi University, Kandilli Observatory and Earthquake Research Institute (KOERI, BU). The algorithm devoloped by Şengezer and Ansal (2006) was followed to carry out the vulnerability assessment of buildings. Topographic, demographic and socio-economic data were obtained from Beşiktaş Municipality, Istanbul Governorship Provincial Disaster Management Center Directorate’s (AYM) and Hazard Information System of Turkey (TABIS) database.

1.2.2. Study Area

Beşiktaş district, which is situated on European side of İstanbul within the boundaries of the İstanbul Metropolitan Municipality, is chosen as study area. Beşiktaş is surrounded by the Bosphorus on the east, the district of Şişli on the west, the district of Sarıyer on the north and the district of Beyoğlu on the south (Figure 1.6).

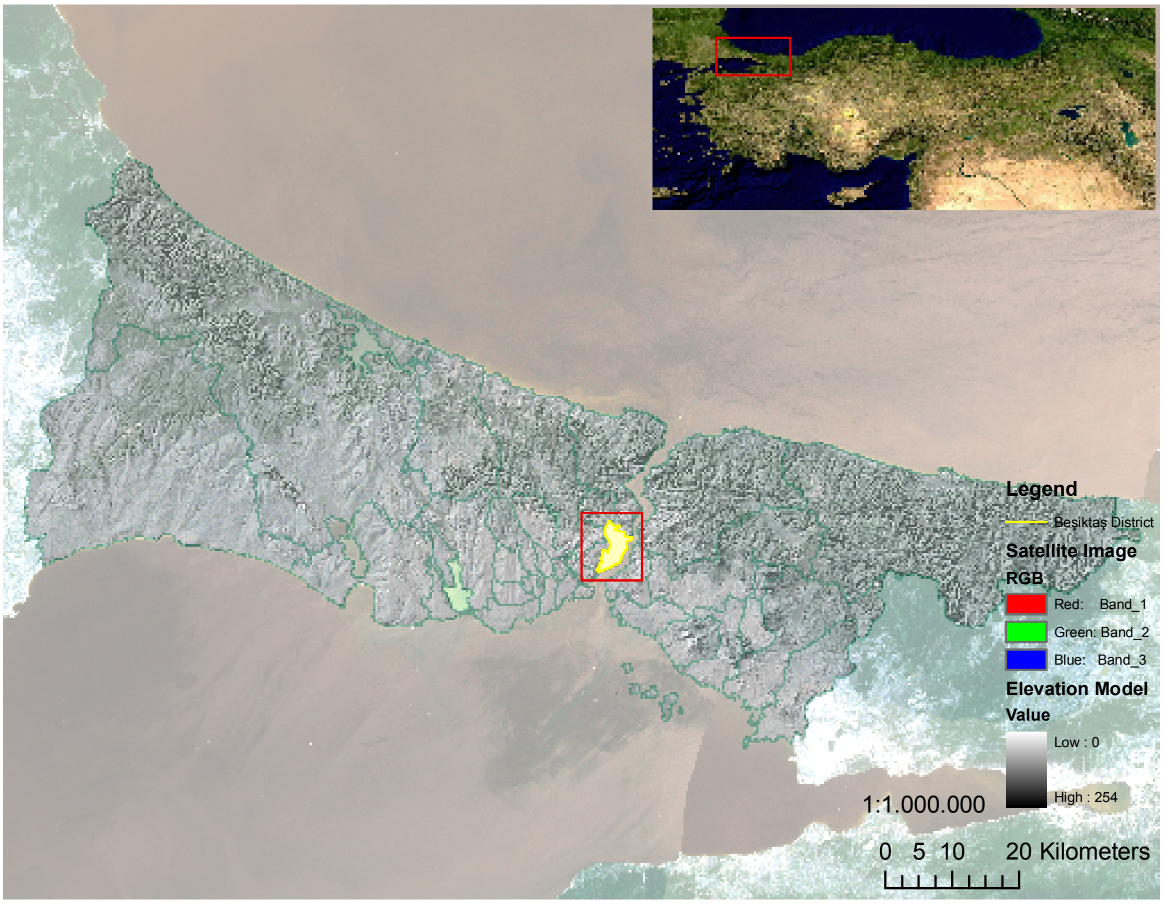


Figure 1.6. Study area

1.3. Motivation

Geographic Information System (GIS) is rapidly becoming a standard technology in many fields. GIS is a computer-based technology that links geographic information (where things are) with descriptive information (what things are like). GIS is used to capture, display, and analyze data spatially. GIS combines layers of information about a place to give users a better understanding of that place. A GIS generated map can present many layers of different information that provide a unique way of thinking about a geographic space. GIS provides interactive maps with access to all types of information, analysis, and data. More important, GIS provides the required information when, where, and how it is needed.

In disaster management; GIS, with the appropriate data, provides a view of the area before the damage occurred, underground infrastructure, control points, potential hazardous material locations, and other information to support emergency response actions. In other words, values at risk can be displayed quickly and efficiently through a GIS (Johnson, 2000). GIS technology brings additional power to the process whereby hazards are evaluated, service demands are analyzed, and resources are deployed. In addition, GIS contributes to the speed with which emergency responders are able to locate, respond size up, and deploy to an emergency.

These data and analyses are coded by user-friendly software called ArcGIS 9.2 that operates through a Geographic Information System. GIS is one of the most desirable tool in disaster management because of its efficiently data sharing, up-to-date data entering, faster data analyzing and multi-purpose data visualizing. With the help of ArcGIS, topographic maps, geological maps and soil classification maps can be visualized and analyzed. Moreover general building stocks, parks, and multi-hazard data such as tenting areas, emergency stations *etc.* can be investigated and then interpreted easily.

The main characteristics and differences of this study from similar ones can be summarized as follows:

- This study is different in terms of data (Beşiktaş building stock, parks *etc.*), data type (updated, integrated different data source), data process in GIS and algorithm followed.
- This study is the only study which deals with the risk model of Beşiktaş district. Similar studies were performed particularly on Avcılar and Zeytinburnu pilot districts because of their vulnerable situations. Beşiktaş district is also vulnerable to earthquakes because of its historical places, universities and commercial sites. This district has high population in daily time as well.
- In the result of this study, one can easily find the meeting points and tenting areas in Beşiktaş district.

2. DEFINITION OF TERMS

2.1. Definition of Hazard and Earthquake

2.1.1. Hazard, Risk and Vulnerability

The concepts of hazard, risk, and disaster are often confused with one another and with the extreme event itself (Gravley, 2001). Different meanings of hazard, risk, and disaster are described as stated below.

Hazard is defined by World Health Organization (WHO) as a natural or human-made event that threatens to adversely affect human life, property or activity to the extent of causing a disaster. Another definition of hazard is an interaction between a system of human resource management and an extreme or rare natural phenomenon, which may be geophysical, atmospheric or biological in origin, greatly exceeding normal human expectations in terms of its magnitude or frequency, and causing a major human hardship with significant material damage to infrastructure and/or loss of life or disease (Chapman, 1994). The characteristics of hazard are defined by Gravley in Table 2.1.

The Institution of Professional Engineers New Zealand (IPENZ, 1983) gives a definition of risk as the probability that a potential hazard will be realized and the probability of the harm itself. Risk is a function of the probability of the specified natural hazard event and vulnerability of cultural entities (Chapman, 1994). The United Nation (UN, 2004) determined that risk to a particular system has two factors: the hazard itself, which is a potentially damaging physical event, phenomenon or human activity that is characterized by its location, intensity, frequency and probability. The other factor is the vulnerability, which denotes the relationship between the severity of the hazard and the degree of damage caused.

Table 2.1. Definitions of hazard characteristics (Gravley, 2001)

Hazard characteristic	**Definition**
Magnitude	Only those occurrences that exceed some common level of magnitude are extreme
Frequency	How often an event of a given magnitude may be expected to occur in the long-run average
Duration	The length of time over which a hazardous event persist, the onset to peak period
Areal Extent	The space covered by the hazardous event
Speed of Onset	The length of time over between the first appearance of an event and its peak
Spatial Dispersion	The pattern of distribution over the space in which its impacts can occur
Temporal Spacing	The sequencing of events, ranging along a continuum from random to periodic.

Disaster, on the other hand, is defined by United Nations (UN, 2004) as a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. Smith (1996) offers a broader definition for disaster that implies a sense of perception. He writes that a disaster generally results from the interaction, in time and space, between the physical exposure to a hazardous process and a vulnerable human population. In other words, the definition of disaster is unique to different cultures and their perceptions of loss. A natural disaster is defined by Emergency Management Australia (EMA, 2007) as a serious disruption to a community or region caused by the impact of a naturally occurring rapid onset event that threatens or causes death, injury or damage to property or the environment and which requires significant and coordinated multi-agency and community response. Each one or a combination, of the following can cause such serious disruption to communities, infrastructure and the environment: bushfire, earthquake, flood, storm, cyclone, storm surge, landslide, tsunami, meteorite strike or tornado. As it can be seen from the Figure 2.1, hazard and disaster differ from each other. Figure 2.2 demonstrates natural hazards such as earthquake, fire and flood (EMA, 2007)

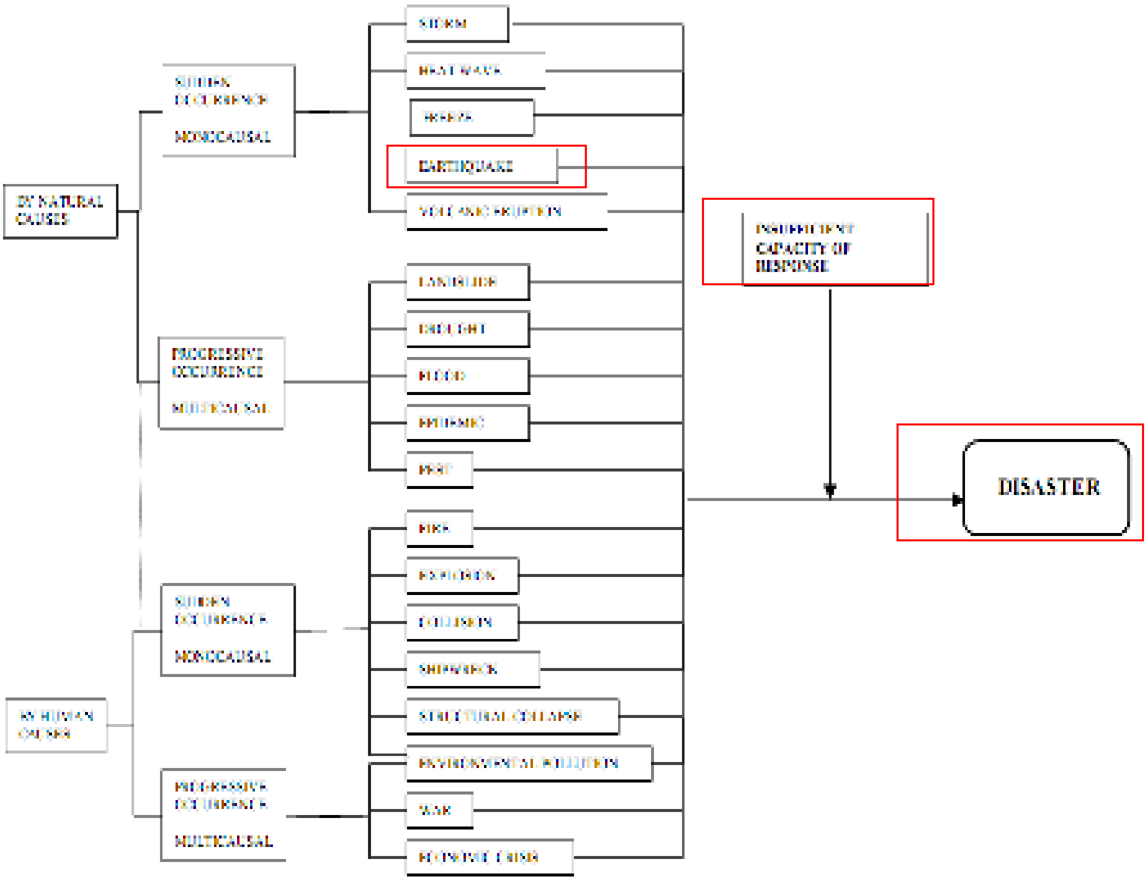
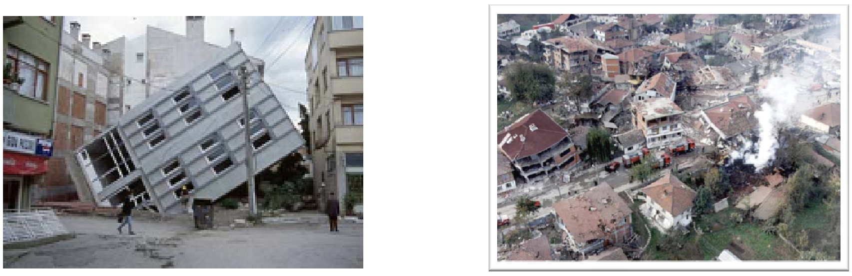


Figure 2.1. The classification of hazards and disasters (EMA, 2009)



a) Earthquake b) Earthquake

c) Fire d) Flood

e) Landslide f) Landslide

Figure 2.2. a-b-c-d-e-f natural hazards such as earthquake, fire and flood (EMA, 2007)

2.1.2. Earthquake

Earthquakes are one of the main natural hazards that cause devastating damages especially in the developing countries (Şengezer *et al.,* 2006). Earthquake is defined by United States Geological Survey (USGS, 2003) as a term used to describe both sudden slip on a fault and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the Earth. Another definition of earthquakes is given by Federal Emergency Management Agency (FEMA, 2009) as earthquakes strike suddenly, violently, and without warning at any time of the day or night. If an earthquake occurs in a populated area, it may cause many deaths and injuries and extensive property damage.

2.1.2.1. Plate Tectonics. The Earth’s outer layer or crust is broken into pieces called tectonic plates which are constantly moving towards, away from or past each other. Because continents are part of these plates, they also move. An earthquake occurs when the rocks break and move as a result of stresses caused by plate movements. Most earthquakes occur on the edge of plates, especially where one plate is forced under another (Figure 2.3).

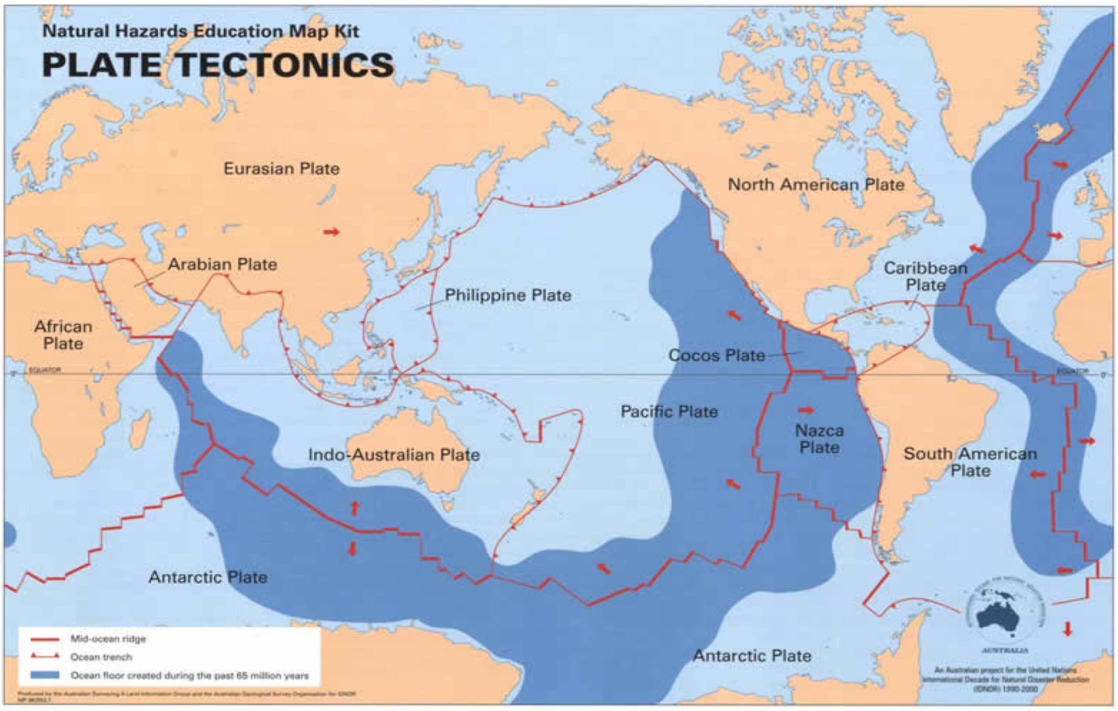


Figure 2.3. Plate tectonics (EMA,2007)

The size of earthquakes is commonly measured using the Richter scale which compares the maximum heights of the seismic waves at a distance of 100 kilometers from the point on the Earth's surface directly above where the earthquake originated within the Earth, the epicenter. The scale divides the size of earthquakes into categories called magnitudes which are an estimate of the energy released by an earthquake (EMA, 2007).

The effects of an earthquake depend on many factors, such as the distance from the epicenter and the local ground conditions. Generally, for locations near the epicenter, the following effects may be observed shown on the Table 2.2.

Table 2.2. Earthquake effects (Australian Government, Geosciences Australia, 2007)

Magnitude	**Description of Effect**
Less than 3.4	Usually felt by only a few people near the epicenter.
3.5 - 4.2	Felt by people who are indoors and some outdoors; vibrations similar to a passing truck.
4.3 - 4.8	Felt by many people; windows rattle, dishes disturbed, standing cars rock.
4.9 - 5.4	Felt by everyone; dishes break and doors swing, unstable objects overturn.
5.5 - 6.1	Some damage to buildings; plaster cracks, bricks fall, chimneys damaged.
6.2 - 6.9	Much building damage; houses move on their foundations, chimneys fall, furniture moves.
7.0 - 7.3	Serious damage to buildings; bridges twist, walls fracture, many masonry buildings collapse.
7.4 - 7.9	Causes great damage; most buildings collapse.
Greater than 8.0	Causes extensive damage; waves seen on the ground surface, objects thrown into the air.

Earthquake damage is mainly controlled by factors related to structural features, local site conditions and earthquake characteristics (Şengezer *et al.,* 2008).

2.1.3. Tectonic Setting and Seismicity of Marmara Region

The active tectonics of northern Turkey is dominated by the right-lateral North Anatolian Fault Zone, running from Karlıova in the east (41ºE) to Istanbul (29ºE) in the west (Ambraseys and Jackson, 2000). North Anatolian Fault Zone is defined as the predominantly strike-slip surface along its entire 1000-km length, which is associated with a series of major earthquakes (Ambraseys, 2002) (Figure 2.5).

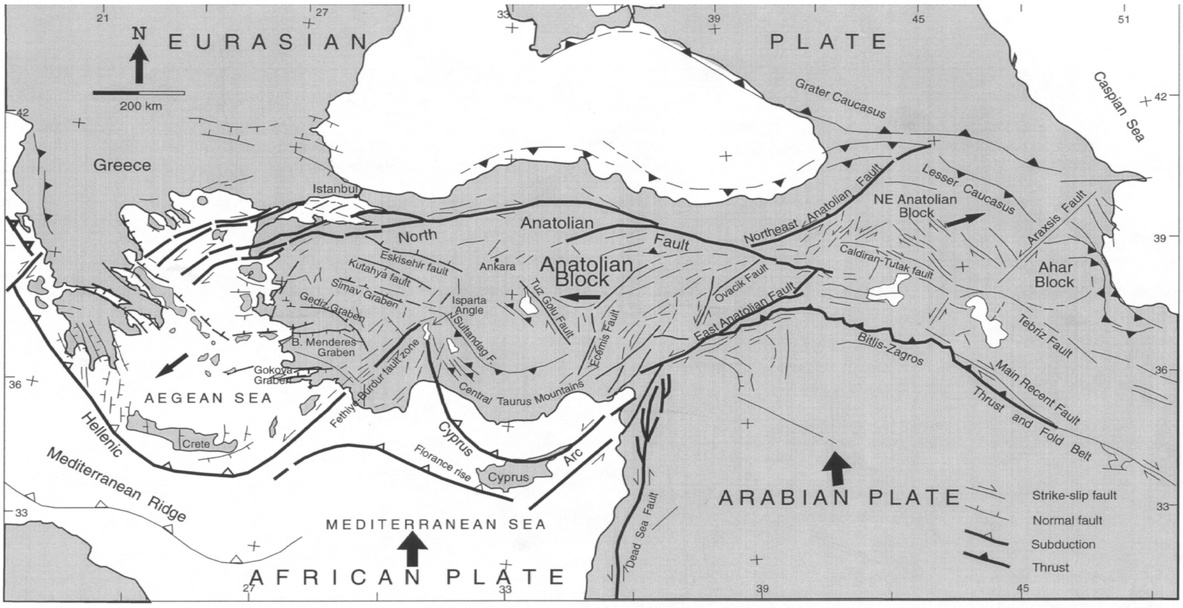


Figure 2.4 Distribution of active faults in the Anatolian Region
(Barka and Reilinger, 1997)

Recent studies show that the Marmara Sea Basin was controlled by a strike-slip fault that extended between the Gulf of İzmit and the Gallipoli Peninsula with a 20 mm/yr vectors to the north (Le Pichon *et al.,* 2000) (Figure 2.5) and (Figure 2.6).

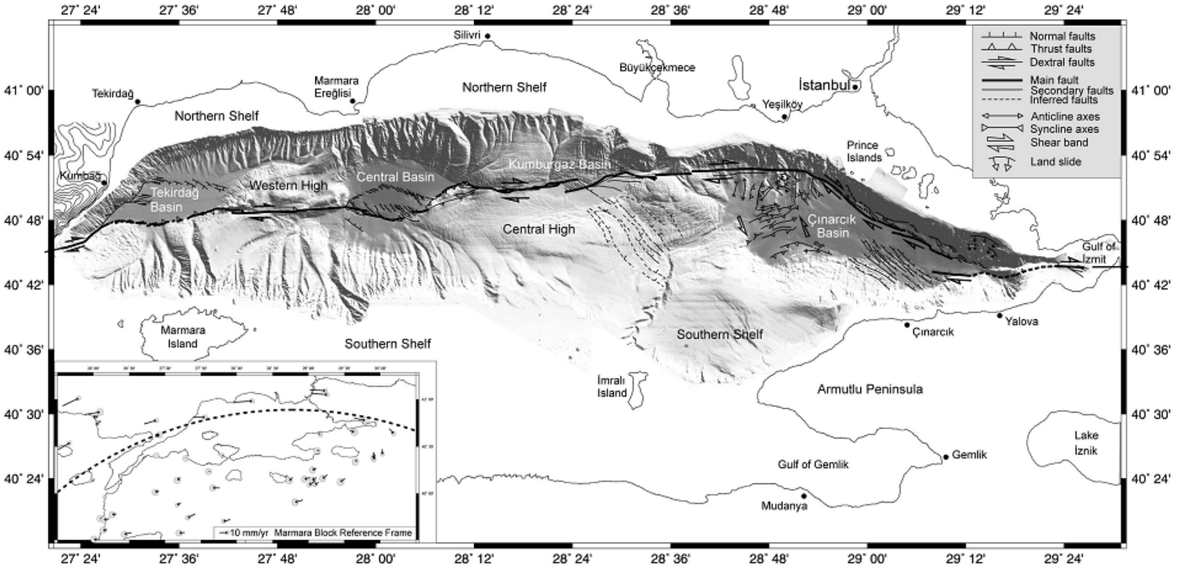


Figure. 2 5. Bathymetric map of the Marmara through with the main active structures (Le Pichon *et al.,* 2000)

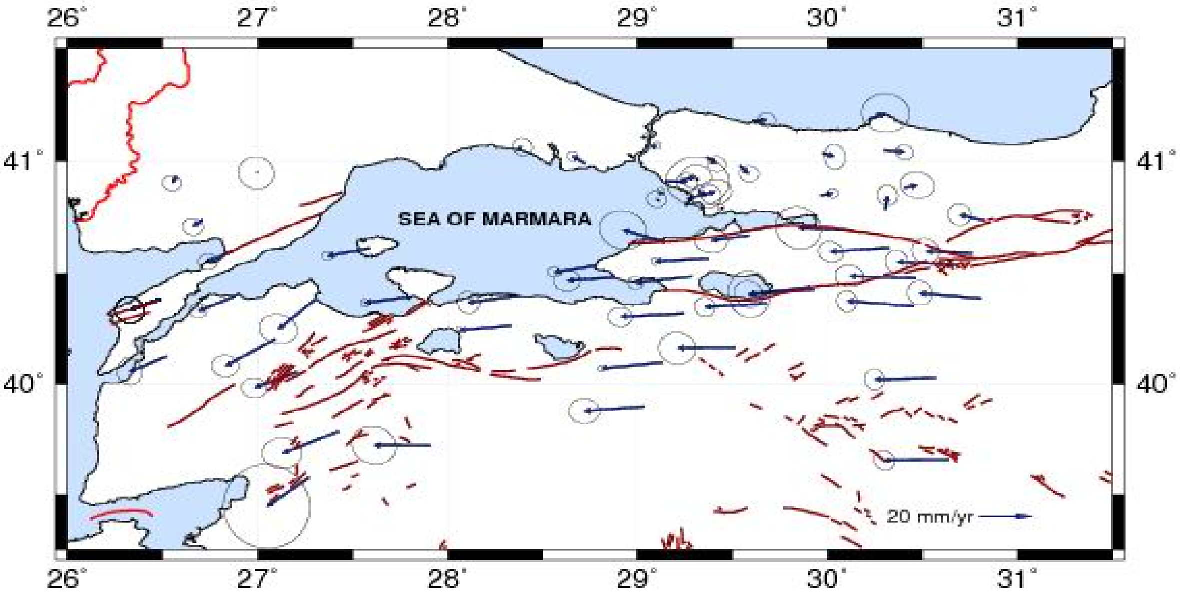


Figure 2.6. Horizontal velocity field of the Marmara region in a Eurasia-fixed reference frame (ellipses are at 95 per cent confidence level and the data covers 2003–2005 time intervals) (Ozener *et. al.,* 2009)

İstanbul metropolitan city located on Marmara region has a complex seismotectonic structure and it has suffered from periodic earthquakes. Turkey is located in the collision zone between the Eurasian, African and Arabian tectonic plates (Figure 2.4). This collision has resulted several plate interactions and seismotectonic activations. Based on historical earthquakes studied by Ambraseys and Finkel in 1991, Istanbul has suffered damage due to earthquakes repeatedly. According to Ambraseys and Jackson (2000), the 20 th century has been particularly active seismically in the Marmara region. Figure 2.7 expresses seismic activities from 1900 to present in Marmara region. In this figure red colors represent shallow earthquakes while big size represents larger earthquakes.

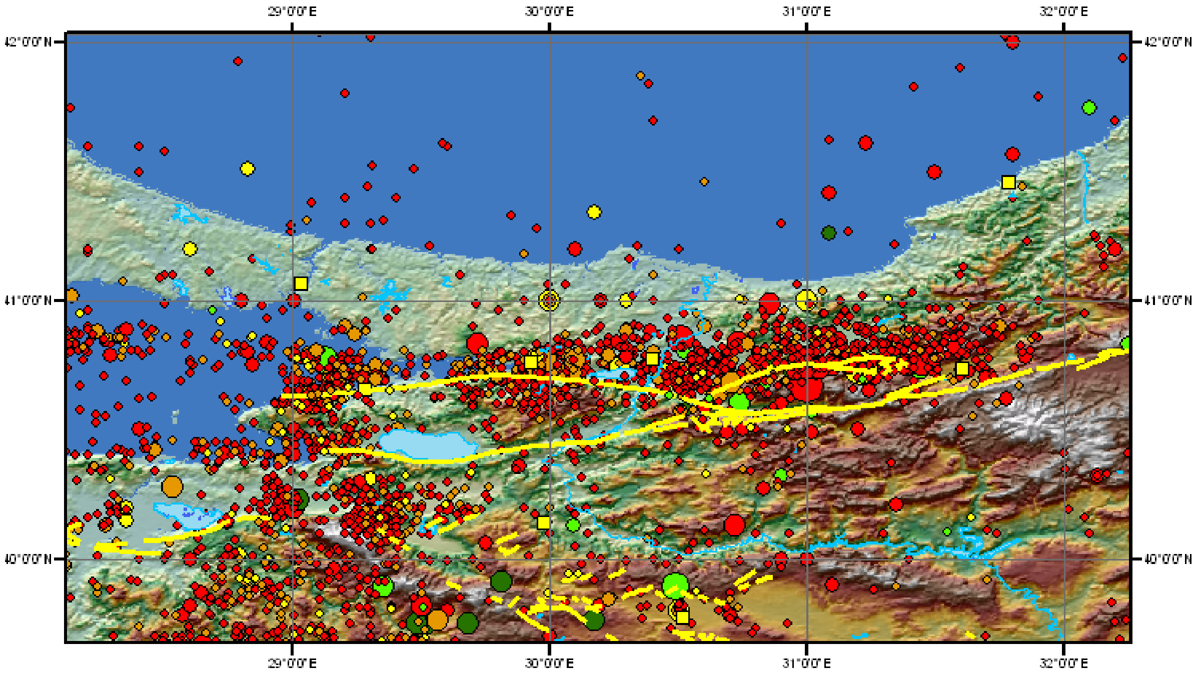


Figure 2.7. Earthquakes with magnitude larger than 3 since 1900 at Western NAFZ (Garagon Dogru, 2008)

2.1.4. Earthquake Faults Segments in Marmara Region

After detailed assessment of the distribution of reported earthquake damages, historical earthquakes that affected the Marmara Sea region between 1500-present have been connected with the fault segmentation model (Erdik *et al.*, 2002) presented in Figure 2.8.

Fault ruptures associated with the fault segmentation have been summarized in Table 2.3. Figure 2.9 shows the Main Marmara Fault that follows the northern boundary of the Çınarcık Basin between Yeşilköy and the entrance of the Gulf of İzmit.

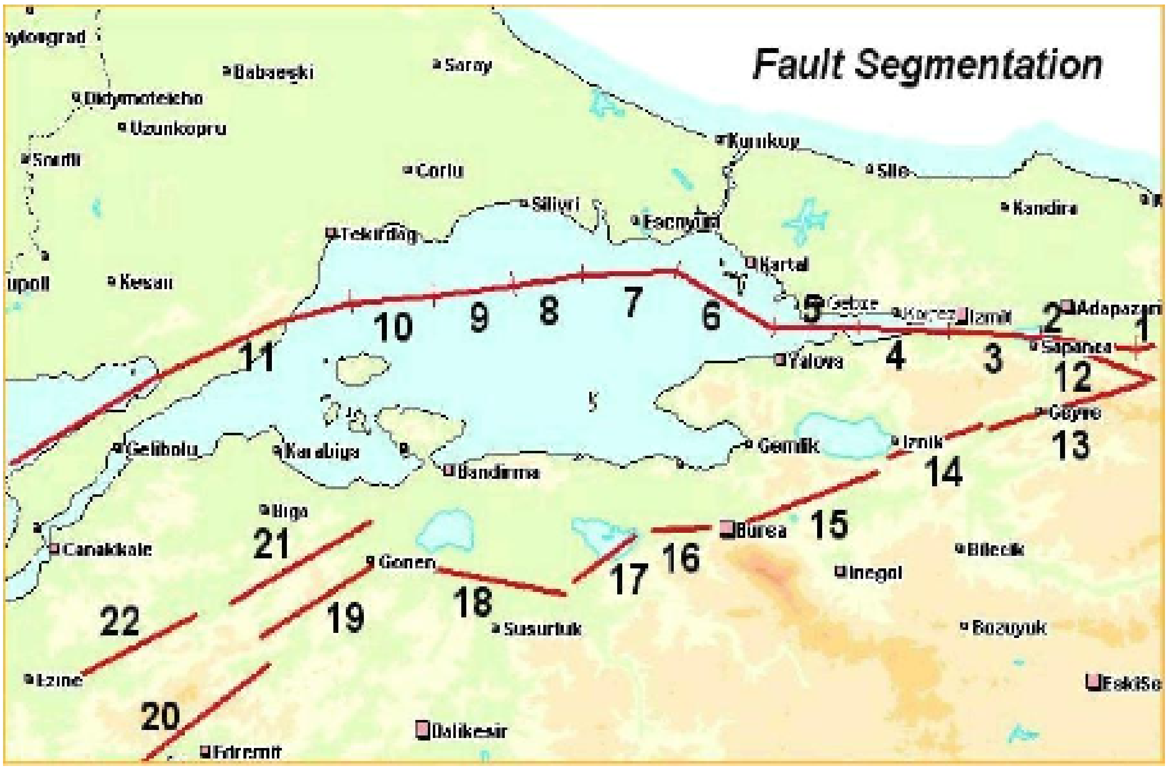


Figure 2.8. Fault segmentation model proposed for the Marmara region (Erdik *et al.*, 2002)

Figure 2.9. Active faults in Marmara Region (Erdik *et al.*, 2002)

Table 2.3. Association of earthquakes between 1500-present with the segmentation proposed for the North Anatolian Fault Zone in the Marmara region (Erdik e*t al.,* 2004*).*

Earthquake	**Fault Segment**
10.9.1509 (Ms = 7.2)	7, 8
10.5.1556 (Ms = 7.2)	9
25.5.1719 (Ms = 7.4)	2, 3, 4, 5
6.3.1737 (Ms = 7:2)	43
2.9.1754 (Ms = 6:8)	6
22.5.1766 (Ms = 7:1)	7, 8
5.8.1766 (Ms = 7:4)	11
28.2.1855 (Ms = 7:1)	40
10.7.1894 (Ms = 7:3)	3, 4, 5
9.8.1912 (Ms = 7:3)	11
1.2.1944 (Ms = 7:3)	19
18.3.1953 (Ms = 7:2)	45
26.5.1957 (Ms = 7:0)	22
22.7.1967 (Ms = 6:8)	12
17.8.1999 (Mw = 7:4)	1, 2, 3, 4
12.11.1999 (Mw = 7:2)	21

Different earthquake magnitude scales are used to describe earthquake’s size The moment magnitude scale, M_w, is used by seismologists to measure the size of earthquakes in terms of the energy released. On the other hand the surface wave magnitude scale, M_s, is used in seismology to describe the size of an earthquake.

2.1.5. Geological Formation of İstanbul and Vicinity

Istanbul and the Kocaeli peninsulas have been divided into groups and formations. According to this classification, the oldest units of the Paleozoic era are named the “İstanbul” group (JICA and IMM, 2002). Geological map of İstanbul is shown in Figure 2.10. Beşiktaş district’s classification of formations are presented in Figure 2.10 and summarized in Table 2.4.

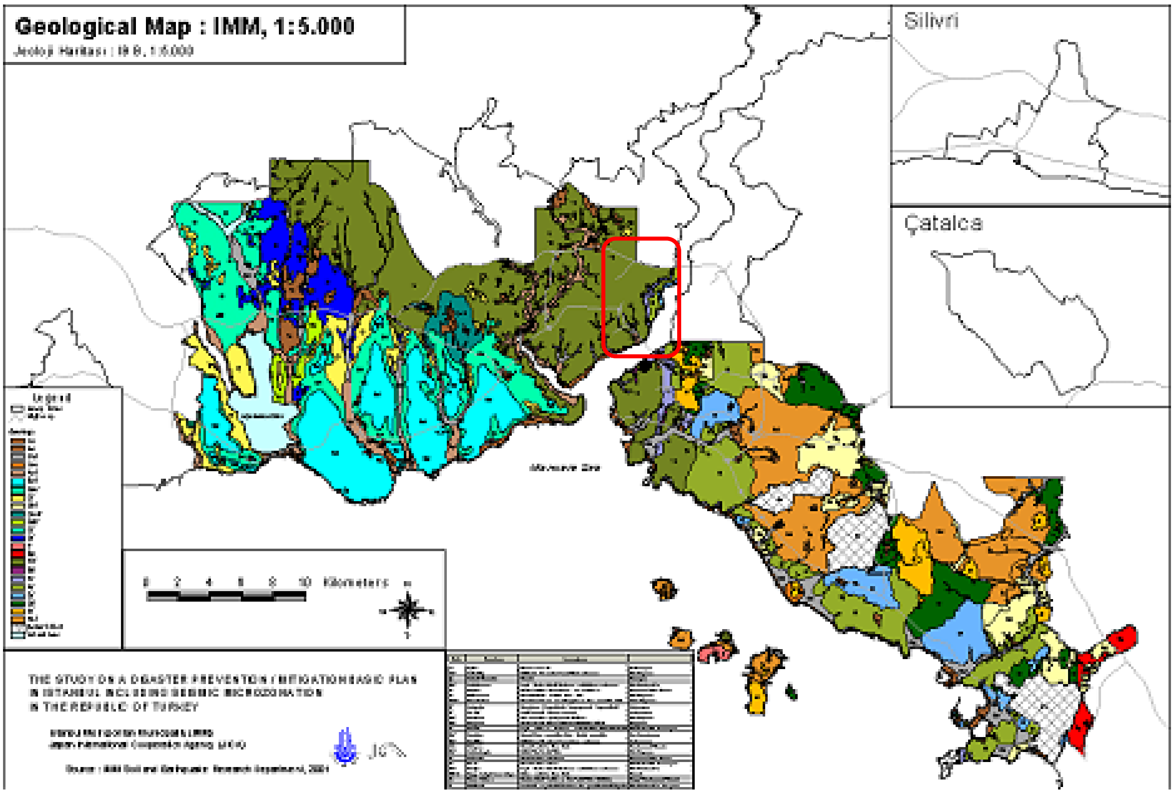


Figure 2.10. Geological map of İstanbul (JICA and IMM, 2002)

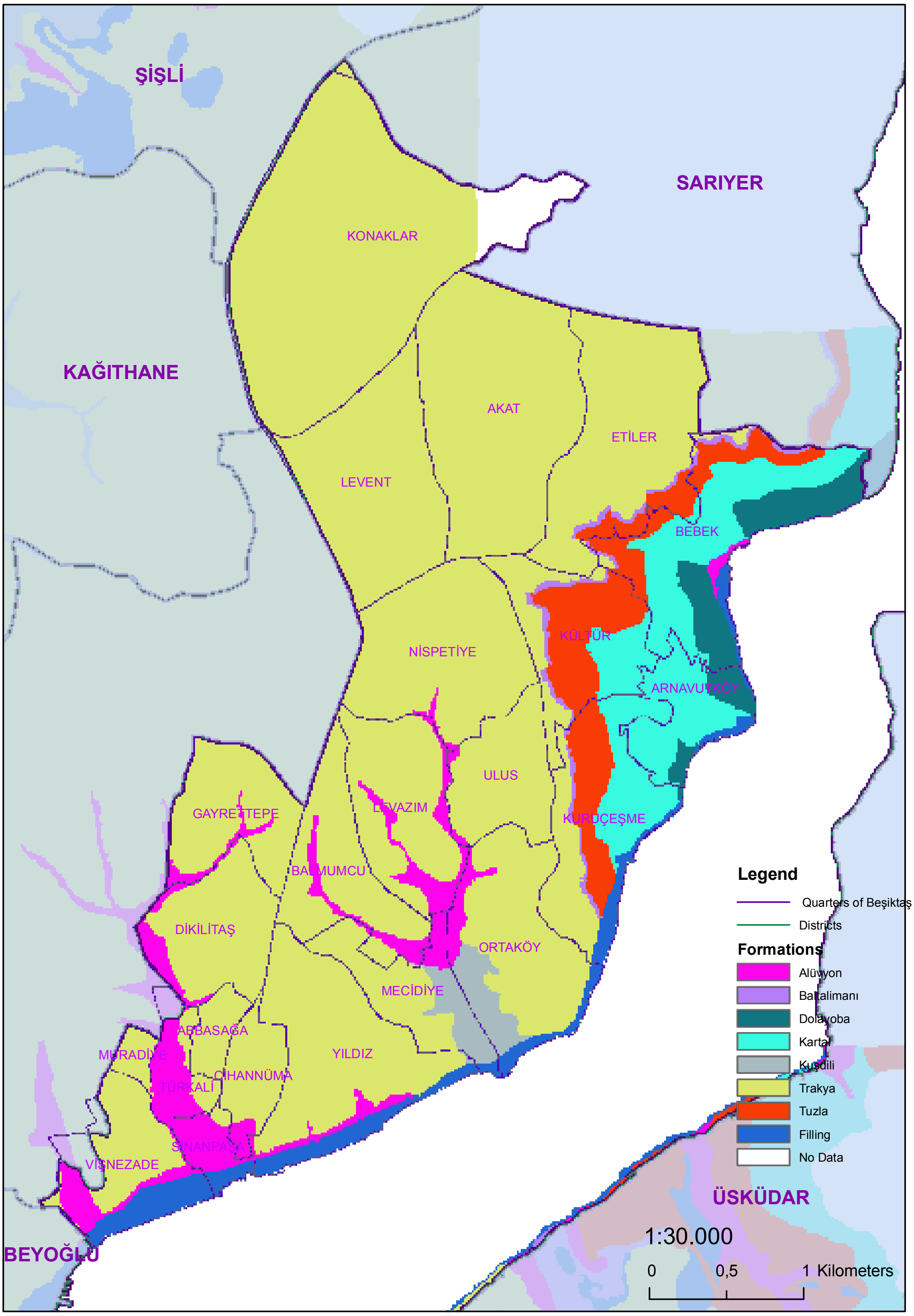


Figure 2.11. Surface geology map of Beşiktaş district

Table 2.4. Formations of Beşiktaş district

Group	**Formation**	**Symbol**	**Explanation / content**
	Filling	Yd	Waste, Antique rubble and made grounds
	Alluvium	Qa	Sand, gravel and clay
	Kuşdili	Kşf	Sand, gravel and clay
İSTANBUL	Tuzla	Tf	Limestone
	Dalayoba	Df	Limestone
	Baltalimanı	Blf	Lydit and silica
	Trakya	Trf	Limestone,claystone and sandstone
	Kartal	Kf	Limestone, claystone and clay

The Formations presented in Table 2.4 are obtained from different sources (Personal communication with Prof. Dr. Erol Güler, JICA and IMM, 2002) and explained from unstable to stable soil in terms of bearing capacity and soil types.

- Filling / Manmade Fill : The ground is not suitable for building because it cannot resist the earthquake. Soil cannot be used for building unless compression process and quality control have done systematically.
- Alluvium / Silt: In general, the bearing capacity is very low (20 – 50 kPa), so the ground is not suitable for building. Softening and liquefaction risks can be seen during an earthquake. It should be noted that one kilo Pascal (kPa) = 101.972 kilogram-force/ square meters.
- Kuşdili : Although bearing capacity is low (50 – 150 kPa), buildings can be made by taking measures.
- Tuzla : It is formed of rock that is earthquake-resistant. The bearing capacity is high (100 – 200 kPa), therefore it is suitable for building.
- Dalayoba : Soil is stable, so it is a solid ground for earthquakes. Bearing capacity is high (100 – 200 kPa) and it is suitable for building.
- Baltalimanı : The bearing capacity is high (100 – 400 kPa). It is originated from earthquake-resistant rock, so it is suitable for construction.

- Trakya : The bearing capacity is changing between 100 - 400 kPa. It is formed by a solid ground, but the soil has breaking, cracking and faulting. While plain areas are suitable for building, sloped areas are not suitable.
- Kartal : It is formed by a solid ground, therefore it is suitable for building. Many researchers believe that it resists earthquakes because it completed the process of rock formation. The bearing capacity is changing between 100 - 400 kPa.

Generally, it is realized that not only vulnerability analyses but also the potential of the earthquake induced ground failure hazards such as liquefaction and landslide are considered in the studies of seismic risk assessment in urban centers. However, the landslides and liquefaction potential are not into consideration in this study because these failures require separate detailed calculation methods. Nevertheless liquefaction data were mapped using GIS through this study (Figure 2.12 and Figure 2.13). Besides landslides were visualized using slope data and suitable areas map (Figure 2.14).

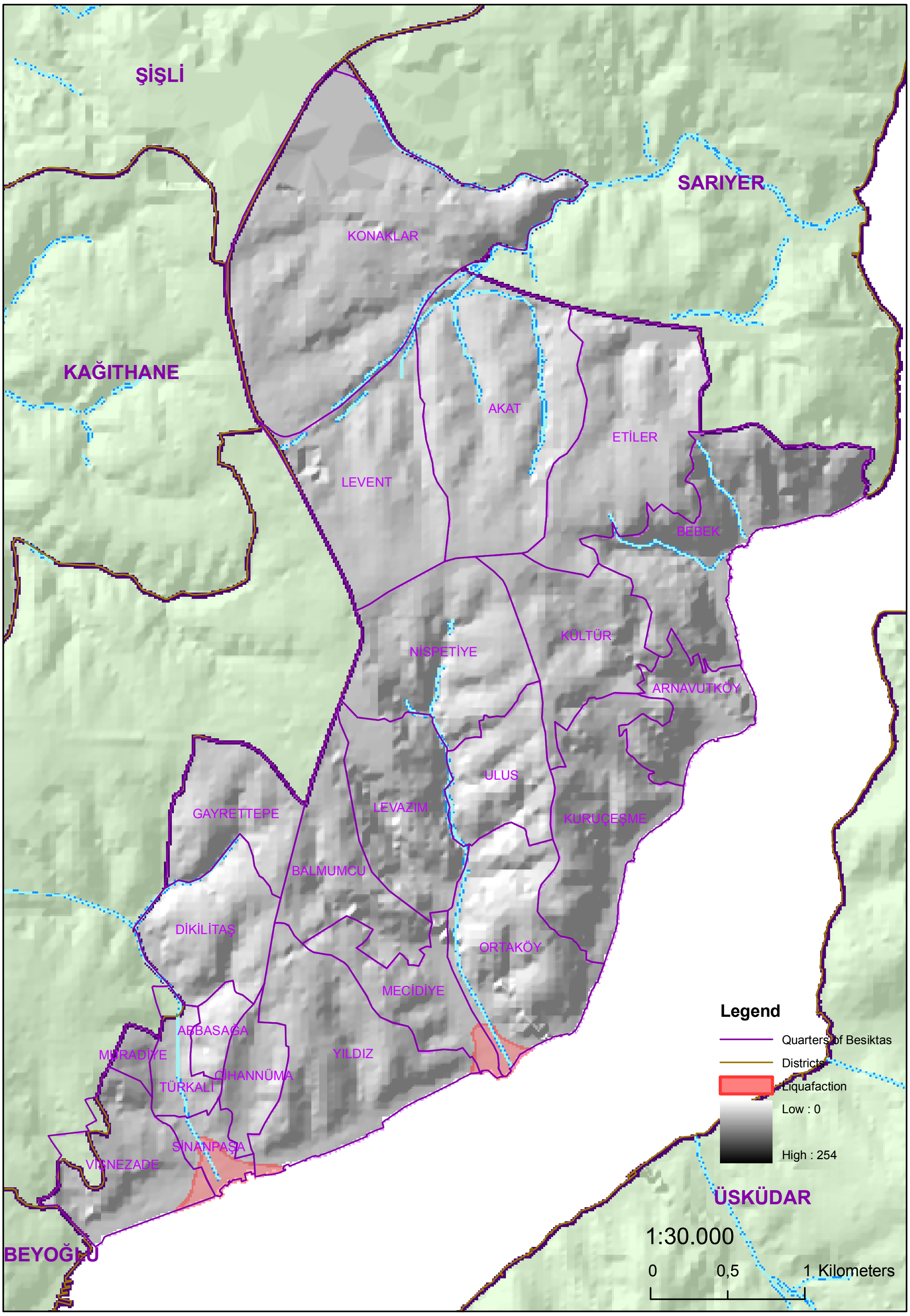


Figure 2.12. Liquefaction susceptibility map with elevation model

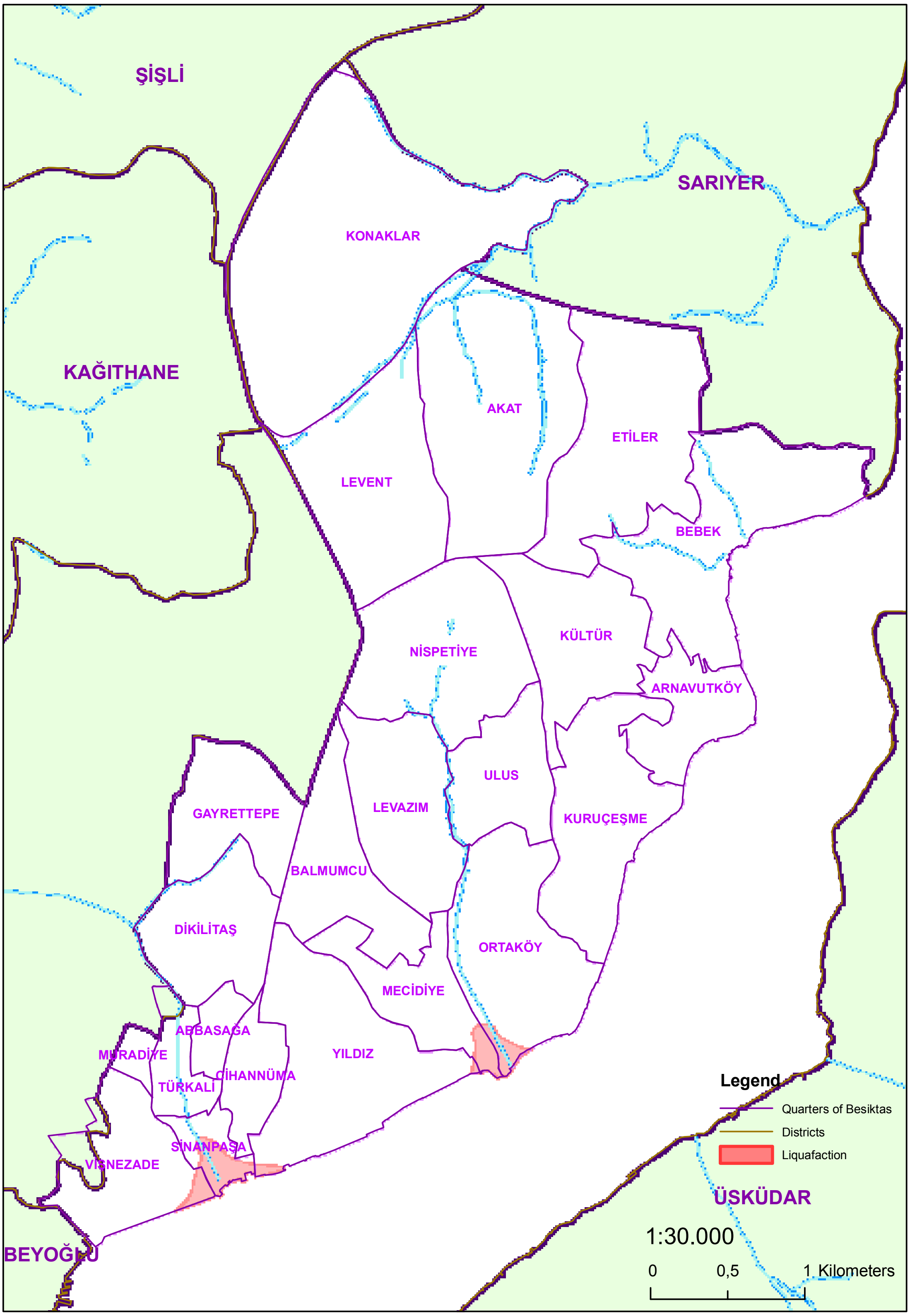


Figure 2.13. Liquefaction susceptibility map

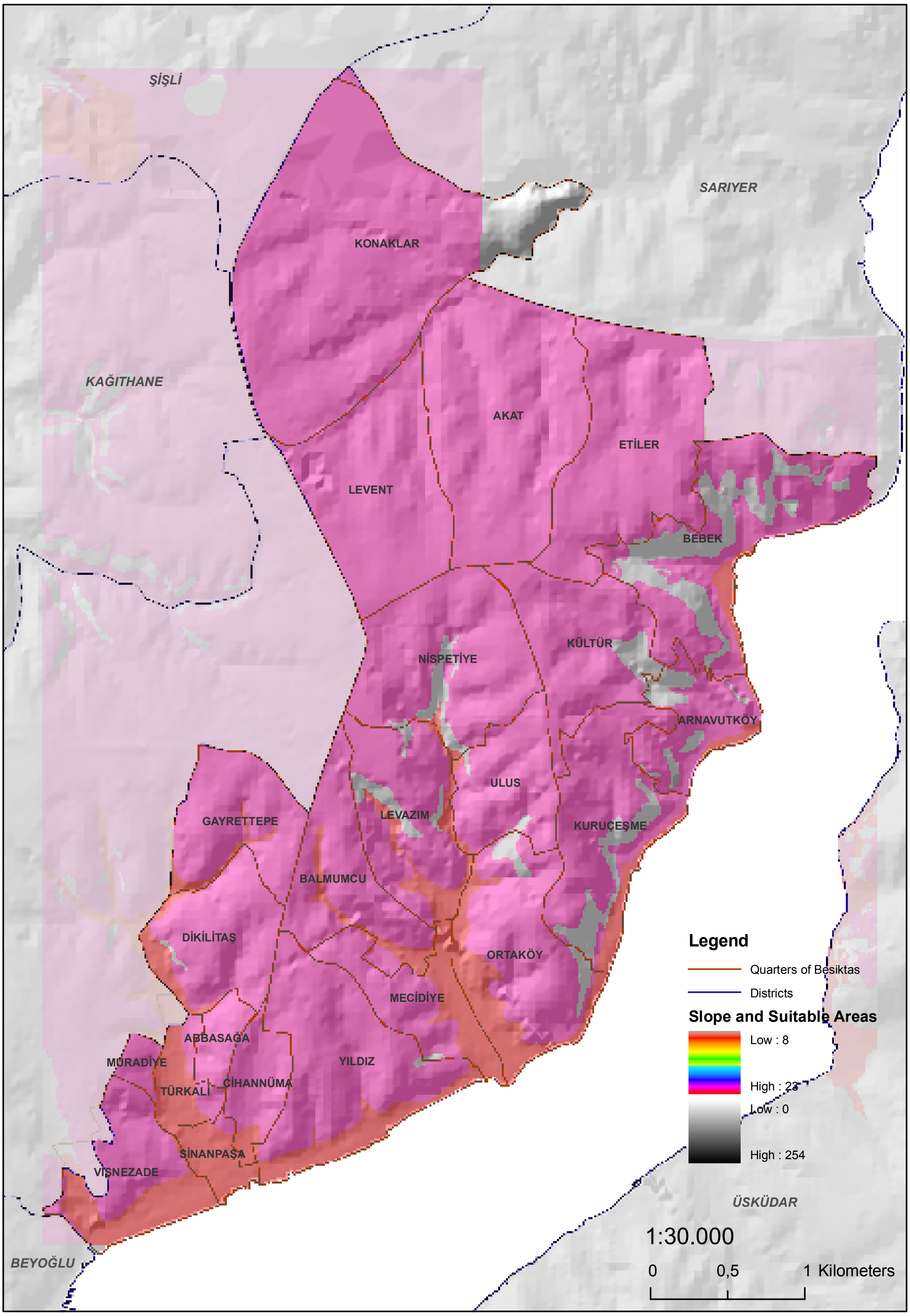


Figure 2.14. Slope stability risk by each quarter

2.2. Definition of Vulnerability and Risk

Vulnerability is defined by International Strategy for Disaster Reduction as the condition determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. Vulnerability of a nation/region to disaster events is often measured in terms of the total numbers of events, people killed, people affected and the economic losses. Specific to the urban context, Rashed (2003) defines vulnerability to natural hazards such as earthquakes as a function of human behavior. United Nations give another definition about vulnerability in 1991 as a degree of loss to an element at risk resulting from the occurrence of a natural phenomenon and expressed on a scale from zero to one. The physical infrastructure vulnerability describes the expected degree of direct damage to the given a specified level of hazard (Davidson, 1997).

In general, the severity of structural damage is assessed as a damage ratio, *i.e.*, the repair cost divided by the replacement cost, and structural vulnerability is portrayed using a vulnerability curve, or fragility curve (Figure 2.15). A damage curve depicts the expected severity of damage associated with the level of hazard (UN, 1999).

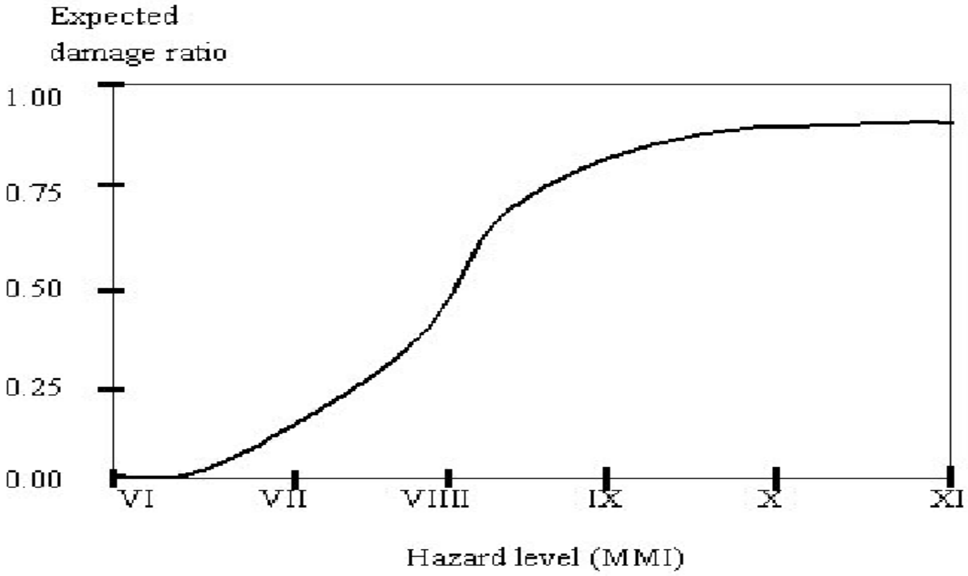


Figure 2.15. Schematic example of a damage curve (based on NIBS, 1997)

The vulnerability of a structure depends mainly on size, mass, structure layout, irregularities, material types and construction details (JICA and IMM, 2002). Vulnerability is embedded as part of the risk framework. The UN determined that risk to a particular system has two factors: the 'hazard' itself, which is a potentially damaging physical event, phenomenon or human activity that is characterized by its location, intensity, frequency and probability. The second factor is the 'vulnerability', which denotes the relationship between the severity of the hazard and the degree of damage caused (Figure 2.16).

$$\text{Risk} = \text{Hazard x Vulnerability (UN, 2004)} \qquad (2.1)$$

Earthquake risk is the building damage, number of people that are hurt or killed, and further economic losses in a certain time period, due to an earthquake with a return period corresponding to this time period. Earthquake risk can be expressed, based on the definitions above, as:

$$\text{Earthquake Risk} = \text{Earthquake Hazard x Vulnerability x Value at Risk} \qquad (2.2)$$

Risk assessment/analysis is a methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend.

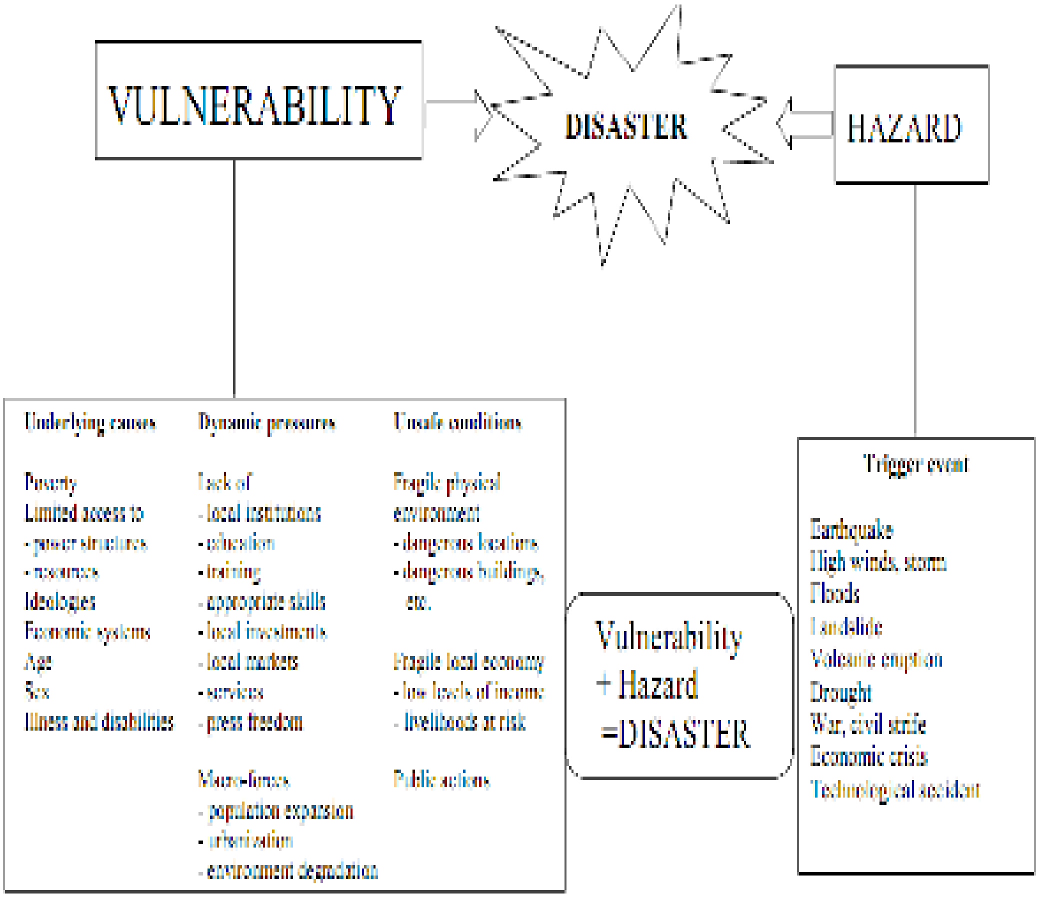


Figure 2.16. The relations between vulnerability, hazard and disaster (WHO, 2002)

An understanding of earthquake risk requires an understanding of how frequent and how large earthquakes are likely to be in any particular region; how the ground shaking caused by the earthquake propagates; and how vulnerable communities and infrastructure are to the ground shaking. In practice, this involves three key stages for assessing likelihood (*i.e.* earthquake source, ground motion and site response models) and two key stages for assessing consequence (*i.e.* exposure and vulnerability models). By combining these models, it is possible to quantify the risk, and to design structures to minimize the chance of catastrophic losses. To achieve this outcome requires high-quality seismic data; knowledge of the regional geological structures, including detailed near- surface geology; and comprehensive building and infrastructure inventories (Australian Government, Geoscience Australia, 2007).

2.3. Disaster Management

Disaster can be defined as the onset of an extreme event causing severely damage or loss as perceived by the affected people. Disaster management involves three phases predisaster, during the disaster, and postdisaster. The predisaster phase consists of risk identification, mitigation, and preparedness. During the disaster, emergency response takes place, and in the postdisaster phase, rehabilitation and reconstruction are applied. The actions create a cycle in time (ESRI, 2006). Disaster management cycle is drown by ESRI and WHO in Figure 2.17 and Figure 2.18, respectively.

Figure 2.17. Disaster management cycle predisaster, during, and postdisaster phases (ESRI, 2006)

In the predisaster phase to identify risk, hazard, risk, and vulnerability assessments are performed. The result of the risk assessment provides a function of hazard probability and vulnerability. Hazard monitoring and forecasting use GIS, mapping, and scenario building. At the end of this phase, risk is identified and mitigated. Land-use planning and building codes related to the risk can be updated and enforced in the community. The public could be educated about risks and trained in prevention. In emergency preparedness, early warning systems, communication systems, networks of emergency responders, shelter facilities, and evacuation plan are key elements.

During the disaster phase, existing early warning systems could be used. In emergency response, humanitarian assistance, temporary repairs, restoration of services, and damage assessment are the basic steps.

After this phase, rehabilitation and reconstruction activities take place. Damaged critical infrastructure is reconstructed; budget and macroeconomic management issues are addressed; revitalization of affected sectors begins; and tourism, exports, and agriculture are managed (ESRI, 2006).

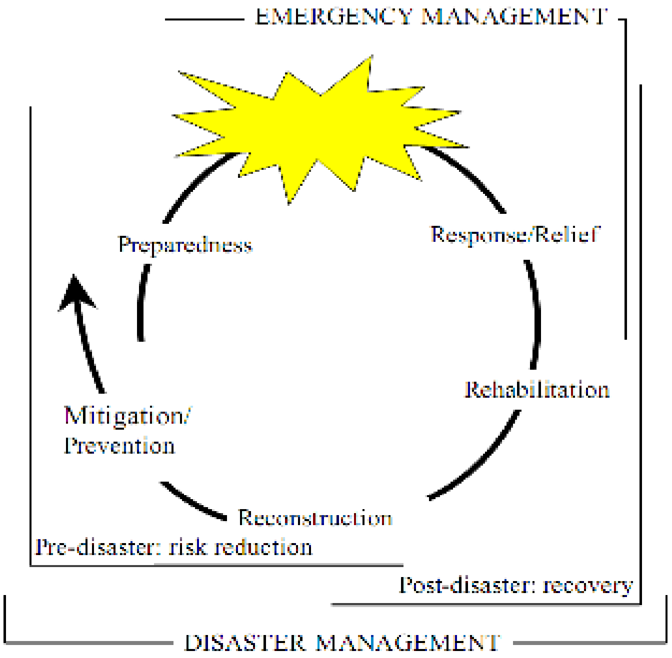


Figure 2.18. Disaster management cycle (WHO, 2002)

According to WHO, aims of disaster management are: reduce (avoid, if possible) the potential losses from hazards, assure prompt and appropriate assistance to victims when necessary and achieve rapid and durable recovery. This study includes pre-disaster phases represented in Figure 2.19, thus the risk and hazard are identified; hazard, risk, and vulnerability assessments are performed.

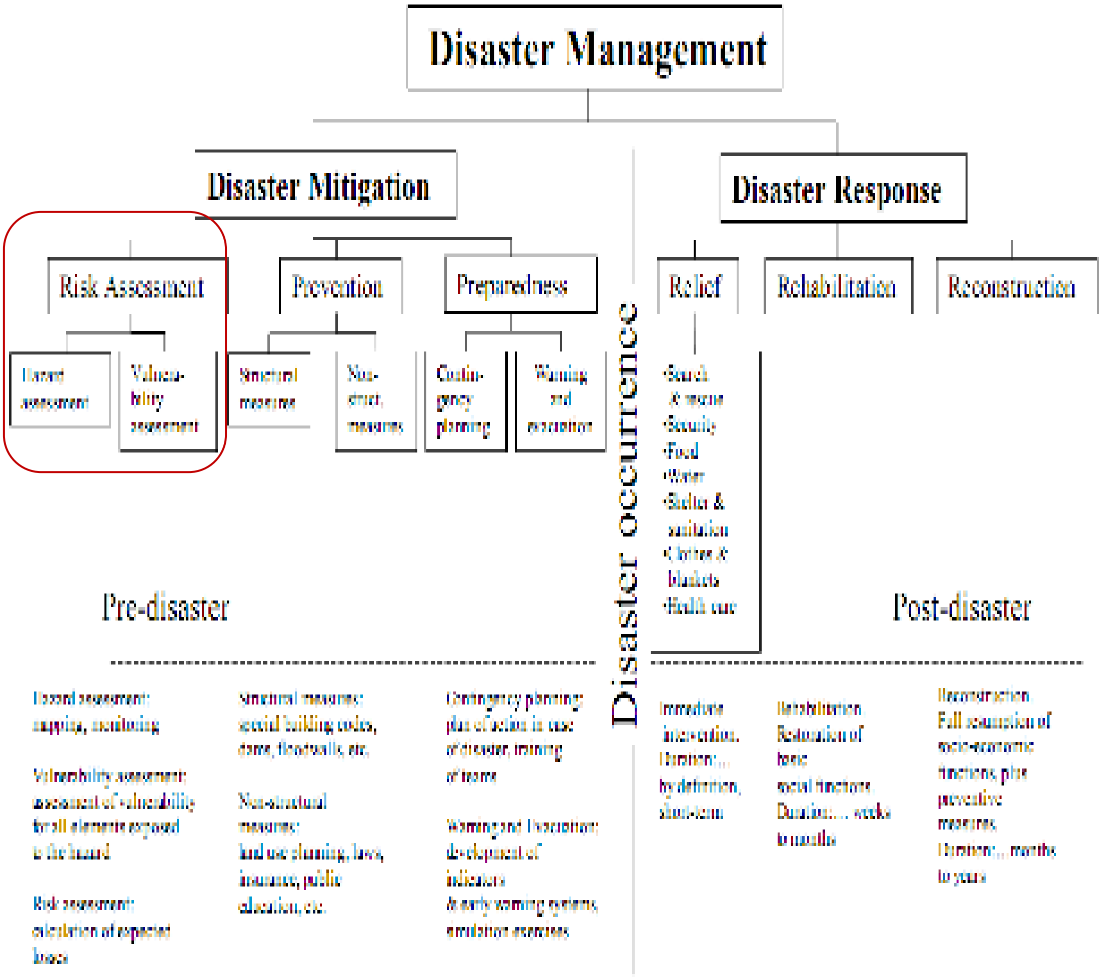


Figure 2.19. Disaster management schema (WHO/EHA, 2002)

2.4. Definition of Terms in Risk Reduction

2.4.1. Mitigation Plan

Natural disaster mitigation has to be taken in order to decrease and eliminate of natural disaster's impact on society and the environment.

National Incidence Management System (NIMS) defines mitigation as an important element of emergency management and incident response. It provides a critical foundation in the effort to reduce the loss of life and property and to minimize damage to the environment from natural or manmade disasters by avoiding or lessening the impact of a disaster. Mitigation provides value to the public by creating safer communities and impeding the cycle of disaster damage, reconstruction, and repeated damage.

According to Federal Emergency Management Agency (FEMA), mitigation planning is a process to identify policies, activities, and tools to implement mitigation actions.

In Turkey, a better level of disaster mitigation may be attained by integrating hazard mitigation efforts into normal development review procedures. The attitude towards disaster mitigation should be reviewed and modified, together with urban and regional planning processes, legal arrangements and financial and social models, so as to develop a sustainable settlement system (Şengezer and Koç, 2005).

Mitigation is any sustained action taken to reduce or eliminate long-term risk to life and property from a hazard event. This process has four steps (FEMA):

- Organizing resources;
- Assessing risks;
- Developing a mitigation plan; and
- Implementing the plan and monitoring progress

First two steps mentioned above were performed in this study. The aim was to build an infrastructure for developing a mitigation program based on hazard and vulnerability assessment. This study comprises of testing of getting ready against earthquake risk of urban areas and analyzing of parks in amount of sufficient number.

3 . CASE STUDY

3.1. Study Area

3.1.1. Location, Topography and Geological Formation

Beşiktaş is one of the oldest districts and neighborhoods of İstanbul, located on the European side of the city. Beşiktaş covers an area of 1800 hectare with a shore line extending for 8.375 m along the Bosporus. There are 22 quarter: Abbasağa, Akat, Arnavutköy, Balmumcu, Bebek, Cihannüma, Dikilitaş, Gayrettepe, Etiler, Konaklar, Kuruçeşme, Kültür, Levazım, Levent, Mecidiye, Muradiye, Nispetiye, Ortaköy, Sinanpaşa, Türkali, Vişnezade and Yıldız (Figure 3.1). Beşiktaş comprises 875 streets, 31 of these being arterial roads attached to the İstanbul municipality.

The topography of the Beşiktaş district consists of two parts – the coastal strip and the country behind it. The coastal strip is in the form of slopes running parallel to the Bosphorus by valleys, most of them with streams. The country consists of fairly smooth terrain forming a continuation of the Beyoğlu plateau in the west, while it consists of small ridges between the valleys on the north and east. The Bosphorus shores within the Beşiktaş district are not particularly irregular. There are promontories at Defterdar point at Ortaköy and Akıntı point at Arnavutköy. The only bay is the Bebek. Contour map and the Triangulated Irregular Network (TIN) model which is obtained from contour lines belong to Beşiktaş district are shown in Figure 3.1 and Figure 3.2 respectively.

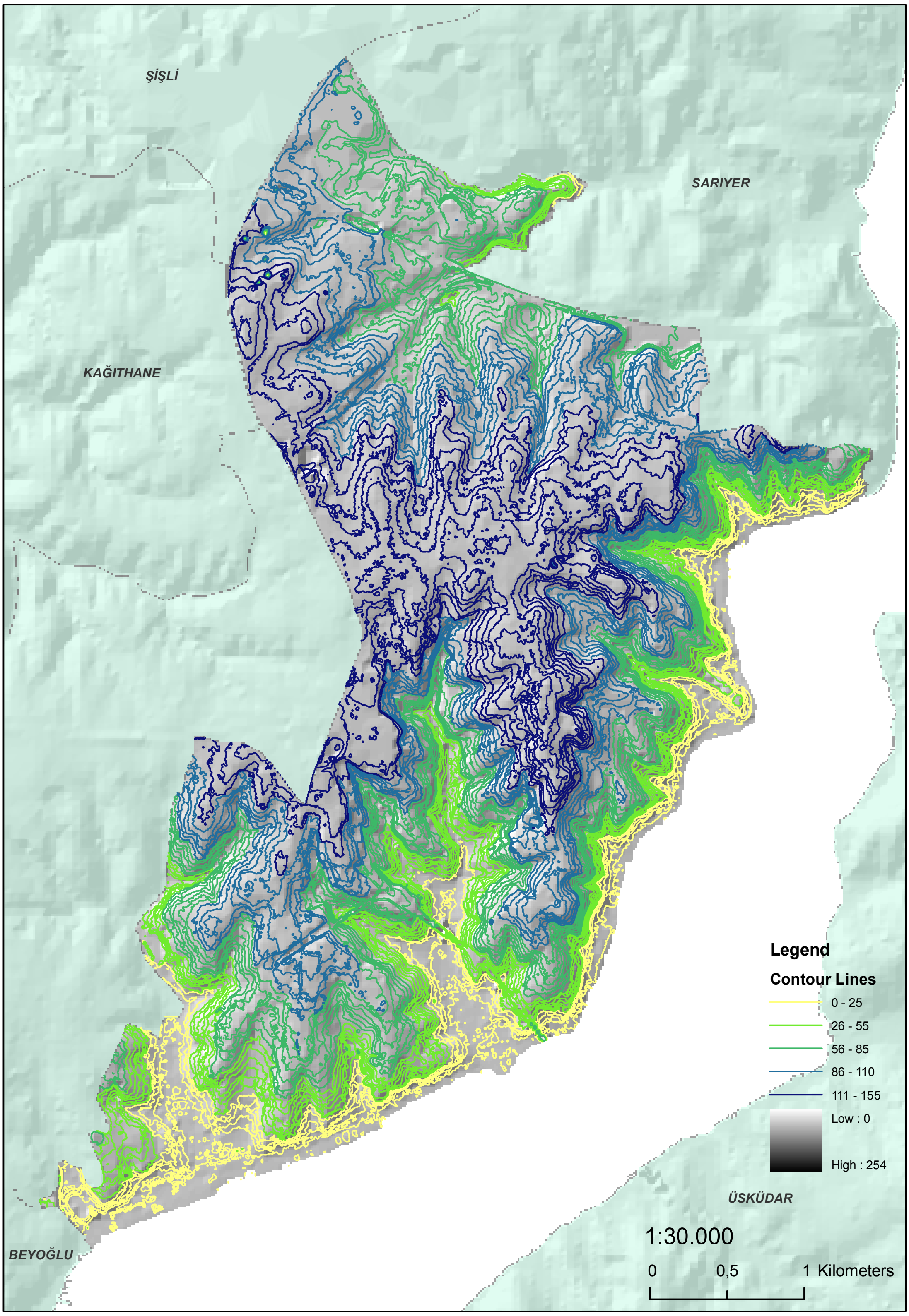


Figure 3.1. Contour map of the study area

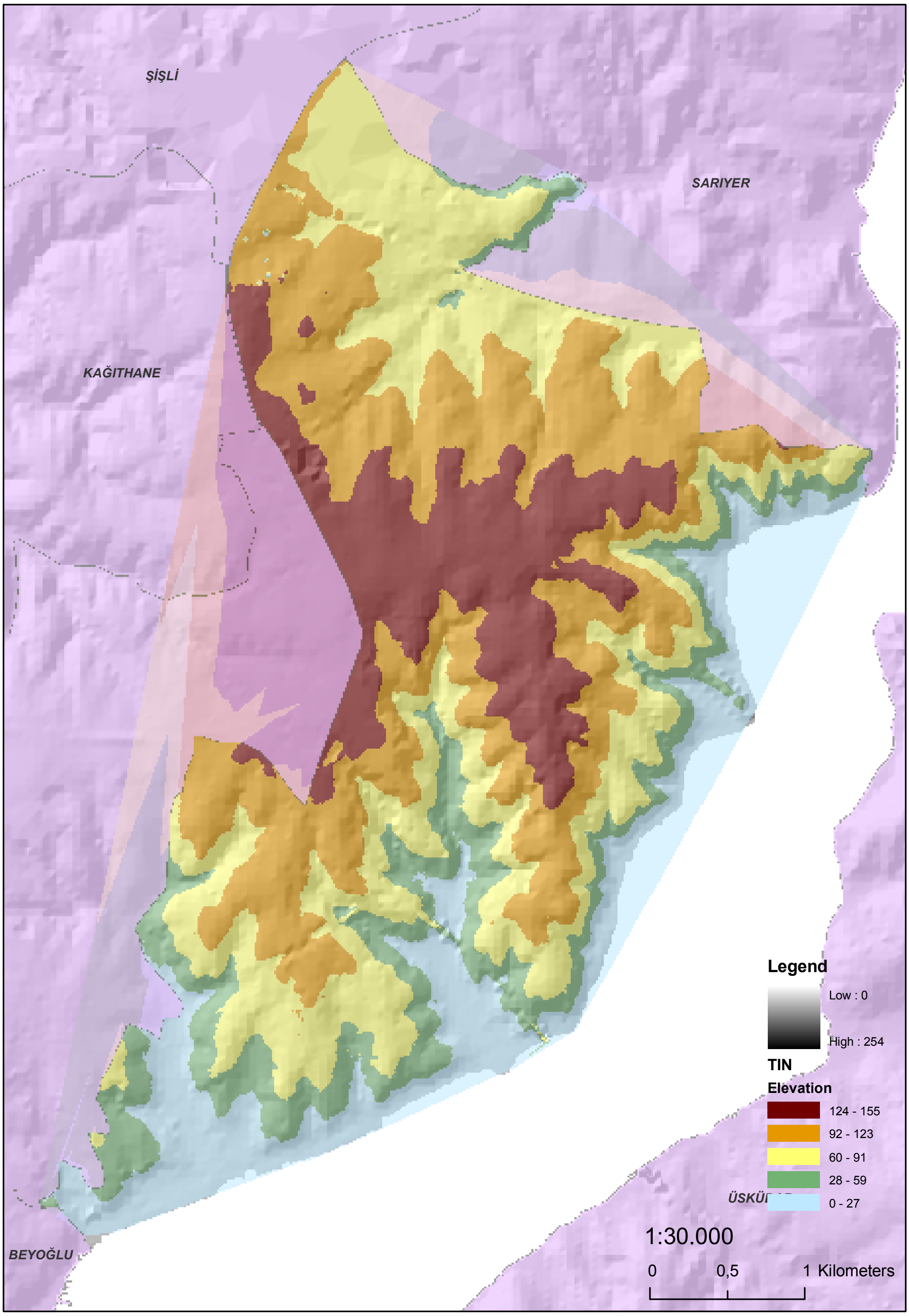


Figure 3.2. TIN model of Beşiktaş district

The only stream remaining Beşiktaş is the Ortaköy stream produced by confluence of three small streams in the valley in the present day districts of Nispetiye and which, after flowing along the border between Ortaköy and Levazım, enters an underground passage at the beginning of Ambarlı Dereiçi street. The other streams have completely disappeared as a result of changes in the topography. These names are Karabali (Dolmabahçe) stream, Beşiktaş stream, Muradiye stream, Fulya stream, Ihlamur stream, Hasanpaşa stream, Yahyaefendi stream, Ortaköy stream, Emekçioğlu stream and Arnavutköy stream.

Large part of the Beşiktaş district is composed of rocks of the Paleozoic Devonian system. This formation, characterized by clayey schist, underwent folding in the Mesozoic and the faults caused by volcanic movements during this period were filled with magma. There is no evidence in Beşiktaş of Tertiary Formations. Large quantities of alluvium have accumulated along the coastal strip, particularly in the valleys carved out by the streams and at the points where the streams emptied into the Bosphorus (Akbayar, 1998).

3.1.2. Population, Economical and Social Life in Beşiktaş District

According to the Population Census of 2007 by the Prime Ministry Turkish Statistical Institute (Turk Stat), the total population of Beşiktaş district is 175,373 and its population density is 100 person / hectare.

The population of Beşiktaş showed a slow but steady increase in the 50 years between 1935 and 1985, but in the last 12 years, it has shown considerable fluctuation. The fact that the residential area has reached the boundaries of the district so that more of the area has been occupied by business premises has meant a drop in the number of actual residents. The population distribution of Beşiktaş district and number of buildings in 1886 and 2007 are shown in Table 3.1 and Figure 3.3 according to the Turk Stat (2007).

Table 3.1. Beşiktaş population in 1886 (No.1301 Statistics Register) (Beşiktaş Municipality) and Beşiktaş population in 2007 (Turk Stat, 2007)

Population in 1886		**Population in 2007**	
Quarter		**Quarter**	
Abbasağa	2459	**Abbasağa**	5671
Arnavutköy	7599	**Akat**	16061
Bebek	2458	**Arnavutköy**	4521
Cihannüma	2501	**Balmumcu**	2454
Ekmekçibaşı	1610	**Bebek**	5731
Kapudan İbrahim ağa	1319	**Cihannuma**	3859
Köyiçi	5267	**Dikilitaş**	7063
Kuruçeşme	4090	**Etiler**	11999
Ortaköy	12217	**Gayrettepe**	13121
Rumali	1792	**Konaklar**	15594
Sinan Paşa-yı Atik	4130	**Kuruçeşme**	3537
Sinan Paşa-yı Cedid	2579	**Kültür**	5010
Süleymaniye	1287	**Levazım**	5825
Şenlik Dede	3135	**Levent**	2977
Teşvikiye	5293	**Mecidiye**	11074
Vişnezade	494	**Nisbetiye**	12653
Yenimahalle	4222	**Ortaköy**	8703
		Sinanpaşa	2247
		Muradiye	5610
		Türkali	11259
		Ulus	7294
		Vişnezade	7065
		Yıldız	6045
TOTAL	**62452**	**TOTAL**	**175373**

This table shows that some quarters' names were changed and new quarters are added during a hundred years. Beşiktaş is considered as one of the city centers, both residential and commercial. Besides having a major public bus and dolmuş terminal, Beşiktaş is also one of the sea hubs on the Bosphorus which boats depart for various neighborhoods on the shores of the Asian side, thus Beşiktaş hosts more than two million of people per day. Business, trade centers and headquarters of Turkey's biggest banks add dynamism to life in Beşiktaş.

Beşiktaş has eight university campuses (Figure 3.4), many preschools, elementary schools and high schools (Table 3.2 and Table 3.3). This provides an important amount of student population. There are more than 1900 historical buildings in Beşiktaş, including the three palaces of the late Ottoman Period (Akbayar, 1998). It is mandatory to perform a risk analysis for such a region where has a strategic importance in terms of either historical and cultural heritage or commercial dynamics.

Table 3.2. Universities located on Beşiktaş district

UNIVERSITIES
1)Bahçeşehir University (main campus)
2)Beykent University (Ortaköy campus)
3)Boğaziçi University (south campus)
4)Galatasaray University (main campus)
5)İstanbul Technical University (Maçka campus)
6)Bilim University (Gayrettepe campus)
7)Mimar Sinan University (the faculty of arts and sciences)
8)Yıldız Technical University (main campus)

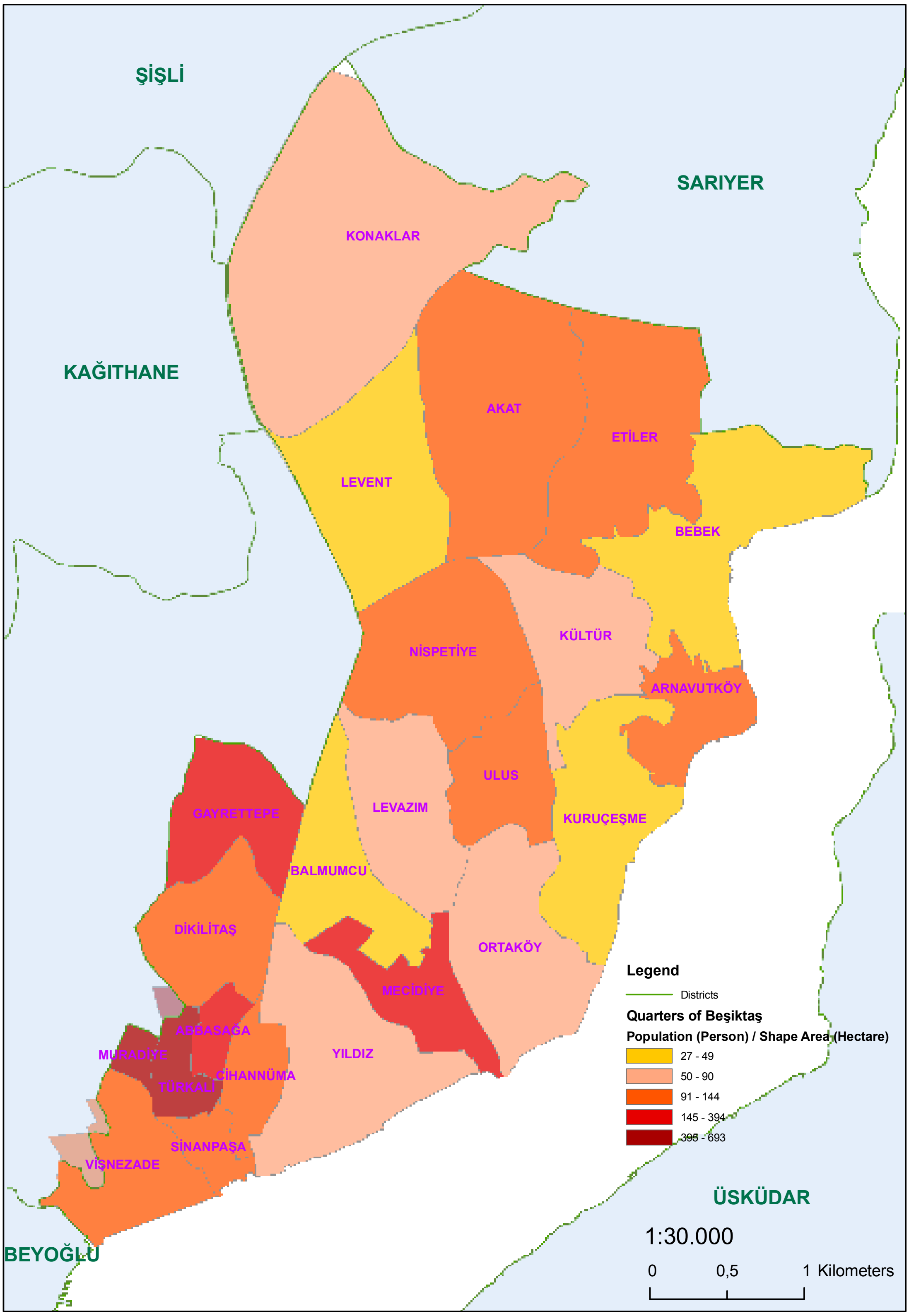


Figure 3.3. The population distribution by each quarter

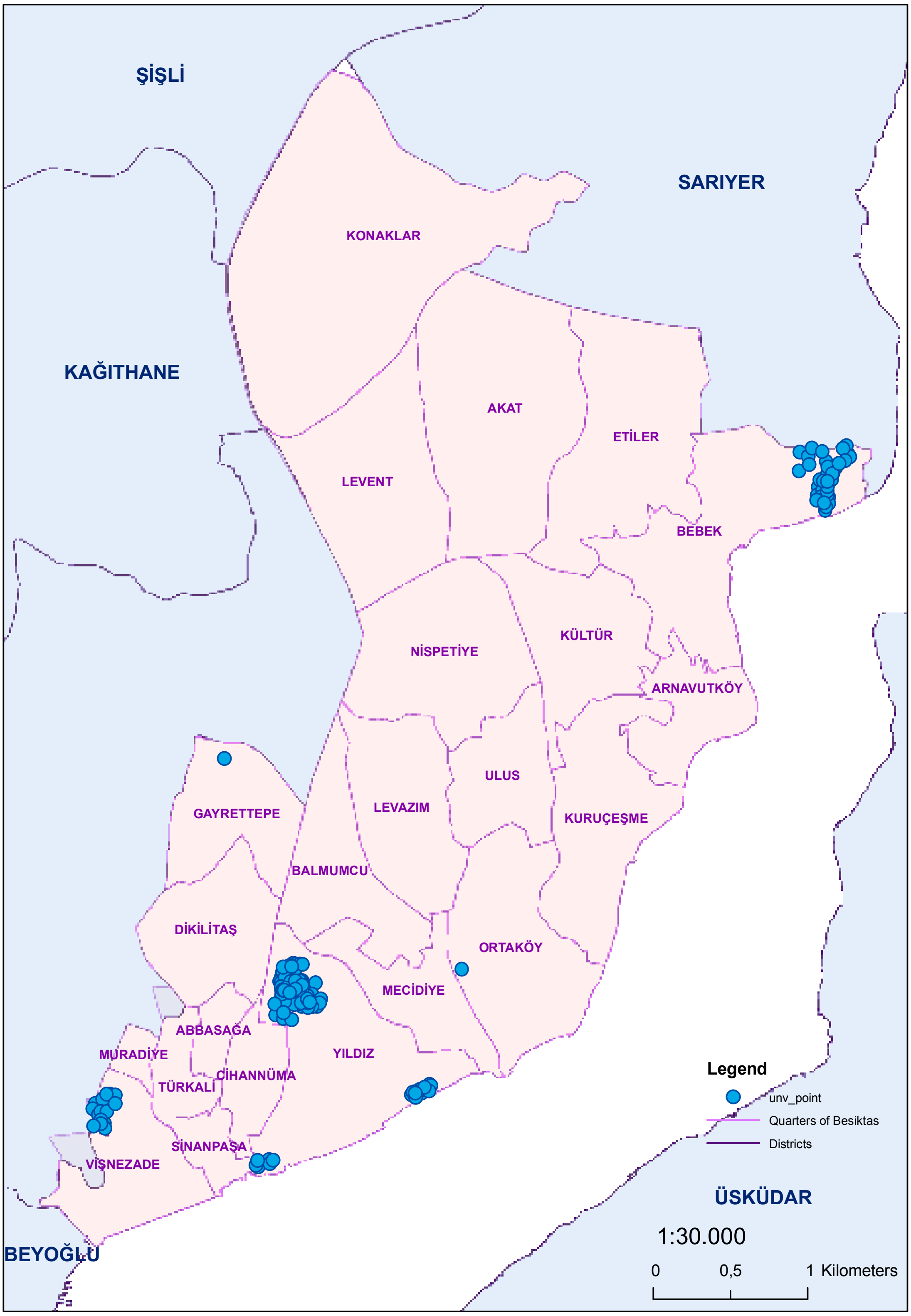


Figure 3.4. Universities located on Beşiktaş district

Table 3.3. Preschool, elementary school and high school situated in Beşiktaş district

PUBLIC SCHOOL	PRIVATE SCHOOL
PRESCHOOL	**PRESCHOOL**
1)Yıldız Erten	1)Ayışığı
2)Akatlar	2)Günay
3)Milli Saraylar	3)Açı
ELEMENTARY SCHOOL	4)Mef
1)50.Yıl Süreyya Artam	5)Şişli Terakki
2)100.Yıl Mustafa Kemal	6)BJK
3)Ali Yalkın	7)Beş İklim
4)Anafartalar	8)Atanur Oğuz
5)Bernar Nahum	9)Su
6)Beşiktaş	10)Avrupa
7)Burak Reis	11)Etiler
8)Büyük Esma Sultan	12)Kabataş Education Faundation
9)Cumhuriyet	13)Mikado
10)Gazi Mustafa Kemal	14)Musevi
11)Gazi Osman Paşa	15)Yeni Nesil 2000
12)Hamiyet Gerçek	16)Sihirli Kelebek
13)Hasan Ali Yücel	17)Papatya
14)Hüseyin Aycibin	18)Bilgi Kozası
15)İsmail Tarman	19)Pinokyo Işıl
16)Kılıç Ali Paşa	**ELEMENTARY SCHOOL**
17)Lütfü Banat	1)British İnternational School
18)Mahmut Erseven	2)Açı
19)Mehmetçik	3)Şişli Terakki
20)Murat Beyaz	4)Yıldız
21)Nimetullah Mahruki	5)İstanbul
22)Orgeneral Kami ve Saadet Güney	6)Takmanças Ermeni
23)Ortaköy Hayat	7)Musevi 1.Karma
24)Rahmi Kirişoğlu	8)Ata
25)Şair Behçet Kemal Çağlar	9)Atanur Oğuz
26)Şair Mehmet Emin Yurdakul	10)BJK Koleji
27)Şair Nedim	11)Mef
28)Tabiyeci Mehmet Emin Ergun	12)Yeni Yıldız
29)Tevfik Fikret	13)Yeni Nesil 2000
30)Mimar Sinan Arts and Ballet	14)Arnavutköy Karma Rum
HIGH SCHOOL	**HIGH SCHOOL**
1)Arnavutköy Korkmaz Yiğit	1)Ata
2)Beşiktaş	2)Atanur Oğuz
3)Bingül Erdem	3)Mef
4)Etiler	4)Yıldız
5)Kabataş	5)Şişli Terakki
6)Sakıp Sabancı	6)Ulus Musevi
7)Yeni Levent	7)Amerikan Robert
8)Levent Profession	8)Mef Uluslarası
9)Anatolian Hotel management and Tourism Vocational	9)Yeni Yıldız
10)M.Ali Büyükhanlı Vocational	10)BJK
11)Rüştü Akın Anatolian Vocational	11)Türsab İst.Anadolu Turizm Otelcilik Meslek
12)Ziya Kalkavan Anatolian Marine Vocational	
13)Zübeyde Hanım	
14)Natuk Birkan	
15)Beşiktaş	
16)Guidance Research center	
17)İ.S.O.V Dinçkök	
18)Beşiktaş Atatürk	

3.1.3. Building Stock

According to Beşiktaş Municipality, Directorate of Real Estate and Expropriation, buildings located on Beşiktaş district were divided into three categories, buildings, housing units and business premises (Table 3.4, Figure 3.5 through Figure 3.9).

Table 3.4. Number of buildings, housing units and business premises, building type and population of Beşiktaş district (December, 2007)

QUARTERS	**BUILDINGS**	**HOUSING UNITS**	**BUSINESS PREMISES**	**WOOD**	**BRICK MASONRY**	**REINFORCED CONCRETE**	**STEEL**	**POPULATION in 2007**
ABBASAĞA	483	2526	294	10	1	388	0	5671
AKAT	1731	6918	898	6	528	765	6	16061
ARNAVUTKÖY	1194	2328	358	197	173	572	0	4521
BALMUMCU	410	989	533	1	0	200	0	2454
BEBEK	1041	2965	353	77	69	490	0	5731
CIHANNUMA	438	2015	952	7	6	387	2	3859
DIKILITAŞ	742	6305	831	2	56	576	3	7063
ETILER	1071	5207	741	0	101	535	3	11999
GAYRETTEPE	669	5411	1177	1	46	461	2	13121
KONAKLAR	517	3883	429	0	14	379	1	15594
KURUÇEŞME	808	1432	178	21	66	311	0	3537
KÜLTÜR	506	2118	505	1	38	230	5	5010
LEVAZIM	387	2317	133	1	13	202	0	5825
LEVENT	2049	1325	1069	1	132	769	13	2977
MECIDIYE	1234	4859	813	30	138	670	1	11074
MURADIYE	322	2808	194	3	0	297	0	5610
NISBETIYE	662	5335	1112	1	9	389	5	12653
ORTAKÖY	1159	3859	367	93	62	588	0	8703
SINANPAŞA	535	1205	1988	3	4	133	6	2247
TÜRKALI	741	5126	764	0	0	94	0	11259
ULUS	526	2897	166	0	7	433	0	7294
VIŞNEZADE	689	3451	535	27	3	529	0	7065
YILDIZ	700	2619	383	14	36	366	1	6045
TOTAL	**18614**	**77807**	**14773**	496	1502	9764	48	**175373**

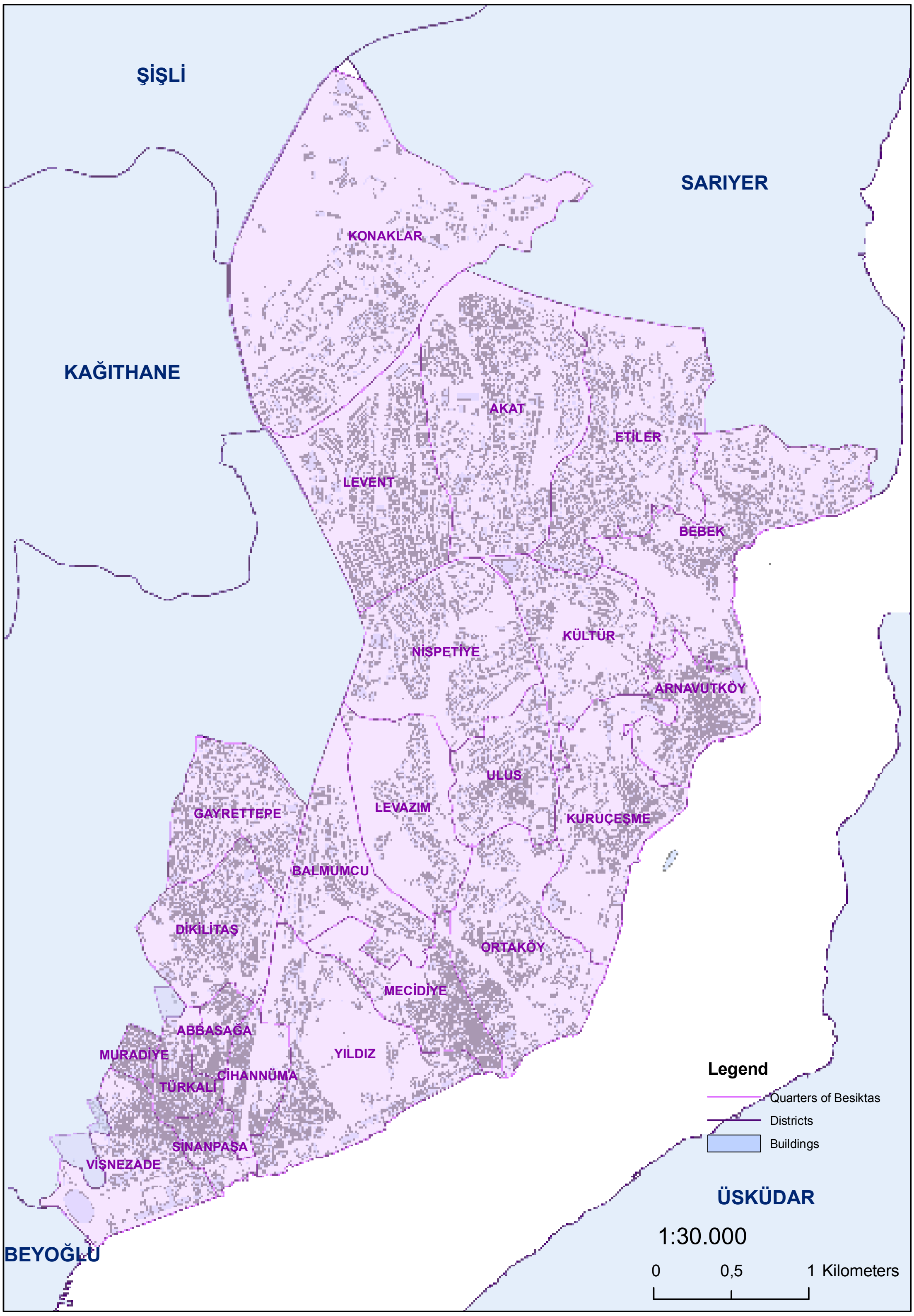


Figure 3.5. Buildings located on Beşiktaş district

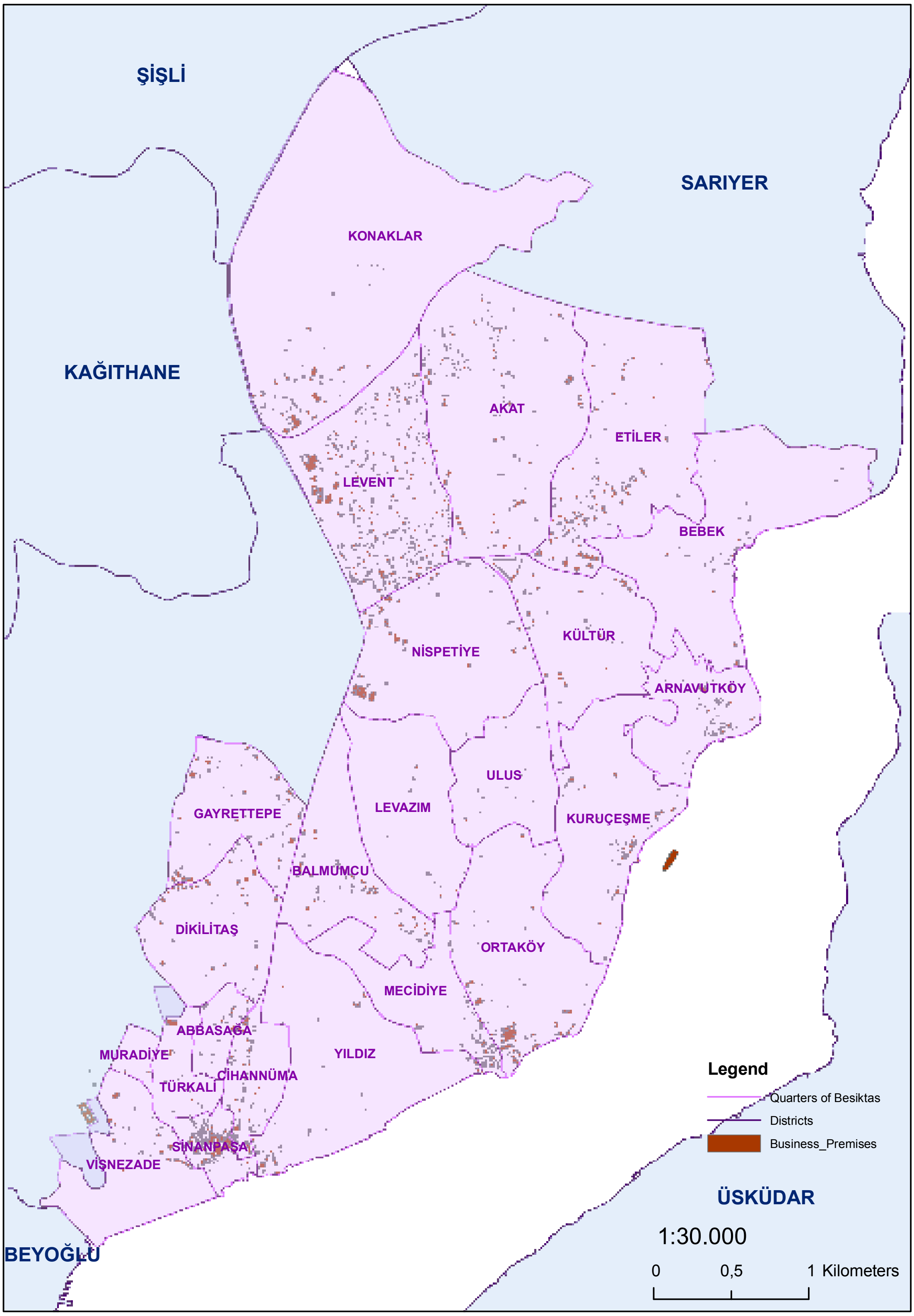


Figure 3.6. Business premises located on Beşiktaş district

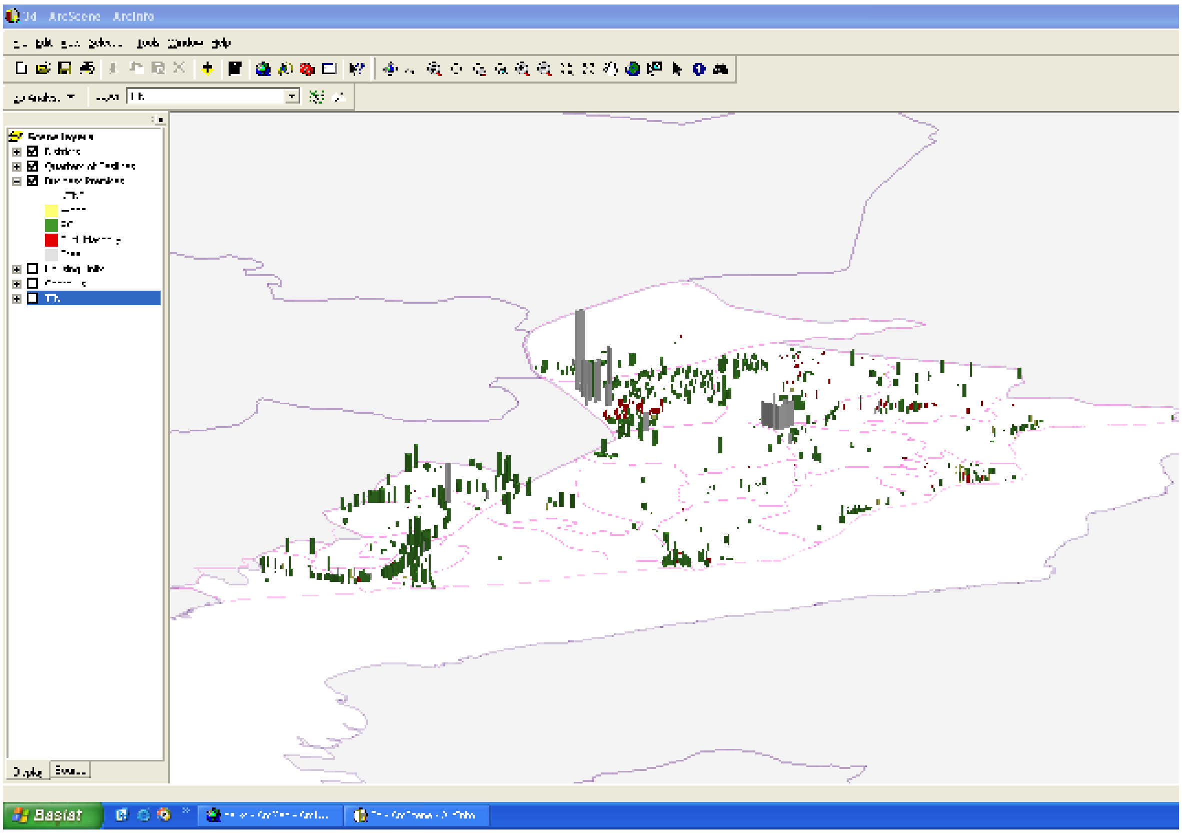


Figure 3.7. Screenshot of 3D view of business premises in ArcScene

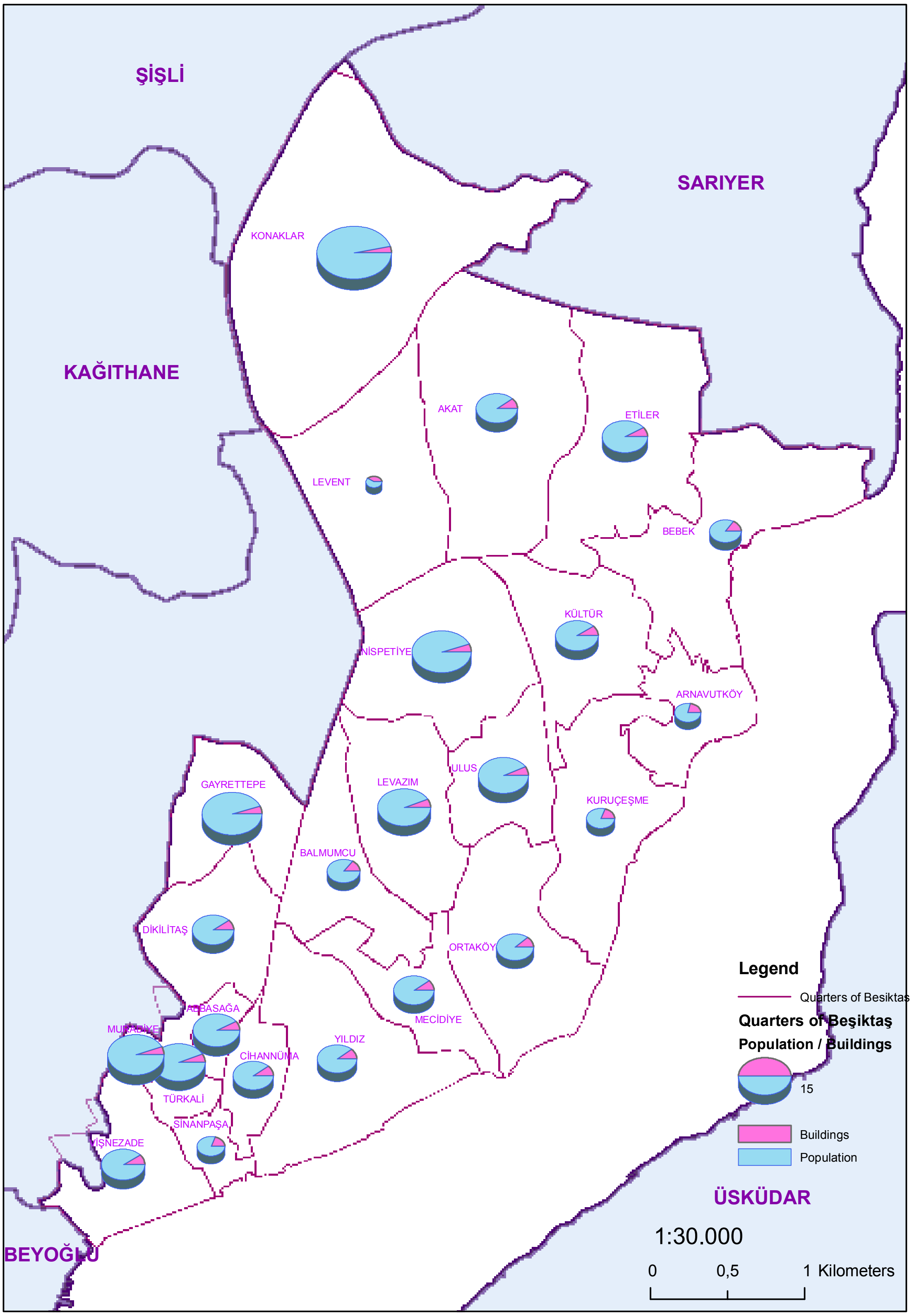


Figure 3.8. Number of buildings by each quarter

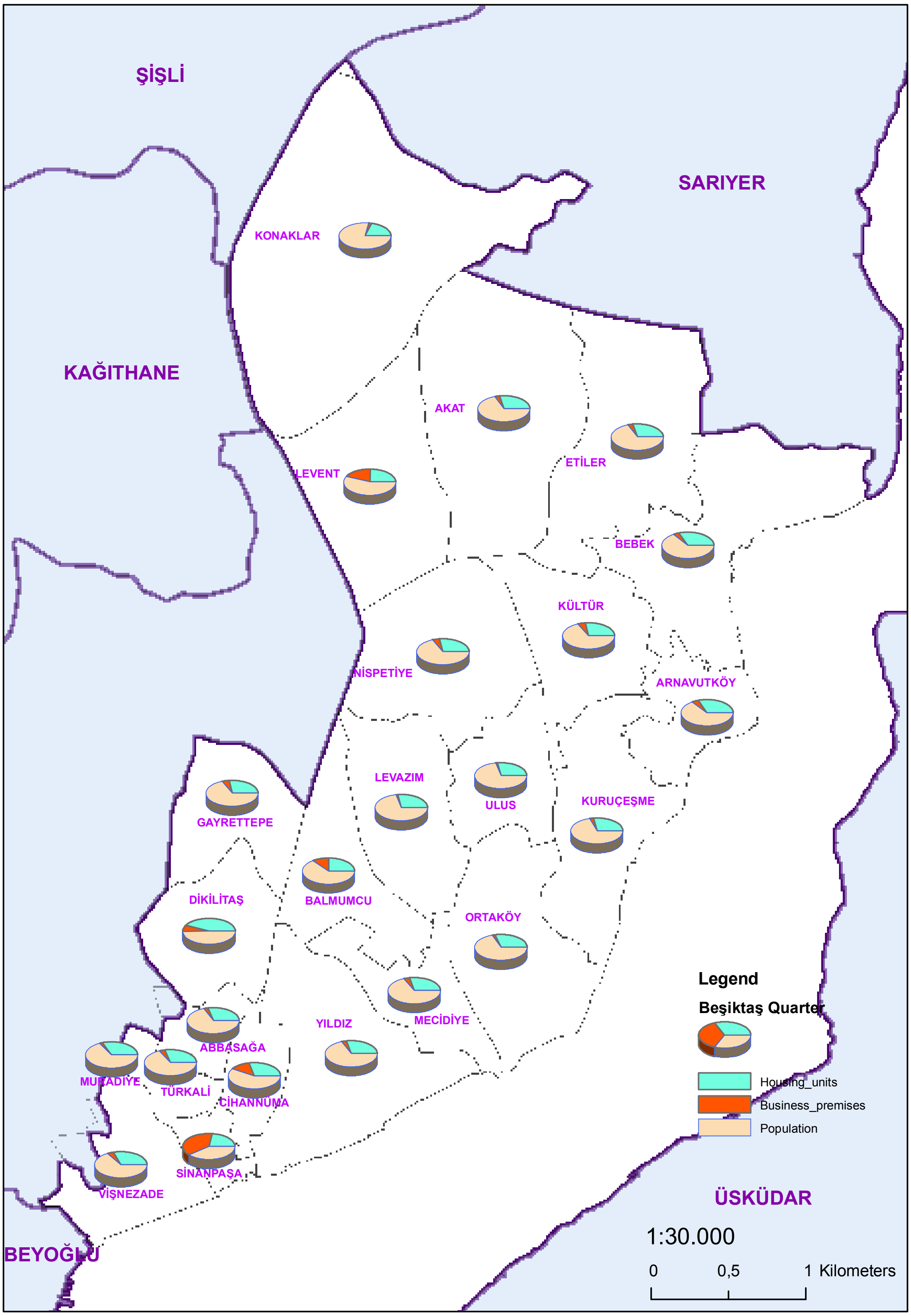


Figure 3.9. Distribution of business premises and housing units in Beşiktaş district

In the 2000 Building Census, building structures were divided into several types. For framed structures, two parts are recognized. One pertains to the framing of the building (1: steel frame, 2: RC frame, 3: wood frame, and 4: other frame) and the other pertains to infill wall materials (1: steel plate, 2: concrete block, 3: briquette, 4: brick, 5: wood, 6: stone, and 7: sun dried brick). Combinations of these parts can exist and they form a variety of building structure types (JICA and IMM, 2002). Building stock that is used in Beşiktaş district is displayed in Table 3.5 and Figure 3.10 through Figure 3.13.

Building structures of İstanbul and its strength for earthquakes are evaluated by Ambraseys (2002). He reported that a general observation about the typical timber house is that its inherent strength was considerable but variable and that its vulnerability to earthquakes was rather low. In contrast, stone and brick constructions, can collapse with great loss of life. Another modern class of man-made structures that seem to have little extra resistance to earthquakes is that of houses built in the last few decades with nontraditional materials, such as reinforced concrete. As the recent earthquakes have shown, in the absence of proper building codes and enforceable regulations, the introduction of new materials and methods of construction has produced of highly vulnerable structures.

Data used in this study are based on two different sources. One is observed data in table format coming from field works and the other one is obtained from Beşiktaş Municipality by using queries in digital format (Table 3.4). In this study, digital format data are used to perform analyses (Figure 3.5 through 3.13).

Table 3.5 shows the breakdown of type of structure by district. In fact, within the study area, the ratio of RC frame structures is 68,36 per cent and of briquette/brick masonry is 29,12 per cent, therefore, 97,48 per cent of structures are made up of these two types.

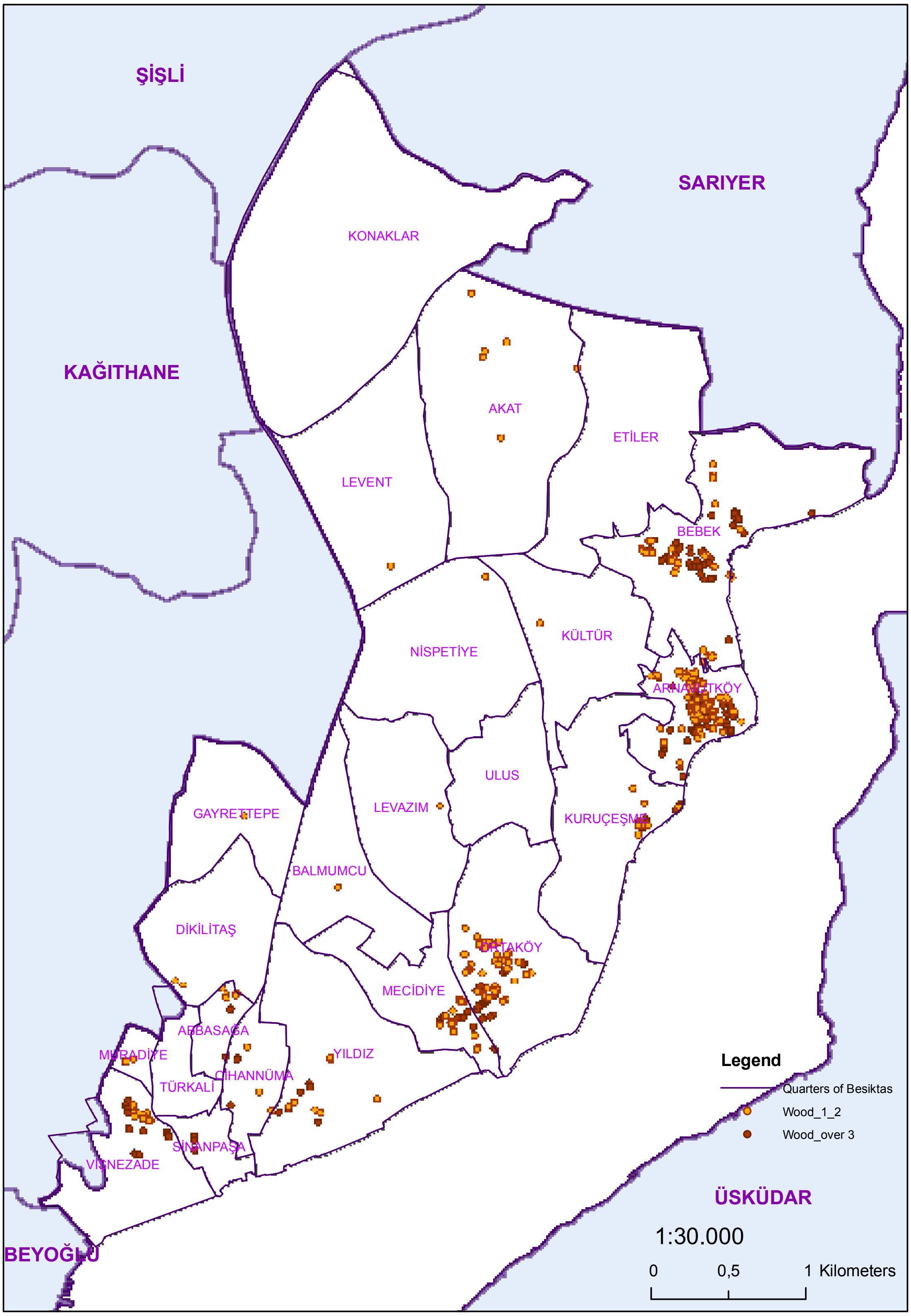


Figure 3.10. Number of stories of wooden structures by quarter

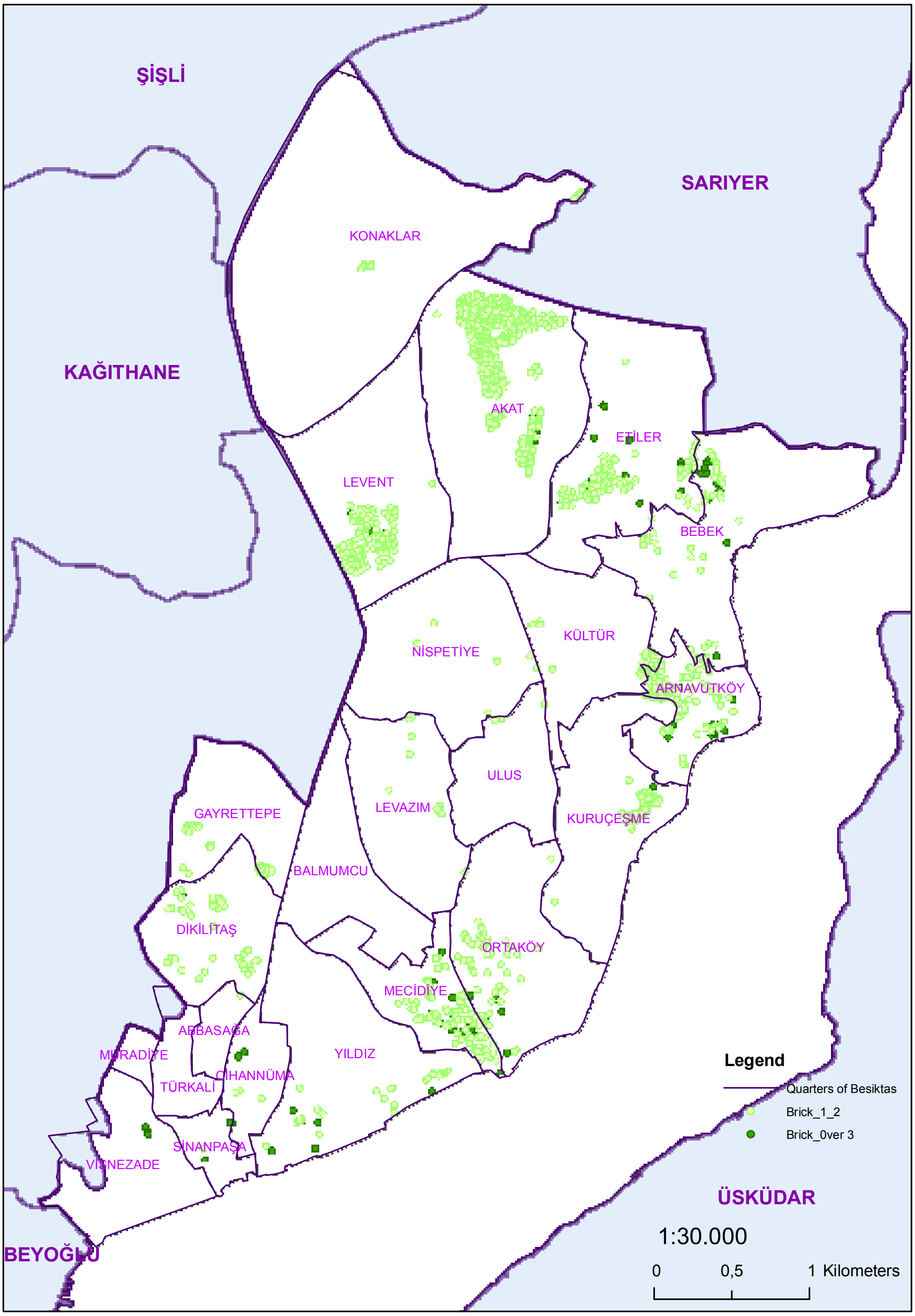


Figure 3.11. Number of stories of brick masonry structures by quarter

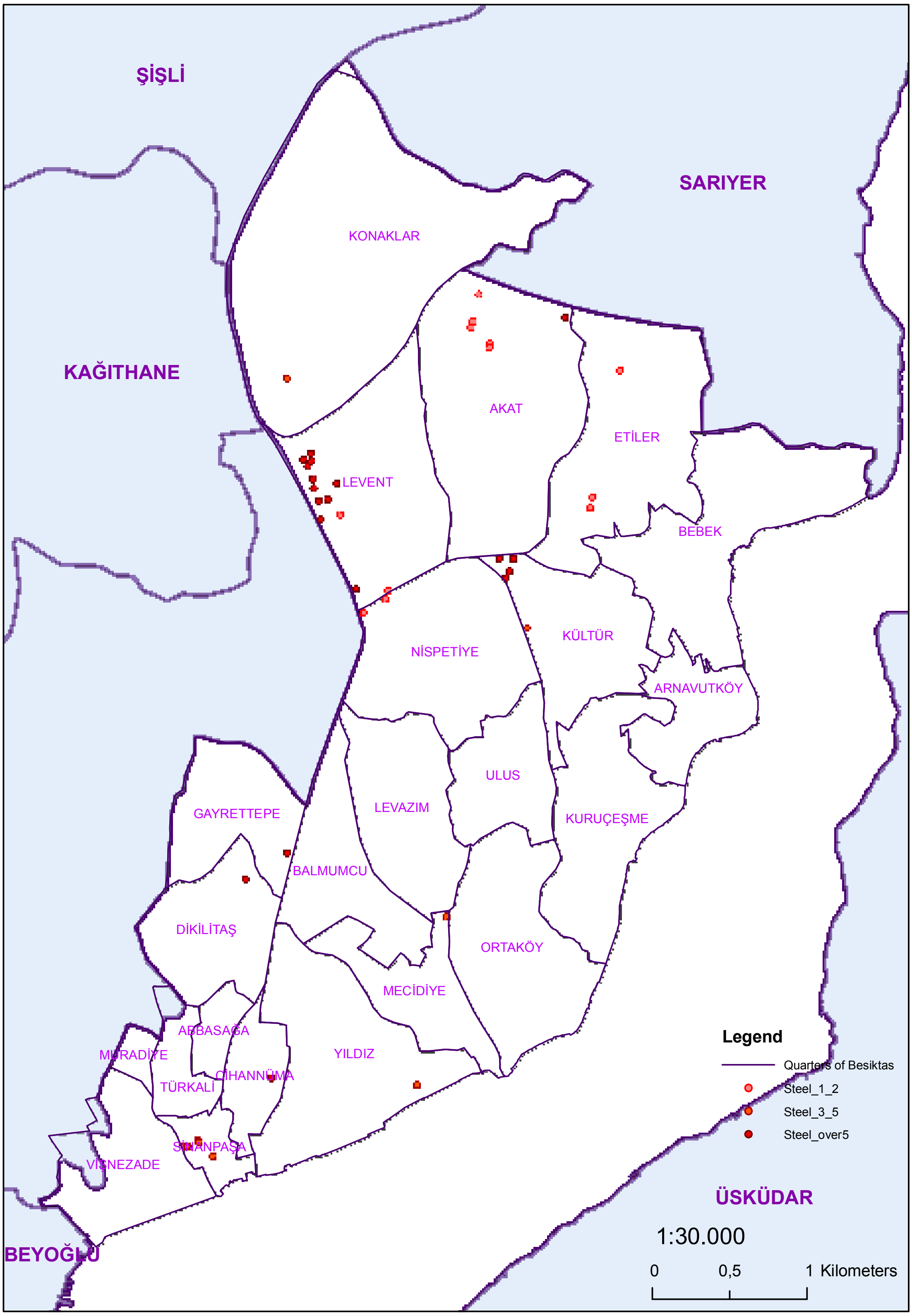


Figure 3.12. Number of stories of steel structures by quarter

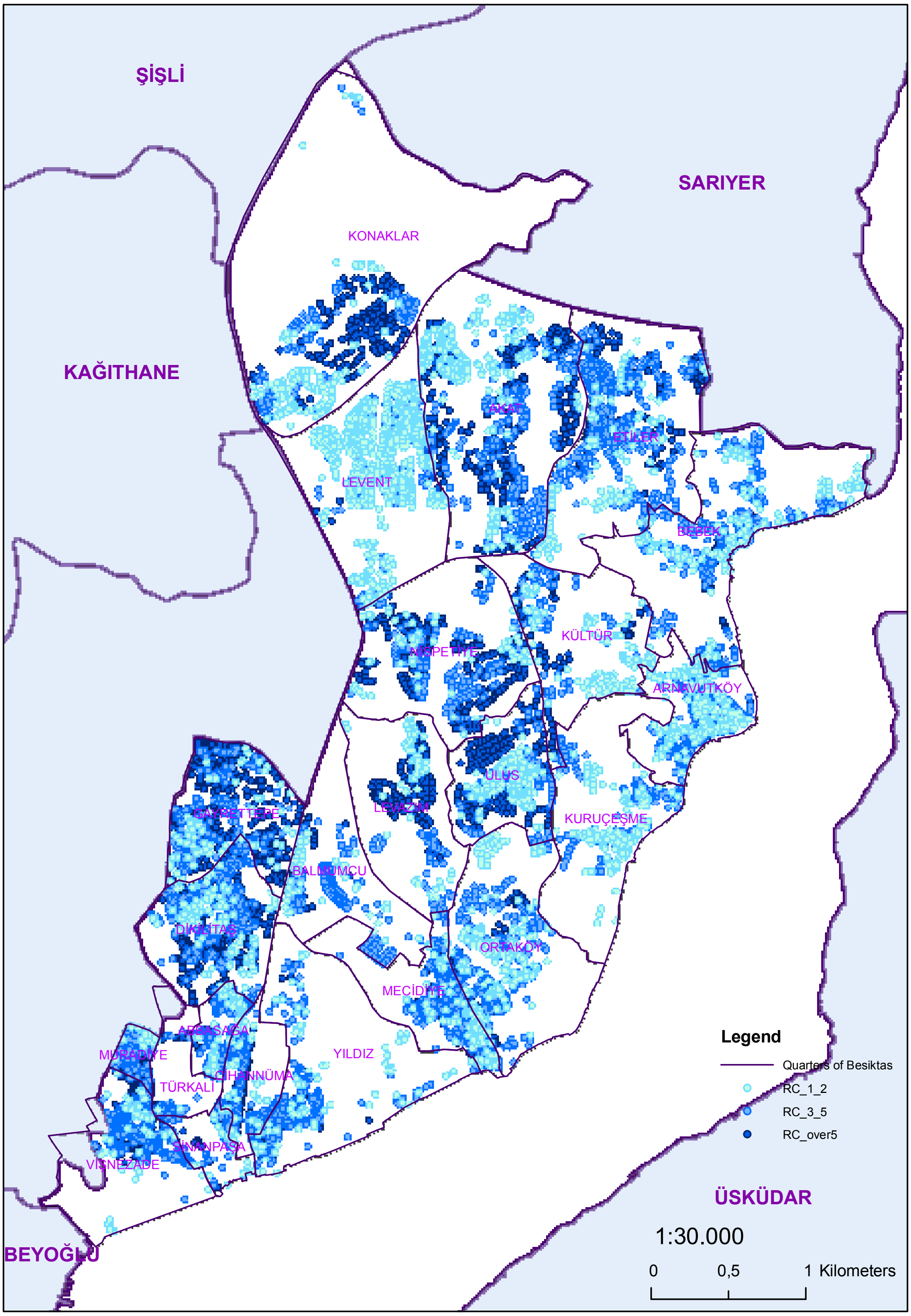


Figure 3.13. Number of stories of RC structures by quarter

Although wood structures are very resistant to earthquake, they are vulnerable to possible fire hazard during an earthquake as well. Brick masonry structures are also too vulnerable to earthquakes since they are very inflexible. Unfortunately, as it can be seen steel structures are in low number which can resist large magnitude earthquakes. RC structures are also quite resistant to the effects of earthquakes. On the other hand, recent observations after the Erzincan (1992), Kocaeli (1995) and Düzce (1999) earthquakes show that in the absence of proper building codes and enforceable regulations, the new materials such as steel and RC and methods of construction has produced of highly vulnerable structures.

3.2. Scenario Earthquake

The geological and seismological information forms the basis to predict the appropriate scenario earthquake, which is usually given broad terms, involving rupture length, location and the magnitude. In general terms, the earthquakes may be associated with local, nearby and distant sources. For "worst case" scenarios the maximum event size is adopted. Scenario earthquake can and has also been defined as the largest earthquakes expected in a reasonable period time (generally 500 years). Although, the use of multiple scenario earthquakes can provide for the range of risk mitigation efforts to be planned, it can also decrease the public credibility of the risk assessment. For intrinsically probabilistic applications, the selection of scenario earthquake is based on the disaggregation of the hazard to show which events contribute most to the loss.

As such, it will be an event with a high likelihood of reoccurrence in the source region, relative to other events that can cause the same loss. For İstanbul almost all these procedures converge to a large earthquake associated with the unruptured sections of the Main Marmara Fault passing from south of the city in the Marmara Sea (Figure 3.14). On these bases and other technical considerations an Mw=7.5 (similar to 1999 Kocaeli earthquake in magnitude and in total rupture length) is selected as the “Credible Worst Case” Scenario event, which is assumed to take place on segments five, six, seven and eight. The segmentation of the northern branch of the North Anatolian Fault Zone in the Marmara Sea can be seen in Figure 3.15 (Erdik e*t al.*, 2002). The fault coordinates are 32 E – 39,5 N and 26,5 E – 42 N.

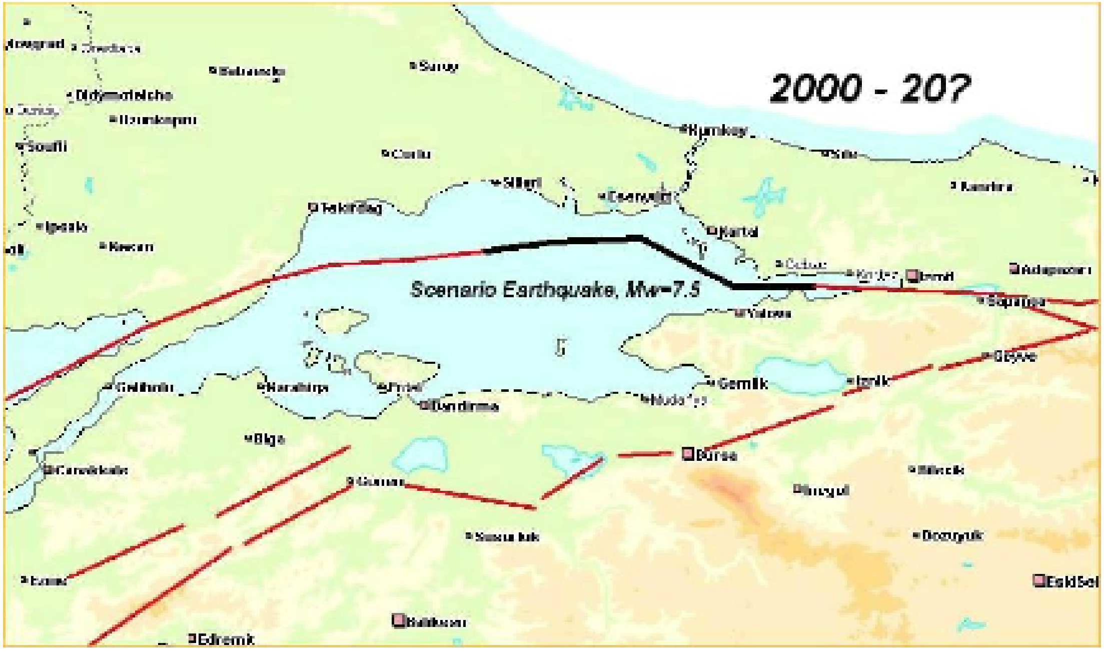


Figure 3.14 Mw=7.5 scenario earthquake for İstanbul and vicinity (Erdik e*t al.*, 2002)

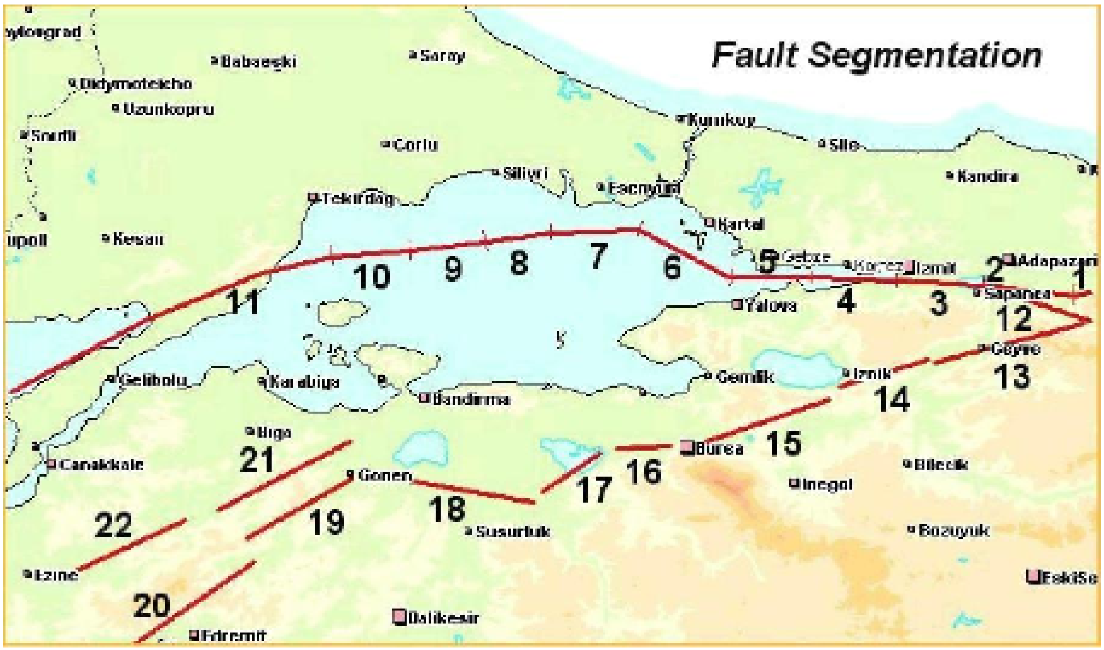


Figure 3.15. The fault segmentation model for the Marmara region (Erdik e*t al.*, 2002)

3.3. Vulnerability Assessment

Empirical, theoretical or hybrid methods can be used for the vulnerability analysis of structures to evaluate the seismic damage data and to obtain probability damage matrices. The information on observed structural damage after earthquakes has critical importance to drive empirical vulnerability methods (Şengezer and Ansal, 2006). Empirically or theoretically vulnerability methods are established based on the relationships between ground motion parameters and damage for given structure types. These are usually expressed by means of fragility curves or Damage Probability Matrices (DPM) (Singhal and Kiremidjian, 1996).

A fragility curve describes the probability of reaching or exceeding a damage state at a specified ground motion level. Thus, a fragility curve for a particular damage state is obtained by computing the conditional probabilities of reaching or exceeding that damage state at various levels of ground motion (Şengezer and Ansal, 2006).

There are some studies about intensity scales to improve to standardize intensity assessment internationally and provide damage functions for vulnerability assessment (Coburn and Spence, 2002; Spence, 2000). Some of the shortcomings in these studies are:

- The scale is subjective in nature;
- The scale is not ideally suited to new types of construction;
- The scale combines long- and short-period structural damage at given intensity levels;
- The intensity scales are different in many ways in defining building categories;
- Most scales rely on maximum values;
- Damage scales offer compromised solutions.

Numerous intensity scales have been developed and are used in different parts of the world. The United States is currently used the Modified Mercalli scale (MM), while the European Macroseismic Scale (EMS-98) is used in Europe. The Shindo scale is used in Japan and the MSK-64 scale is used in India, Israel and Russia. Most of these scales have 12 degrees of intensity, which are roughly equivalent to one another in values but vary in the degree of sophistication employed in their formulation. Modified Mercalli Intensity scale used in this study is described Table 3.6 in detail.

Vulnerability of a structure is established in two steps. First step is evaluation of the vulnerability functions that give the average loss as per cent of total value of the structure for different intensities (Modified Mercalli Intensity Scale - MMI) and building classes. Second step is the evaluation of damage distribution models that are function of average damage.

Table 3.5. Modified Mercalli Intensity scale (MMI)

Magnitude	Intensity	Intensity	Explanation
1.0 - 3.0	**I**	**Instrumental**	Not felt by many people unless in favorable conditions.
3.0 - 3.9	**II**	**Feeble**	Felt only by a few people at best, especially on the upper floors of buildings. Delicately suspended objects may swing.
	III	**Slight**	Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
4.0 - 4.9	**IV**	**Moderate**	Felt indoors by many people, outdoors by few people during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. Dishes and windows rattle alarmingly.
	V	**Rather Strong**	Felt outside by most, may not be felt by some outside in non-favorable conditions. Dishes and windows may break and large bells will ring. Vibrations like large train passing close to house.
5.0 - 5.9	**VI**	**Strong**	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
	VII	**Very Strong**	Difficult to stand; furniture broken; damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by people driving motor cars.
6.0 - 6.9	**VIII**	**Destructive**	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved.
	IX	**Ruinous**	General panic; damage considerable in specially designed structures, well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and over	**X**	**Disastrous**	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Rails bent.
	XI	**Very Disastrous**	Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly.
	XII	**Catastrophic**	Total damage - Almost everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move position.

3.3.1. Modified Beta Distribution (MBeD)

The hybrid methodology of Braga *et al.* (1982) and Akbar (1989) were converted from Beta Distribution to MBeD.

$$f(P) = \frac{e^{-0.5[(k-S\mu)/D\sigma]^2}}{\sigma\sqrt{2\pi}} mP^k (1-P)^{(n-1)} \tag{3.1}$$

σ = standard deviation of the normal distribution (σ = 1.118), μ = mean of the normal distribution (μ = 2.5), m and n are positive integers (m = 100 the number of average damage, n =5 number of damage level), D = Ductility parameter, S = Strength parameter, k = damage level (k =0,1,2,3,4,5), P = probability changing between zero and one. Ductility and Strength are comprehensive descriptors of the seismic performance of a building. When the ‘‘D’’ and ‘‘S’’ value is getting smaller, the model shows that the damage level is decreasing. On the contrary, when the ‘‘D’’ and ‘‘S’’ value is getting higher, the model shows that the damage is getting higher.

MBeD gave the best fit for observed damage data on RC buildings and, brick masonry buildings. The other result is that the same model (S =4, D = 2.7) can be used for both RC and brick masonry buildings in Turkey (Şengezer and Ansal, 2006).

The Damage distribution matrix derived from fragility curve for reinforced concrete buildings (Figure 3.16) and brick masonry buildings (Figure 3.17) are presented in Table 3.6 and Table 3.7 respectively.

In this study vulnerability curve and damage distribution matrices are not created. Şengezer and Ansal’s vulnerability curve and damage distribution matrices are used for Beşiktaş building stock.

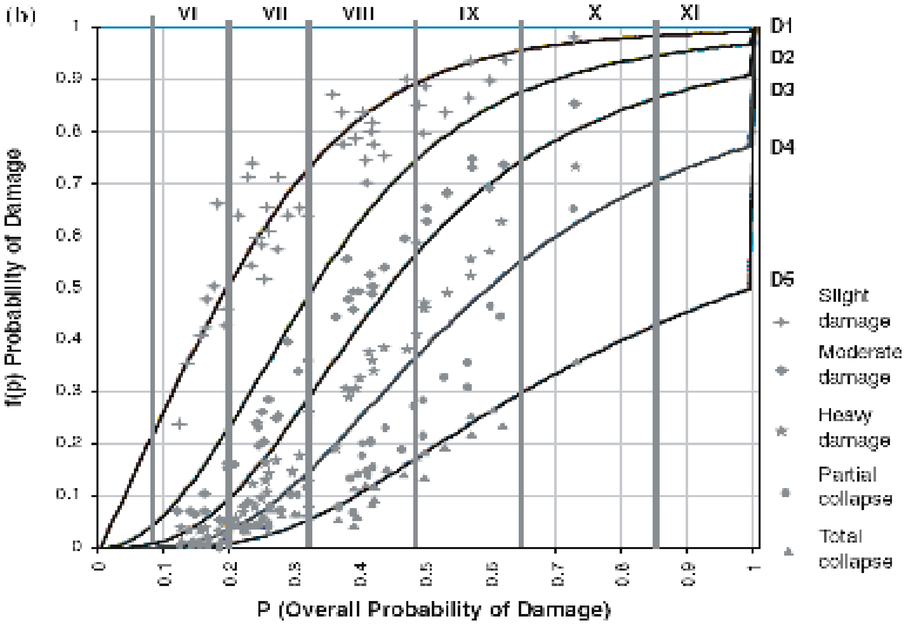


Figure 3.16. Modified beta distribution for reinforced concrete buildings (S:4 D:2.7) (Şengezer and Ansal, 2006)

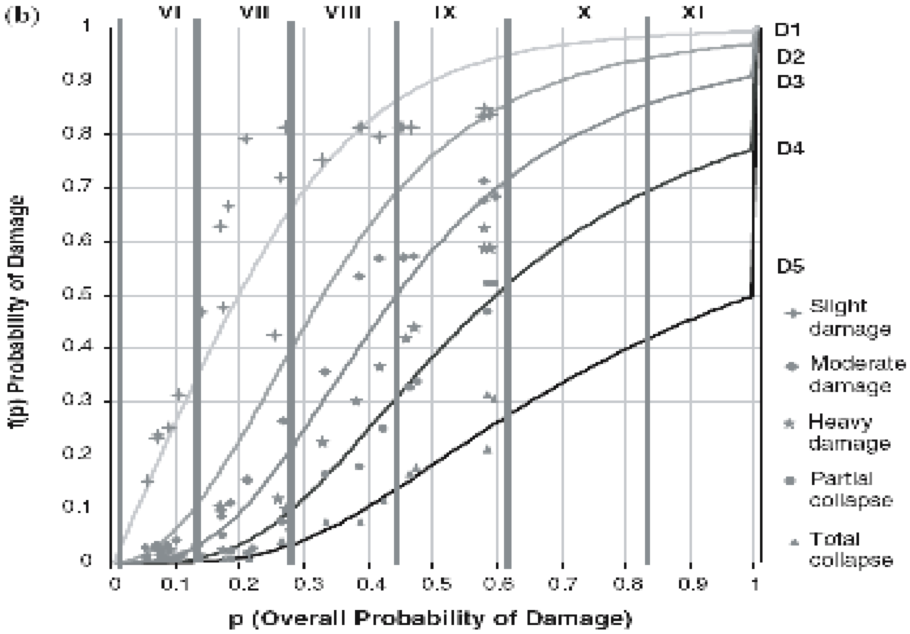


Figure 3.17. Modified beta distribution for brick masonry buildings (S:4 D:2.7) (Şengezer and Ansal, 2006)

Table 3.6. Damage distribution matrix derived from MBeD for reinforced concrete buildings

Damage level	V_{min}	VI_{min}	VII_{min}	$VIII_{min}$	IX_{min}	X_{min}	XI_{min}	XII_{min}
	-	V_{max}	VI_{max}	VII_{max}	$VIII_{max}$	IX_{max}	X_{max}	XI_{max}
None	1	0.94	0.63	0.33	0.14	0.05	0.02	0
Slight	0	0.05	0.25	0.26	0.17	0.09	0.04	0
Moderate	0	0.01	0.09	0.19	0.19	0.14	0.08	0
Heavy	0	0	0.03	0.19	0.19	0.19	0.16	0
Partial Collapse	0	0	0.01	0.17	0.17	0.25	0.27	0
Total Collapse	0	0	0	0.14	0.14	0.29	0.42	1
Average Damage Ratio	0,00	0,01	0,11	0,29	0,50	0,68	0,77	1

Table 3.7. Damage distribution matrix derived from MBeD for brick masonry buildings

Damage level	V_{min}	VI_{min}	VII_{min}	$VIII_{min}$	IX_{min}	X_{min}	XI_{min}	XII_{min}
	-	V_{max}	VI_{max}	VII_{max}	$VIII_{max}$	IX_{max}	X_{max}	XI_{max}
None	1	0.99	0.67	0.33	0.14	0.05	0.02	0.01
Slight	0	0.01	0.21	0.27	0.16	0.1	0.04	0.02
Moderate	0	0	0.07	0.2	0.19	0.16	0.09	0.06
Heavy	0	0	0.05	0.1	0.2	0.19	0.16	0.13
Partial Collapse	0	0	0	0.08	0.16	0.22	0.28	0.28
Total Collapse	0	0	0	0.02	0.15	0.28	0.41	0.5
Average Damage Ratio	0,00	0,00	0,10	0,28	0,51	0,65	0,77	0,83

3.4. Beşiktaş Municipality Data and Analysis

3.4.1. Projections and Datum

Spatial data has the most important role in GIS studies. Accurate, reliability and usability of spatial data are based on the geodetic infrastructure. It relates to datum and projection. The geodetic datum used in this study is ED50 (European Datum, 1950) which is based on the International Ellipsoid of 1924 (Hayford Ellipsoid of 1909 with radius of the earth's equator 6378,388 km and flattening 1:279) (Table 3.8).

Data used in this study are from different sources that each of them has its own projection system: UTM 3 degree and UTM 6 degree. (Table 3.9 and Figure 3.18).

Table 3.8. Data sources and their coordinate systems

Data Source	Geographic Coordinate System	Projected Coordinate System
Beşiktaş municipality data	UTM	ED_1950 zone 30
İstanbul governorship disaster management center's data	UTM	ED_1950 zone 35
TABIS (Turkey Hazard Information System) data	UTM	ED_1950 zone 30 & zone 35

Table 3.9. Projection systems used in this study

	Name	**Factors**
UTM, 3 degree	Alias name	UTM, 3 Degree
	Projections	Universal Transversal Mercator
	Central meridian	30 E
	Referance latitude	0
	Scale factor	1.0000
	False easting	500000
	False northing	0
UTM, 6 Degree	Alias name	UTM, zone 35
	Projections	Universal Transversal Mercator
	Central meridian	27 E
	Referance latitude	0
	Scale factor	0.9996
	False easting	500000
	false northing	0

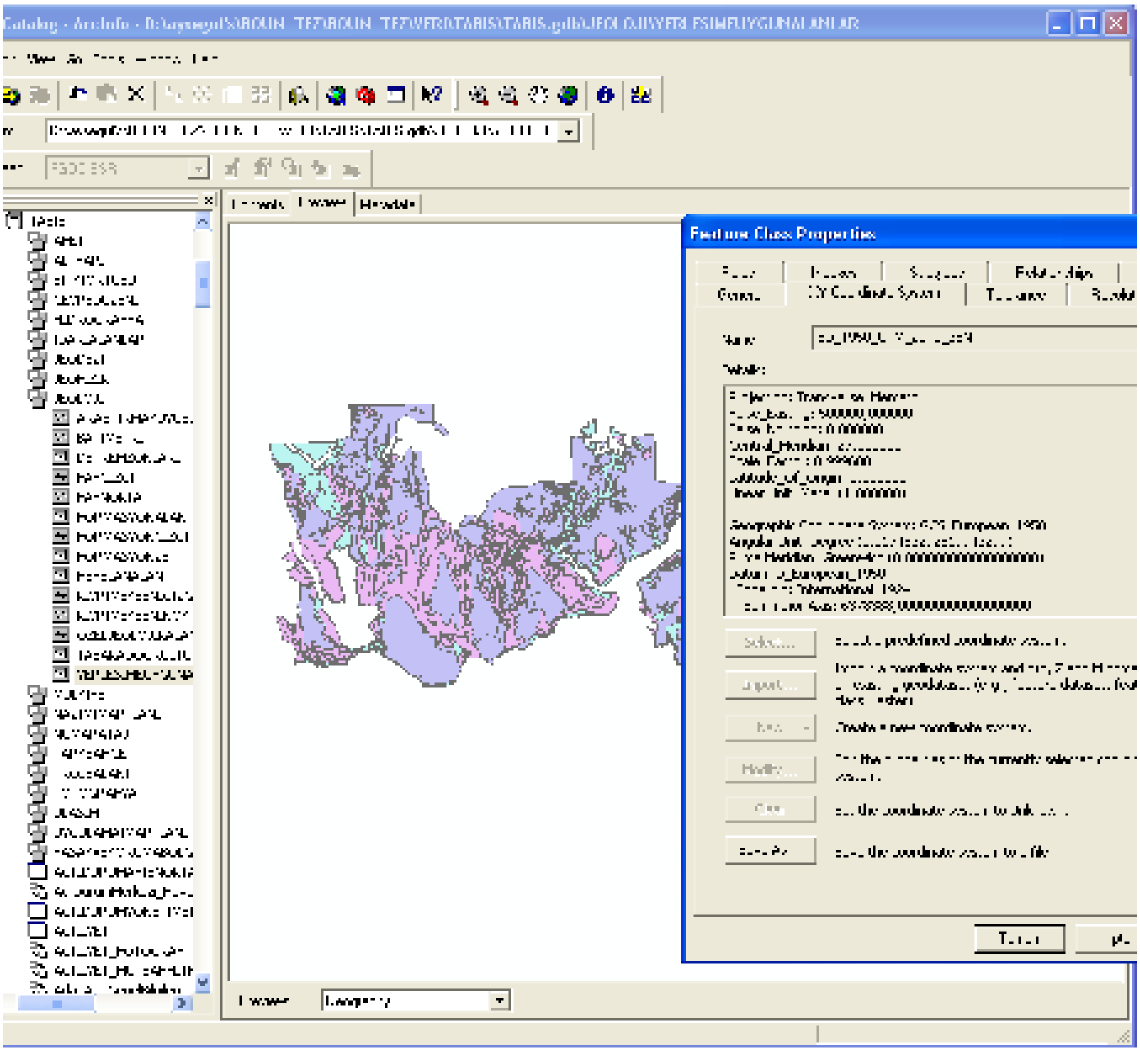


Figure 3.18. Screenshot of coordinate system of suitable areas data

3.4.2. Data Analysis

In this study data were analyzed by using ArcGIS model builder and ArcToolbox as well as spatial analyst toolbar (Figure 3.19).

Beşiktaş municipality uses urban information system and this system has ArcGIS Multiuser Geodatabase (Figure 3.20).

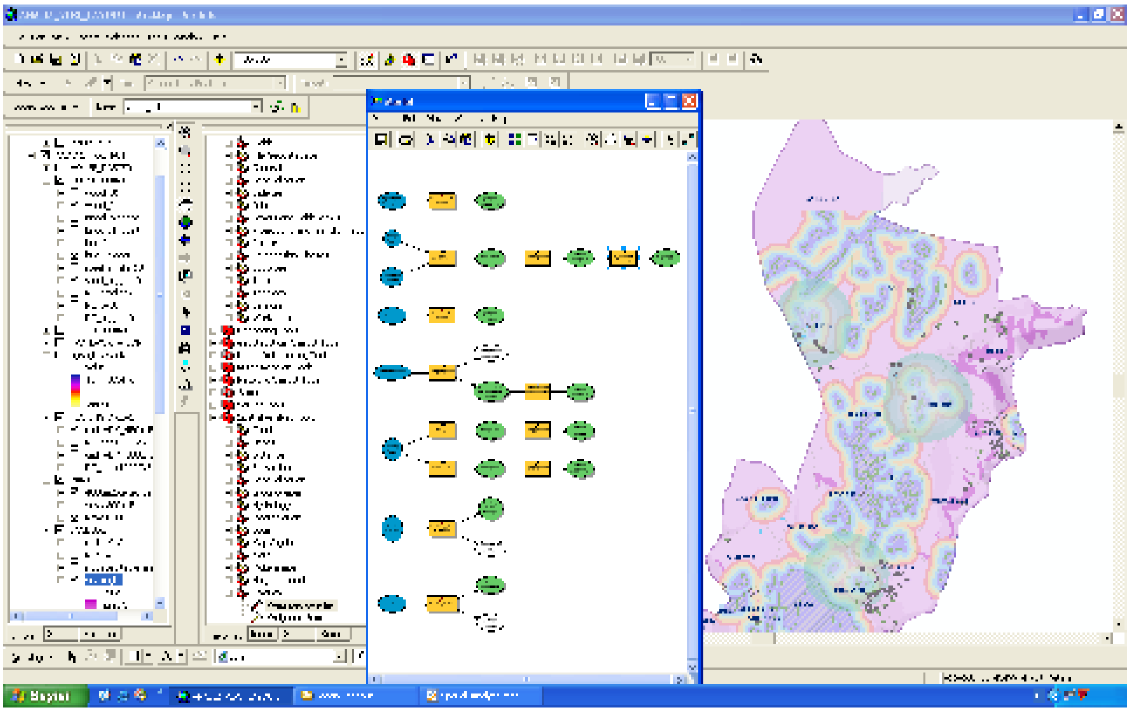


Figure 3.19. Screenshot of data analysis methods used in this study

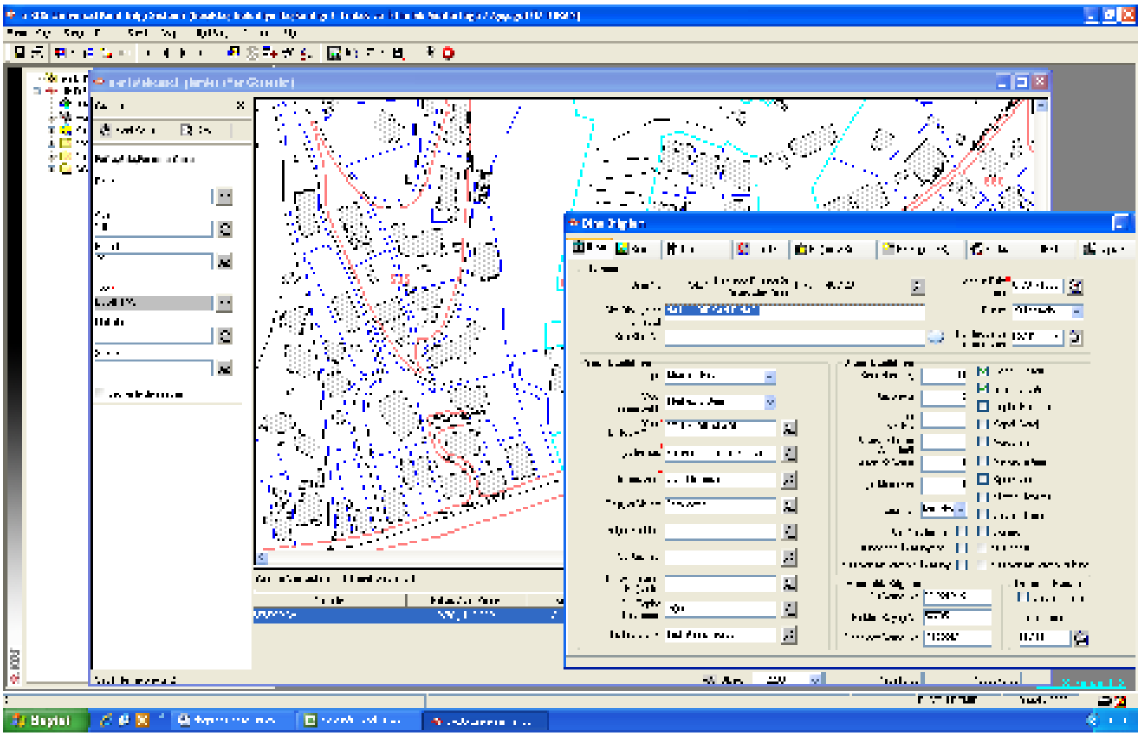


Figure 3.20. Screenshot of database used in Beşiktaş municipality

According to JICA and IMM Project (2002), number of hospital and polyclinics in Beşiktaş district are very few compared to other districts of İstanbul (Figure 3.21). In this study each health center's data was obtained from Beşiktaş municipality and analyzed individually in terms of number of beds and number of doctors. According to this research, total numbers of health centers located in study area are 49 (Table 3.10), but most of them are polyclinics and branch clinics that have one or two doctors and no beds. Suitable health centers are selected in terms of locations, number of beds, number of doctors and hospital capabilities (Table 3.11). Moreover these centers are selected in building data, but some of them cannot be shown due to the lack of the graphical/digital data.

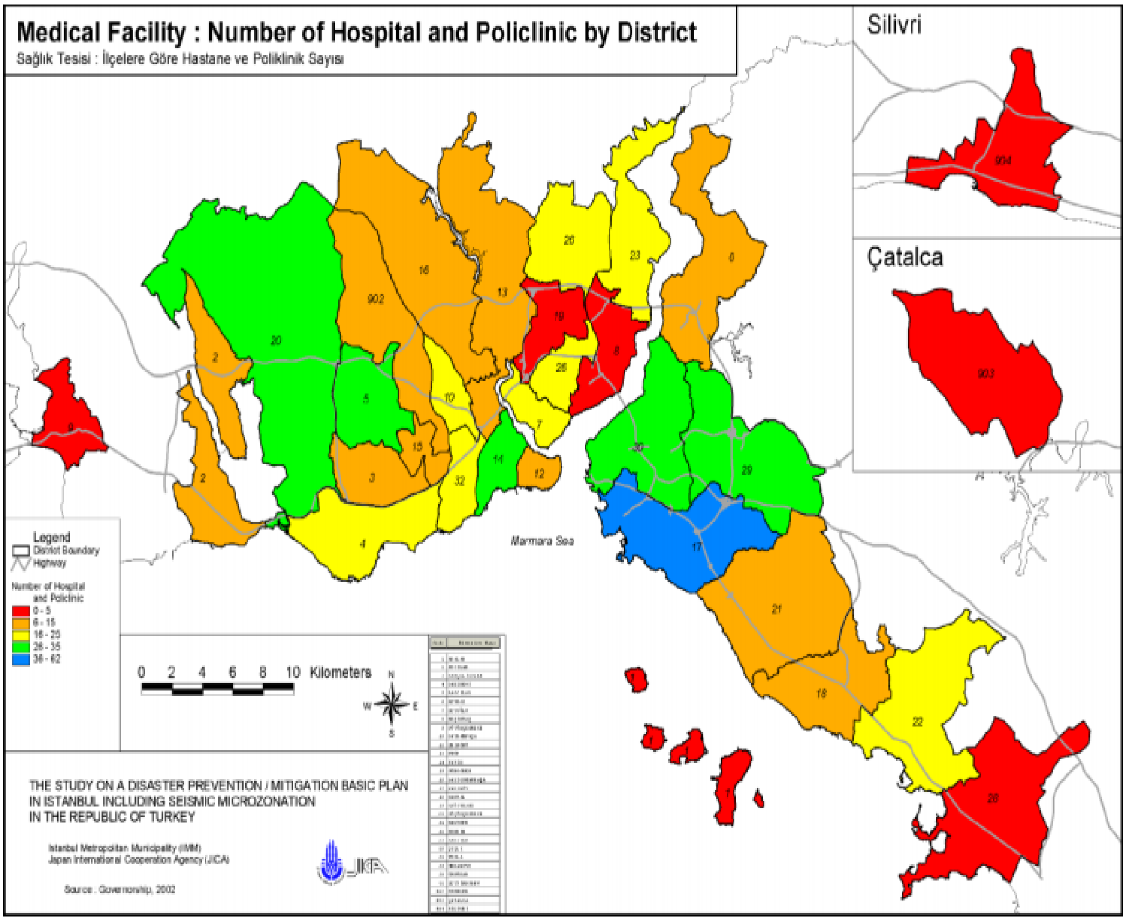


Figure 3.21. Number of hospital and polyclinics by districts (JICA and IMM, 2002)

Table 3.10. All health centers located on Beşiktaş district

	HOSPITALS
1	Dünya Göz
2	Hattat
3	Metropolitan Florance Nightıngale
4	Yeditepe Göz
	PUBLIC CLINICS AND DISPENCARIES
5	Beşiktaş Dikilitaş
6	Beşiktaş Verem Sağlık
7	Merkez
8	Ana Çocuk
9	SSK
10	Sait Çiftçi
11	Ortaköy Beltaş
12	Levent
13	Karanfilköy
	MEDICAL CENTER
14	Baykent
15	Boğaziçi
16	Ota
17	Jinemed
18	Dikilitaş
19	Acıbadem Etiler
20	İnternational Etiler
21	Ortaköy
	POLYCLINICS
22	Levent
23	Şaban Gündeş
24	Ege
25	Beşiktaş
26	Transmad
27	Cosmed P
28	Yaşasın Hayat
29	Medis
30	Clinika Gayrettepe
31	Micromed
32	Etiler Cardiology
33	Refresh
34	Tunç
35	Güzel Günler
36	Otim Med Dialysis
37	Renmed Dialysis
	BRANCH CLINICS
38	K.S.V Onkoloji
39	Cosmed Estetik ve Plastik Cerrahi
40	Levent Genel Cerrahi
41	İstanbul Anestezi
42	İstanbul Ortopedi
43	Onep Estetik ve Plastik Cerrahi
44	Novita surgery
45	Özel Acıbadem Göz Sağlığı
46	Özel Dünya Göz Sağlığı
47	Sevgi Kadın Sağlığı - etiler memorial
48	Fertijin Kadın Sağlığı ve Tüp Bebek
49	Jinepol

Suitable health centers are selected from all health centers located on Beşiktaş district, but some hospitals' data (Acıbadem Etiler Medical Center, Ortaköy Medical Center, Merkez Cottage Hospital, Levent Cottage Hospital and Karanfilköy Cottage Hospital) could not be gained, so these cannot be shown in Figure 3.22.

Table 3.11. Suitable health centers data located on Beşiktaş district for casualties

Hospital	**Number of bed**	**Number of doctor**
Dünya Göz Hospital	41	10-15
Nisbetiye Quarter Saydam St.		
Metropolitan Florance Nightıngale Hospital	100	45
Gayrettepe Quarter Cemil Arslan Güder St.		
Hattat Hospital	11	16
Levent Quarter Yeni Sülün St.		
Baykent Medical Center	9	13
Nisbetiye Quarter Aydın St.		
Boğaziçi Medical Center	8	13
Dikilitaş Quarter Yenidoğan St.		
Ota Medical Center	-	17
Sinanpaşa Quarter Beşiktaş Steet		
Jinemed Medical Center	22	15-20
Muradiye Quarter Deryadil St.		
Acıbadem Etiler Medical Center	1	20-25
Nisbetiye Quarter Aytar St.		
Ortaköy Medical Center	-	5
Balmumcu Quarter Varnalı St.		
Sait Çiftçi Dispensary	-	20
Dikilitaş Quarter Barbaros Boulevard		
SSK Dispensary	-	30
Cihannuma Quarter Bostancı Veli St.		
Beşiktaş Verem Sağlık dispensary	-	2
Sinanpaşa Quarter Sinanpaşa Köprüsü St.		
Dikilitaş polyclinic	-	11
Dikilitaş Quarter Karakol Çıkmazı St.		
Clinika Gayrettepe polyclinic	-	15
Gayrettepe Quarter Yıldız Posta St.		
Merkez cottage hospital	-	3
Yıldız Quarter Çırağan St.		
Ortaköy Beltaş cottage hospital	-	4
Mecidiye Quarter Müverrih Saadettin St.		
Levent cottage hospital	-	3
Nisbetiye Quarter Yücel St.		
Karanfilköy cottage hospital	-	2
Akat Quarter Zeytinoğlu St.		
TOTAL	192	244

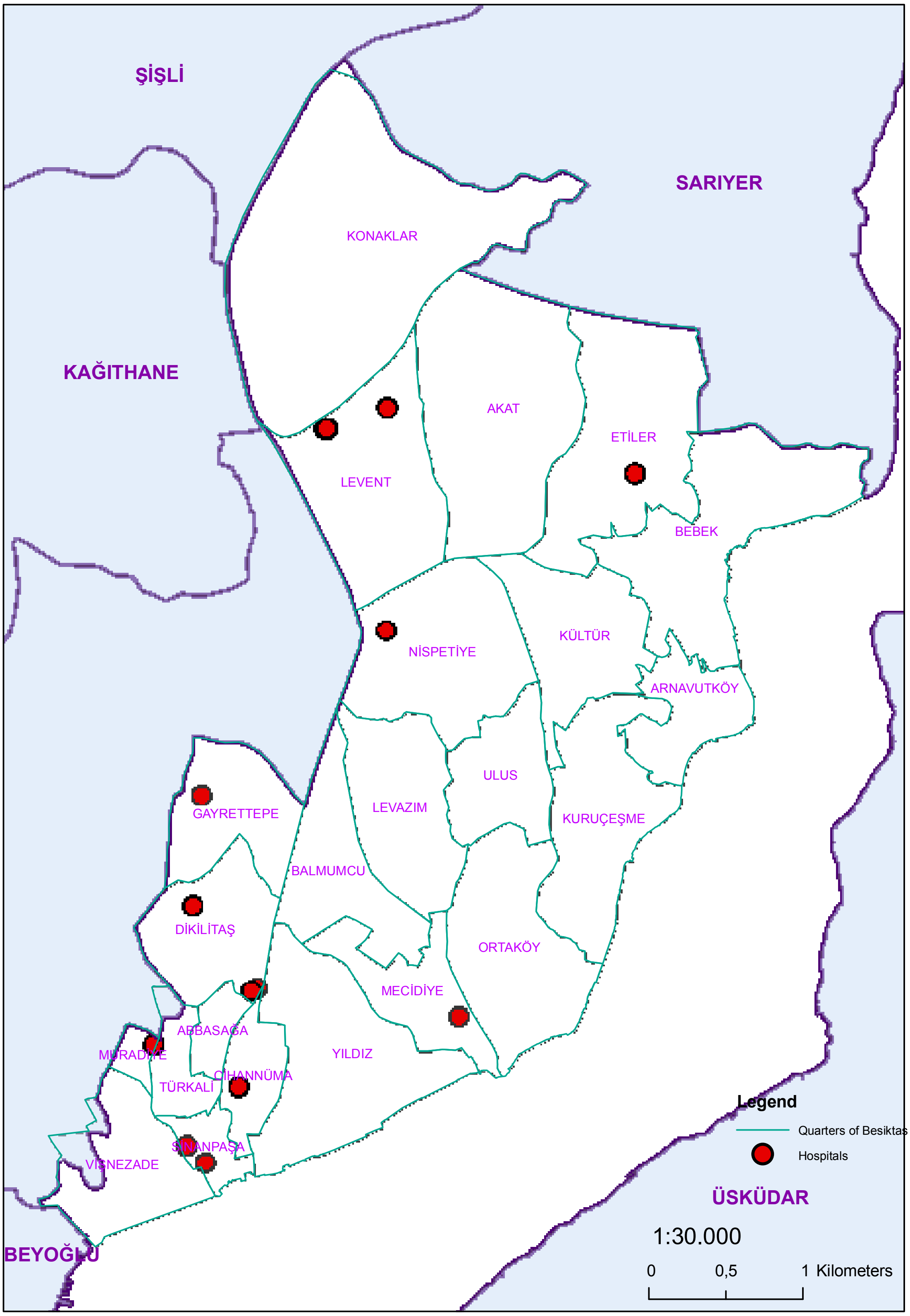


Figure 3.22 Suitable health centers

According to AYM, arterial roads shown in Figure 3.23 can be used during an earthquake. In this study two different tenting areas are used. One is determined by AYM (Figure 3.24) and the other one is chosen Beşiktaş municipality's parks data. Tenting areas determined by AYM are buffered with 1000 m² and displayed in Figure 3.25. Parks can be used as meeting place and tenting areas alternatively (Figure 3.26). Parks that are bigger than 4000 meter square are chosen as tenting areas and meeting points and then buffered with 500 m² (Figure 3.27). Tenting areas which are determined by both AYM and parks data in this study are shown in Figure 3.28. Slope stability and tsunami potential are evaluated for chosen suitable areas. According to these analyses areas that are located on manmade fill/coastal strip and having a high landslide potential were not considered as tenting areas and meeting points. The suitable tenting areas are shown in Figure 3.29. Landuse maps are considered in the determination of meeting place and tenting areas (Figure 3.30). Besides, appropriate educational sites are suggested for an alternative to current tenting areas and meeting points Table 3.12 and Figure 3.31.

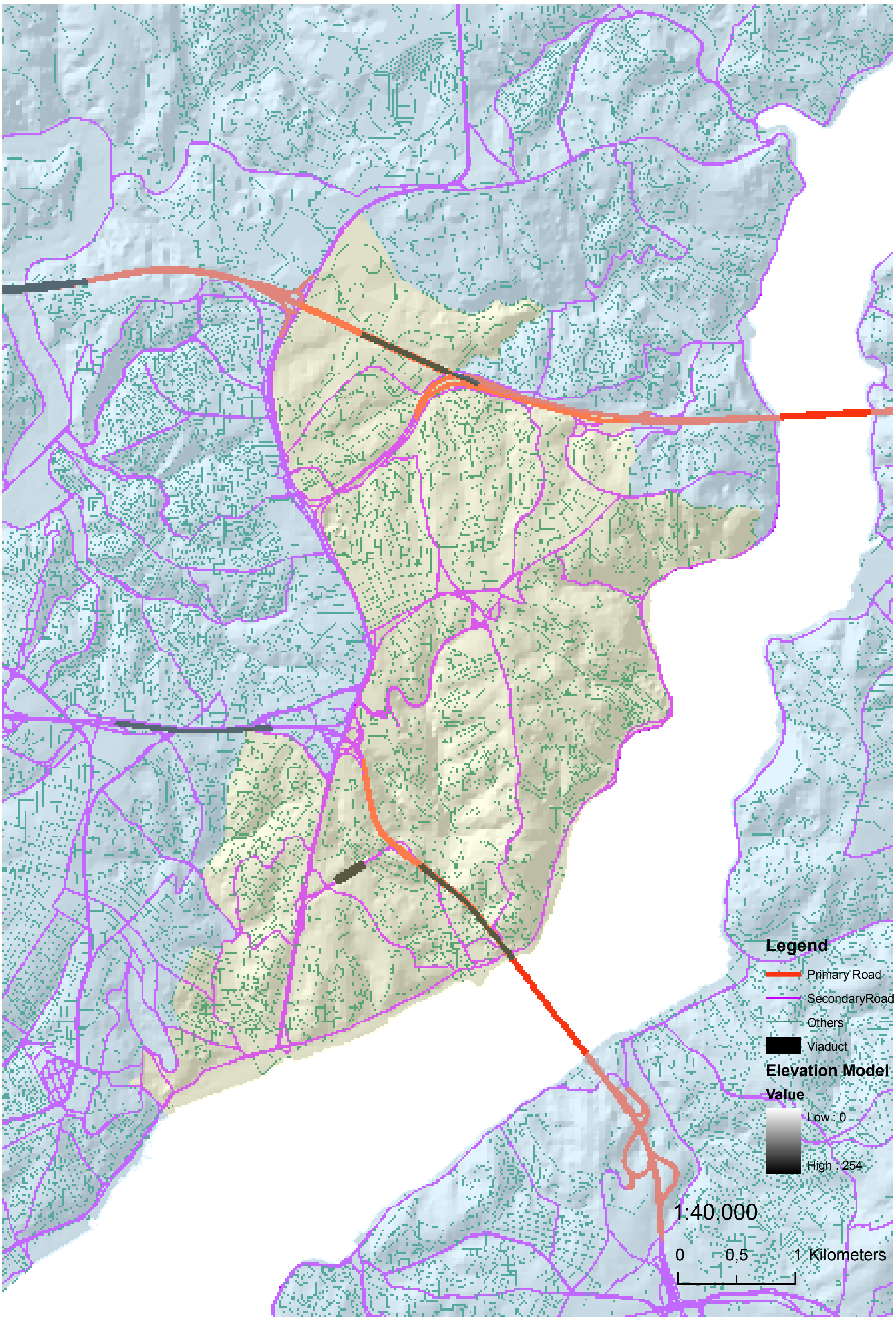


Figure 3.23. Viaduct and arterial roads

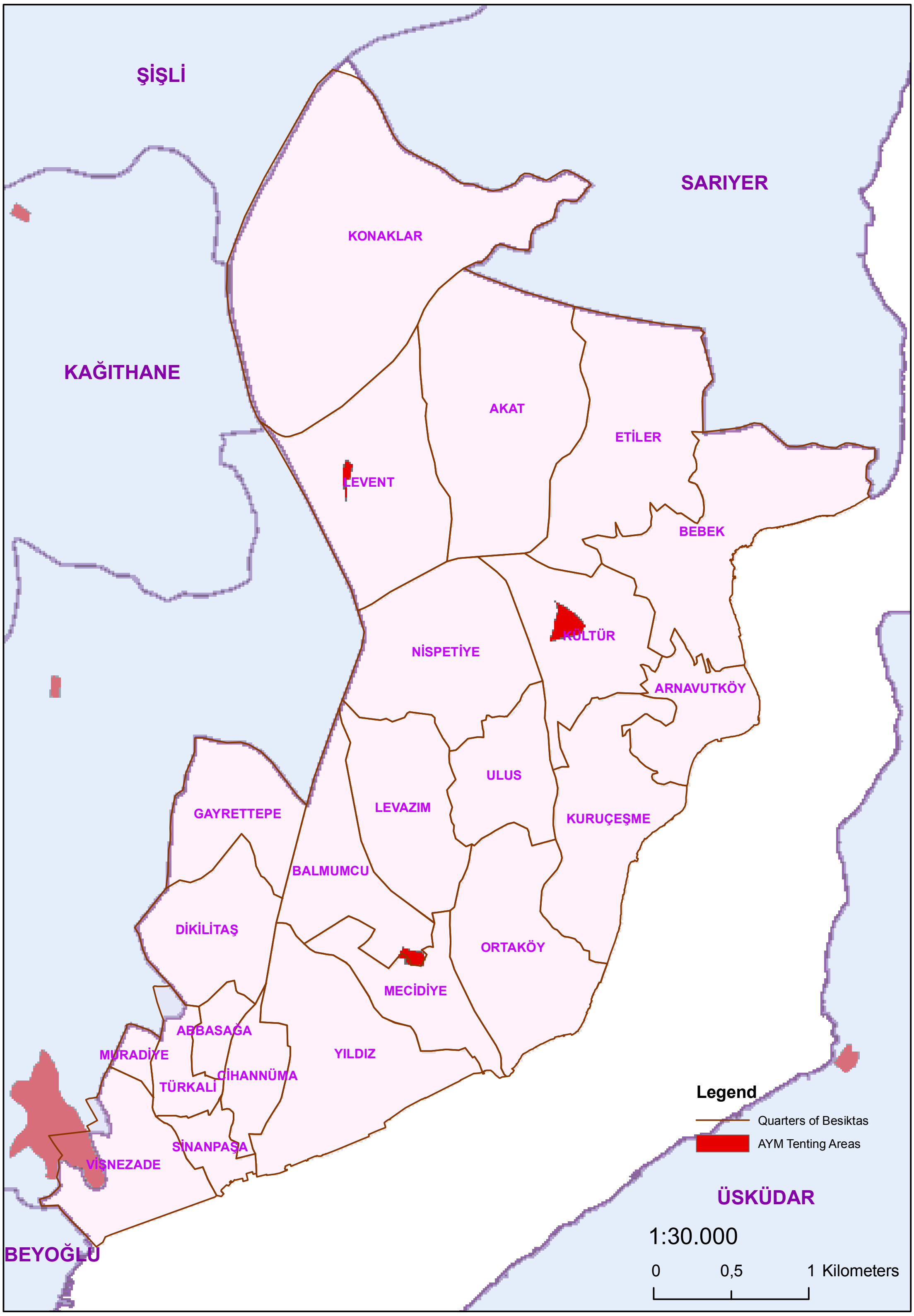


Figure 3.24. Tenting areas determined by AYM

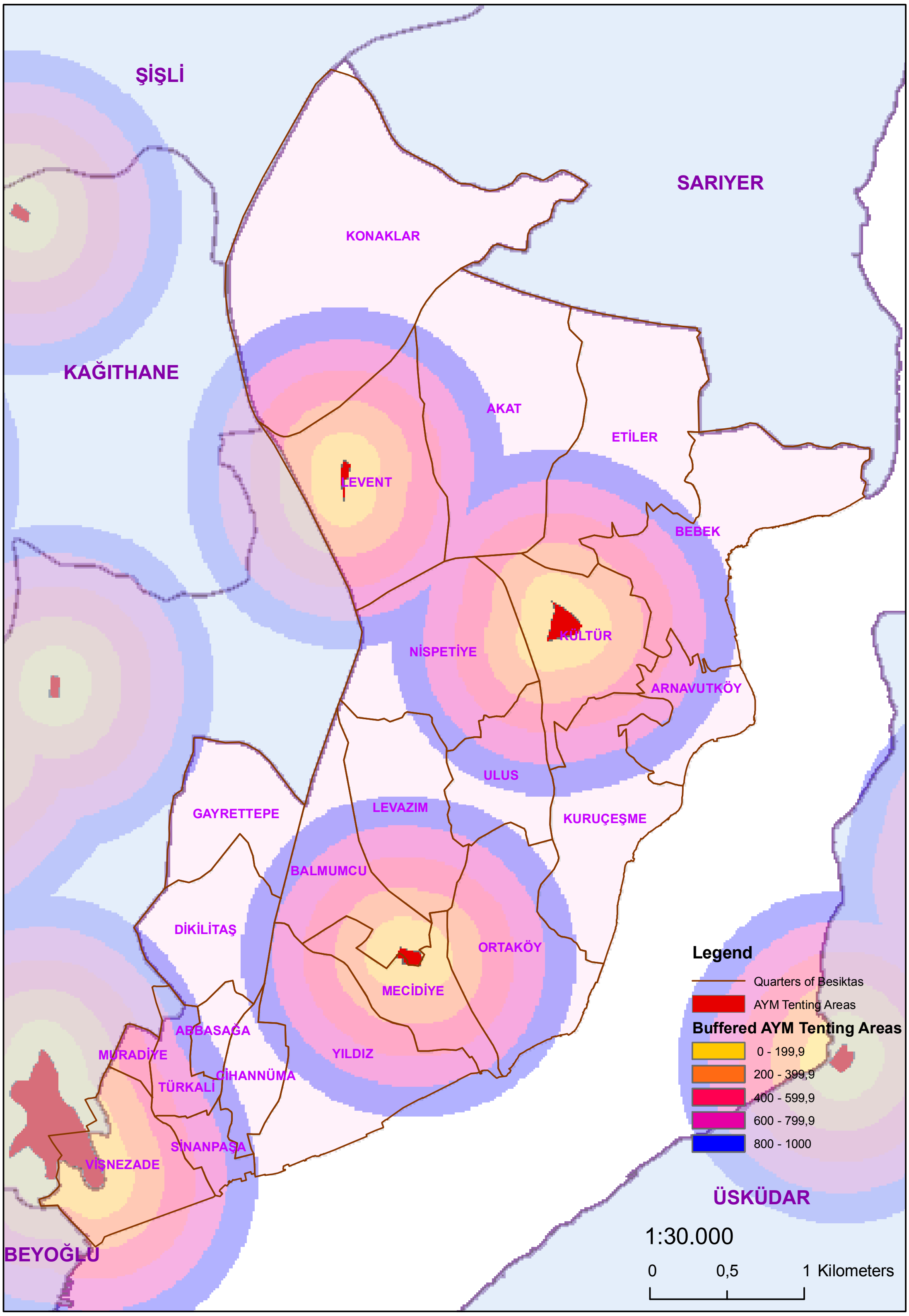


Figure 3.25. AYM Tenting areas

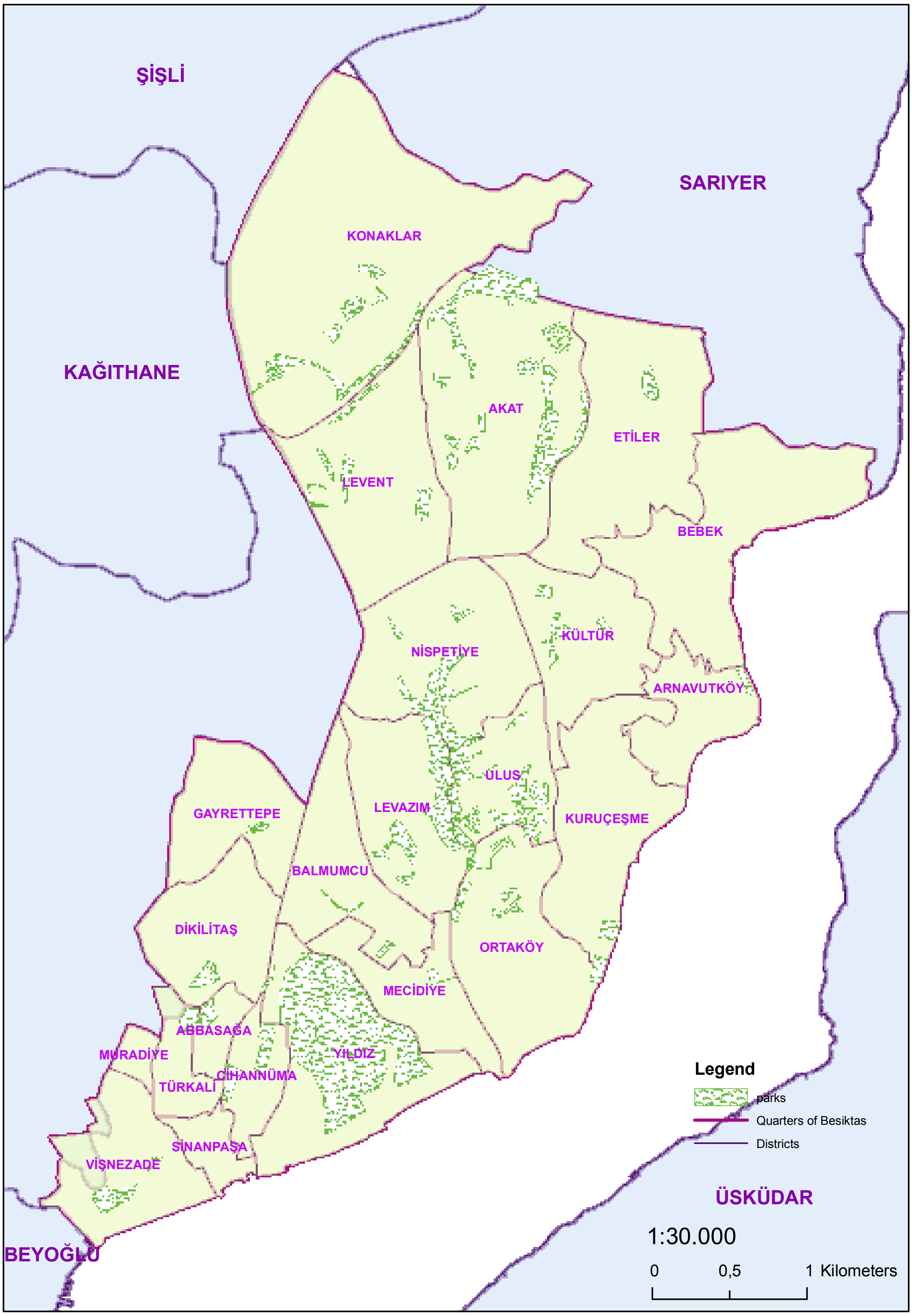


Figure 3.26. Parks in Beşiktaş district

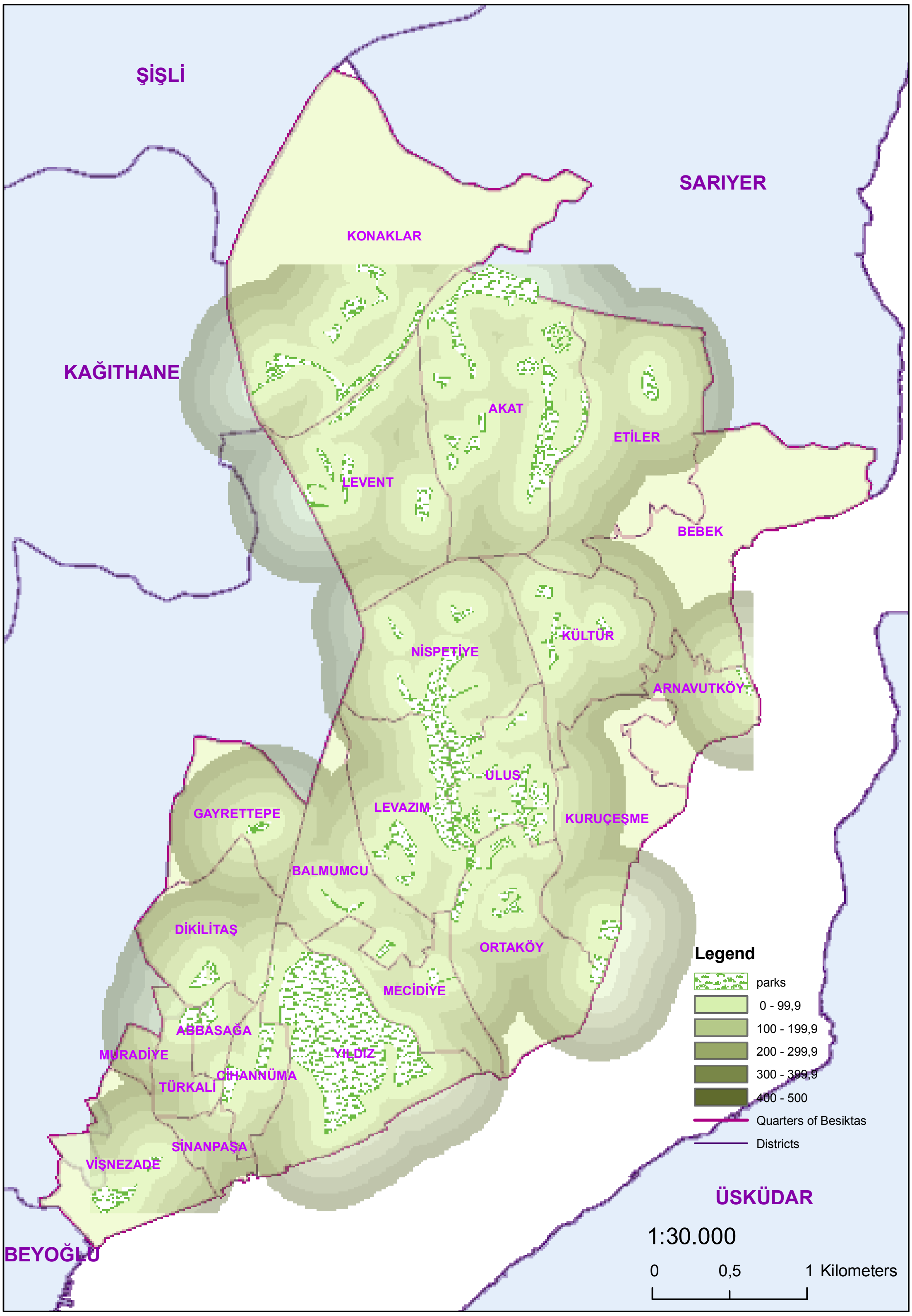


Figure 3.27. Parks used as meeting place and tenting areas.

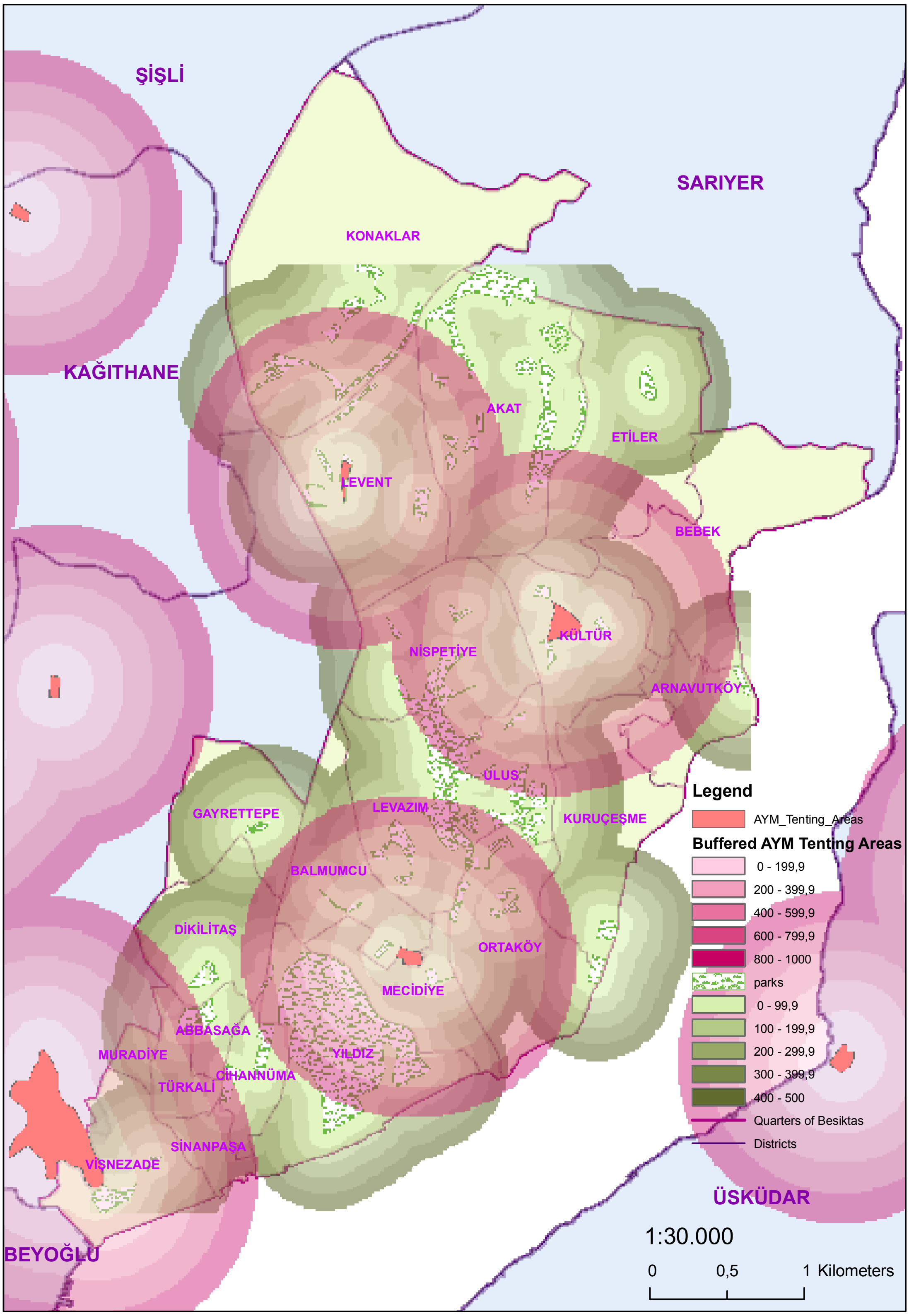


Figure 3.28. Parks and AYM tenting areas

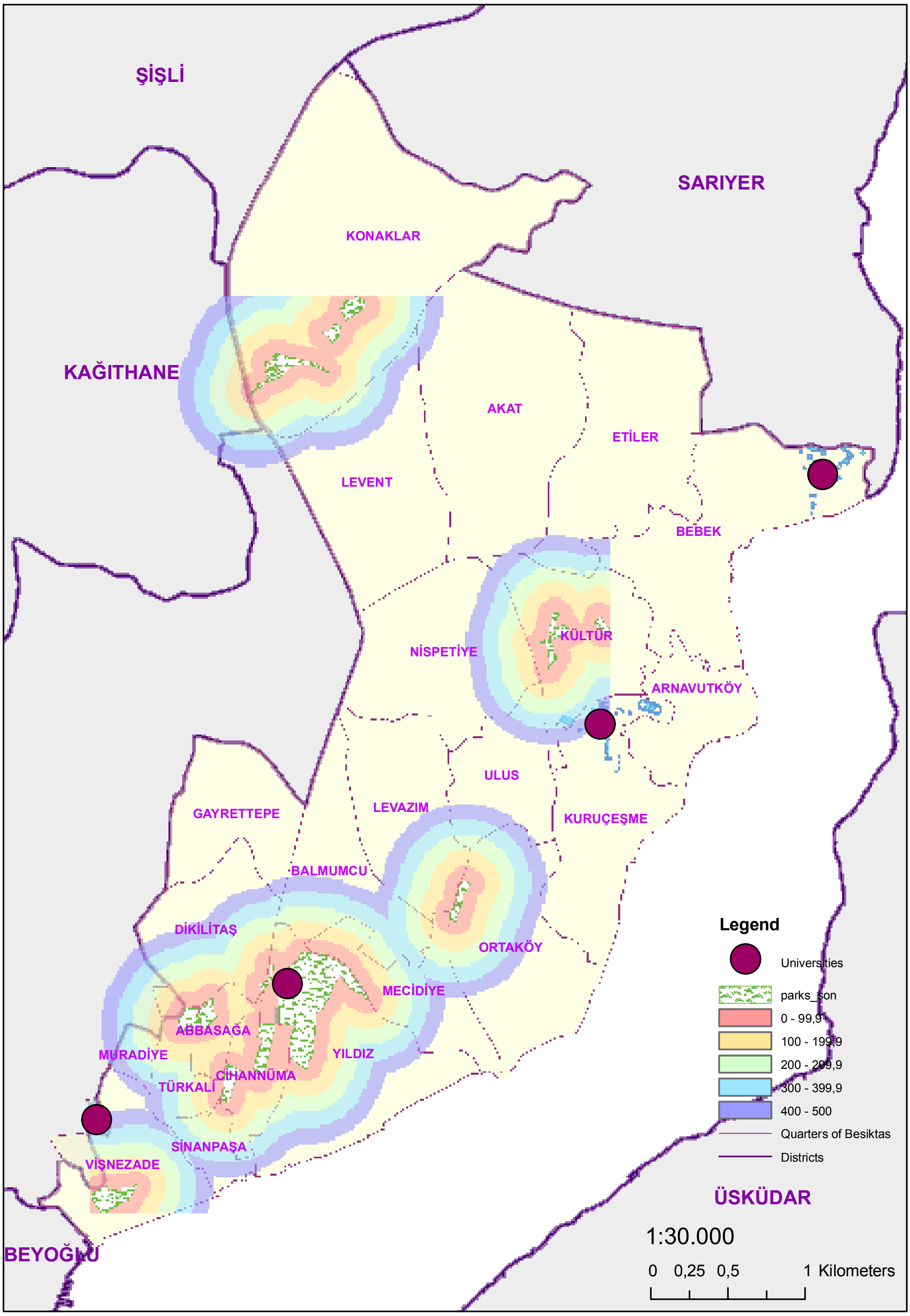


Figure 3.29. Parks and appropriate campuses used only as tenting areas due to slope stability and tsunami potential

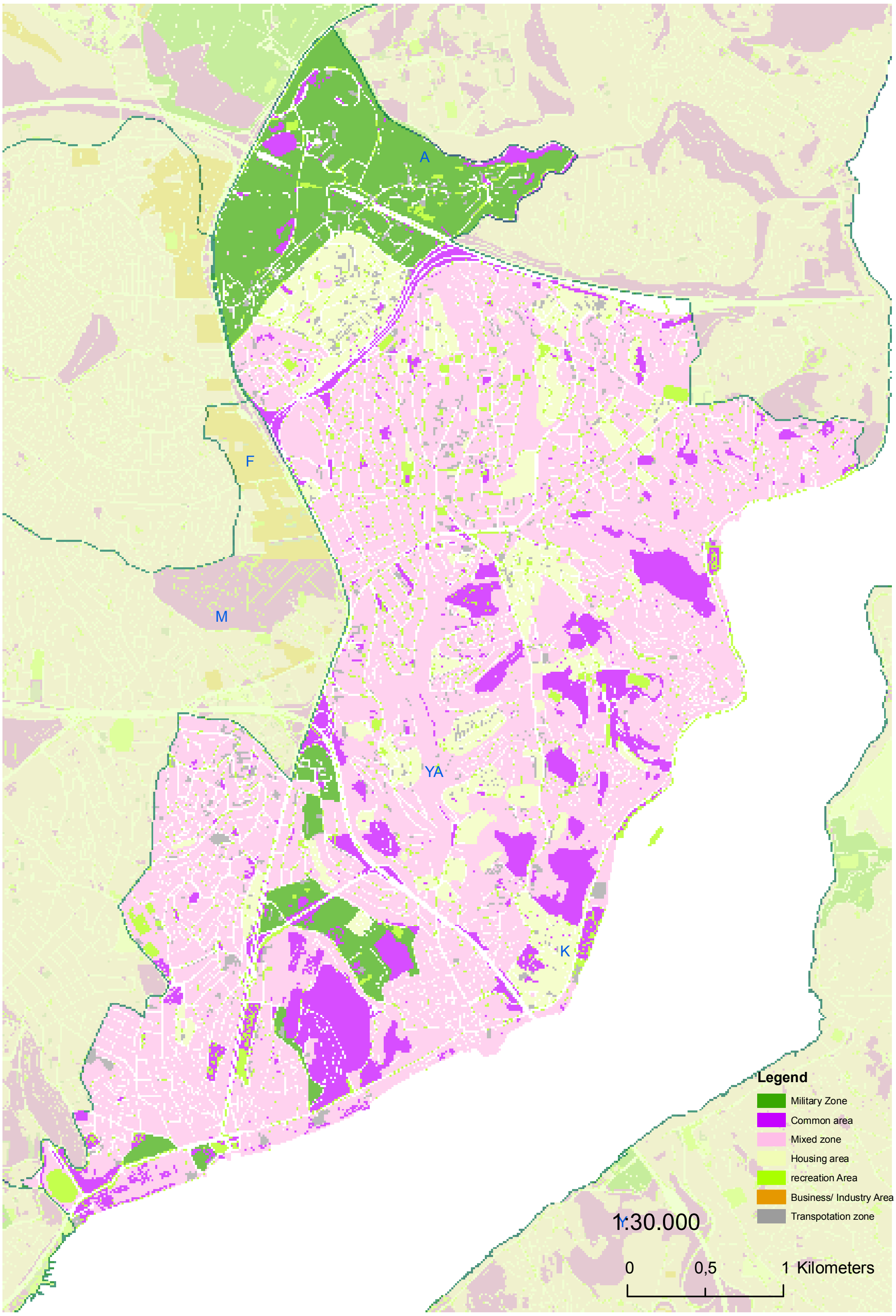


Figure 3.30. Landuse map of Beşiktaş district

Table 3.12. Appropriate campuses

Suitable Campuses		
Boğaziçi University Bebek QuarterŞehitlik Dergahı St. No:2. Bebek QuarterCevdetpaşa St. No:115	it is suitable for both meeting place and tenting area	87260m²
İstanbul Technical University Vişnezade QuarterSüleyman Seba St. No:90	it is suitable for both meeting place and tenting area	19760 m²
Yıldız Technical University Yıldız QuarterHamam St. No:2	it is suitable for both meeting place and tenting area	172000m²
American Robert College Bebek QuarterCevdetpaşa St. No:115	it is suitable for both meeting place and tenting area	182945m²

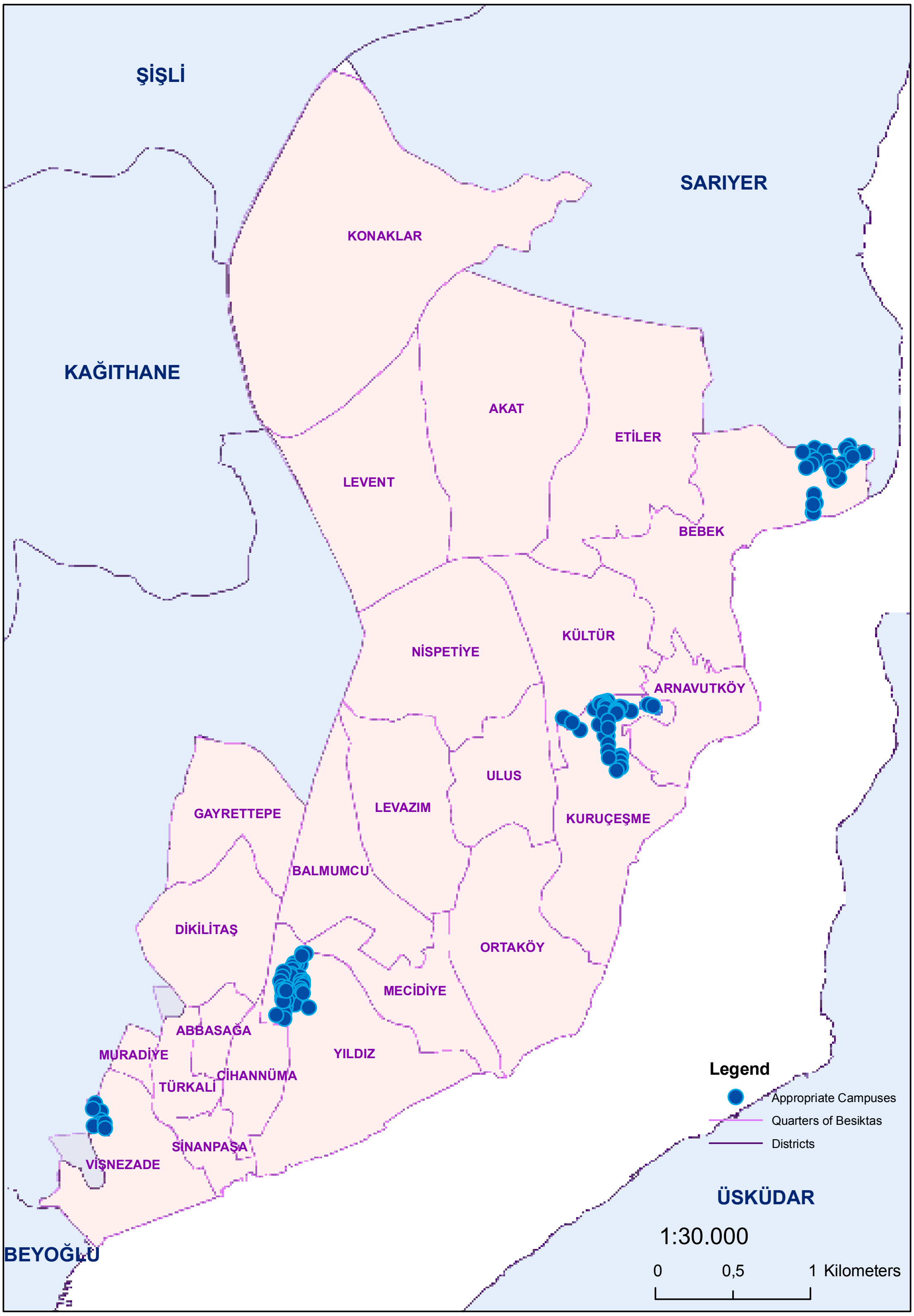


Figure 3.31. Suitable campuses

3.4.3. Vulnerability Assessment of Beşiktaş District

In this study data from Figure 3.32 which displays site dependent deterministic intensity distribution of İstanbul is used. According to this; stable grounds are related to VI – VII and unstable ones to VII – VIII intensity distribution.

In the studies of vulnerability assessment, construction year, building structure type, site conditions and number of stories are the essential/basic information used for the evaluation stage. However, in this study, information of construction year is not considered mainly because of the lack of data. In fact new buildings have been relatively constructed after 1998 regulation. Besides, Şengezer studies on Erzincan-1992, Dinar-1995 and Kocaeli-1999 earthquakes show that the information of construction year has lower effect on the vulnerability assessment therefore it can be ignored in the evaluation of vulnerability assessment.

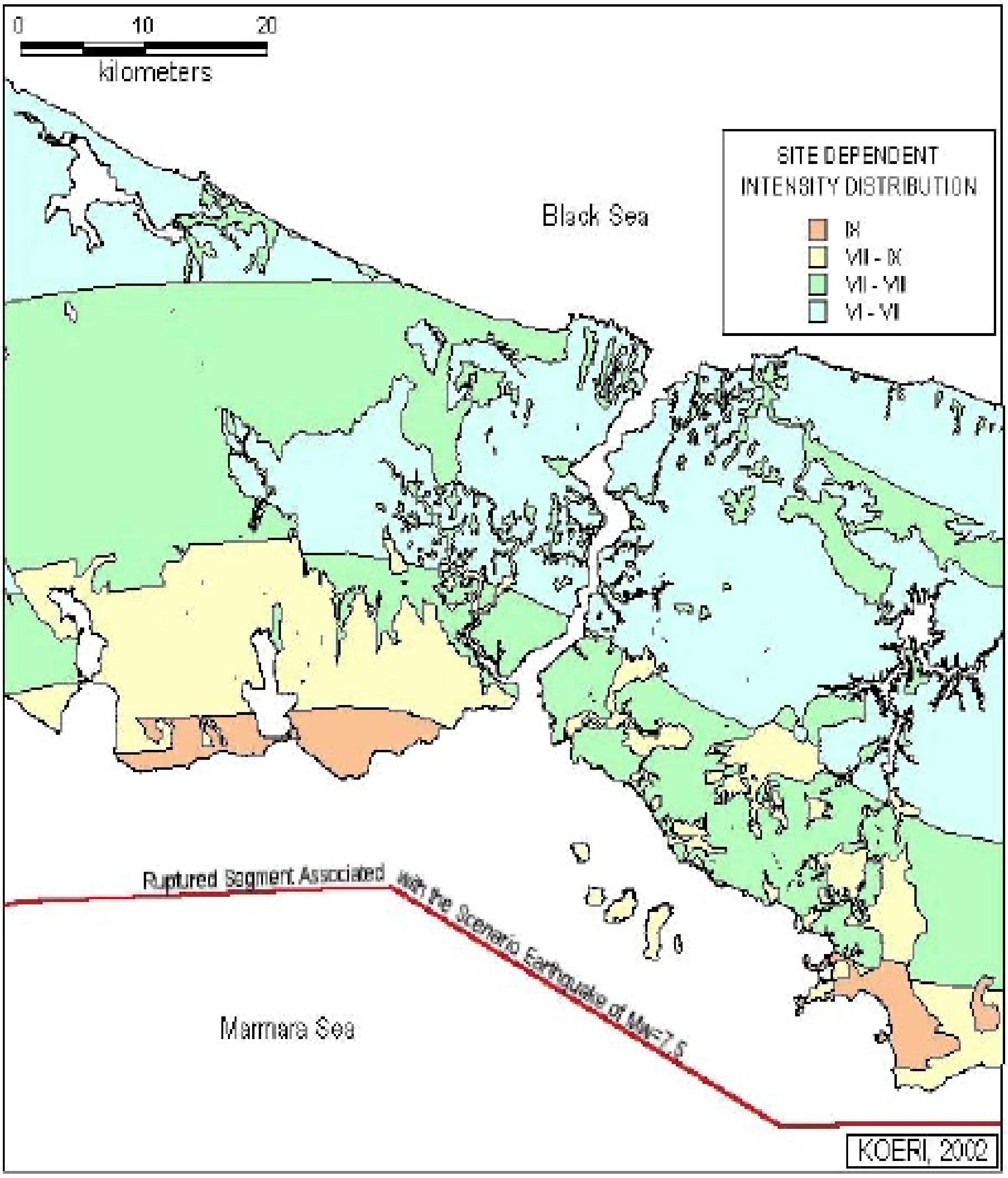


Figure 3.32. Site dependent deterministic intensity distribution (Erdik e*t al.*, 2002)

3.4.3.1. Number of Damaged Building. For the damage estimation carried out in this study, data on the number of stories are classified into main four categories and three sub categories (Table 3.13):

- For wooden buildings; a) 1-2 stories, b) 3 stories and over.
- For brick masonry; a) 1-2 stories, b) 3 stories and over.
- For steel buildings; a) 1-2 stories, b) 3-5 stories, c) 5 stories and over.
- For RC buildings; a) 1-2 stories, b) 3-5 stories, c) 5 stories and over.

Table 3.13. Number of buildings in terms of number of stories

Building Structure Type	Unstable Soil		Stable Soil	
	Groups of Stories	Number of Buildings	Groups of Stories	Number of Buildings
RC	1 - 3 stories	265	1 - 3 stories	2753
	3-5 stories	795	3-5 stories	3899
	5 stories and over	200	5 stories and over	1858
Steel	1 - 3 stories	0	1 - 3 stories	12
	3-5 stories	7	3-5 stories	3
	5 stories and over	0	5 stories and over	20
Wooden	1-2 stories	41	1-2 stories	199
	3 stories and over	49	3 stories and over	207
Brick masonry	1-2 stories	103	1-2 stories	1259
	3 stories and over	33	3 stories and over	92

These data were compiled in GIS environment and Table 3.13 was created using select by attributes and select by location tools of GIS software. The results of these processes were obtained very quickly by benefitting from GIS.

Buildings with more than five stories, buildings situated on alluvial land and wooden and masonry buildings are most vulnerable to earthquakes. In this study, wooden construction and steel construction are evaluated as RC construction. Unstable Soil includes Alluvium, Manmade Fill and Kuşdili Formation and Stable Soil contains Tuzla, Baltalimanı, Trakya , Kartal, Dalayoba formations. RC, Steel, Wooden and Brick masonry buildings' damage distribution matrices were created and analyzed both stable and unstable soils. Table 3.14 through 3.17 show results of these processes.

Table 3.14. Damage distribution matrix derived from MBeD for RC, steel and wooden buildings on stable soil

Construction Type		**Wooden, RC and steel (1-2 stories)**	**Wooden (over 2 stories) - RC and steel (3-5 stories)**	**RC and steel (over 5 stories)**				
Damage level	V_{min}	**VI_{min}**	**VII_{min}**	**$VIII_{min}$**	IX_{min}	X_{min}	XI_{min}	XII_{min}
	-	**V_{max}**	**VI_{max}**	**VII_{max}**	$VIII_{max}$	IX_{max}	X_{max}	XI_{max}
None	1	**0,94**	**0,62**	**0,33**	0,14	0,05	0,02	0
Slight	0	**0,05**	**0,25**	**0,26**	0,17	0,09	0,04	0
Moderate	0	**0,01**	**0,09**	**0,19**	0,19	0,14	0,08	0
Heavy	0	**0**	**0,03**	**0,12**	0,19	0,19	0,16	0
Partial Collapse	0	**0**	**0,01**	**0,07**	0,17	0,25	0,27	0
Total Collapse	0	**0**	**0**	**0,03**	0,14	0,29	0,42	1
Average damage ratio	0,00	**0,01**	**0,11**	**0,29**	0,50	0,68	0,77	1

Table 3.15. Damage distribution matrix derived from MBeD for brick masonry buildings on stable soil

Construction type			**Masonry (1-2 stories)**	**Masonry (over 2 stories)**				
Damage level	V$_{min}$	VI$_{min}$	**VII$_{min}$**	**VIII$_{min}$**	IX$_{min}$	X$_{min}$	XI$_{min}$	XII$_{min}$
	-	V$_{max}$	**VI$_{max}$**	**VII$_{max}$**	VIII$_{max}$	IX$_{max}$	X$_{max}$	XI$_{max}$
None	1	0,99	**0,67**	**0,33**	0,14	0,05	0,02	0,01
Slight	0	0,01	**0,21**	**0,27**	0,16	0,1	0,04	0,02
Moderate	0	0	**0,07**	**0,2**	0,19	0,16	0,09	0,06
Heavy	0	0	**0,05**	**0,1**	0,2	0,19	0,16	0,13
Partial collapse	0	0	**0**	**0,08**	0,16	0,22	0,28	0,28
Total collapse	0	0	**0**	**0,02**	0,15	0,28	0,41	0,5
Average damage ratio	0,00	0,00	**0,10**	**0,28**	0,51	0,65	0,77	0,83

Table 3.16. Damage distribution matrix derived from MBeD for RC, steel and wooden buildings on unstable soil

Construction type			**Wooden, RC and steel (1-2 stories)**	**Wooden (over 2 stories) - RC and steel (3-5 Stories)**	**RC and steel (over 5 stories)**			
Damage level	V$_{min}$	VI$_{min}$	**VII$_{min}$**	**VIII$_{min}$**	**IX$_{min}$**	X$_{min}$	XI$_{min}$	XII$_{min}$
	-	V$_{max}$	**VI$_{max}$**	**VII$_{max}$**	**VIII$_{max}$**	IX$_{max}$	X$_{max}$	XI$_{max}$
None	1	0,94	**0,62**	**0,33**	**0,14**	0,05	0,02	0
Slight	0	0,05	**0,25**	**0,26**	**0,17**	0,09	0,04	0
Moderate	0	0,01	**0,09**	**0,19**	**0,19**	0,14	0,08	0
Heavy	0	0	**0,03**	**0,12**	**0,19**	0,19	0,16	0
Partial collapse	0	0	**0,01**	**0,07**	**0,17**	0,25	0,27	0
Total collapse	0	0	**0**	**0,03**	**0,14**	0,29	0,42	1
Average damage ratio	0,00	0,01	**0,11**	**0,29**	**0,50**	0,68	0,77	1

Table 3.17. Damage distribution matrix derived from MBeD for brick masonry buildings on unstable soil

Construction Type				**Masonry (1-2 stories)**	**Masonry (over 2 stories)**			
Damage level	V_{min}	VI_{min}	VII_{min}	**$VIII_{min}$**	**IX_{min}**	X_{min}	XI_{min}	XII_{min}
	-	V_{max}	VI_{max}	**VII_{max}**	**$VIII_{max}$**	IX_{max}	X_{max}	XI_{max}
None	1	0,99	0,67	**0,33**	**0,14**	0,05	0,02	0,01
Slight	0	0,01	0,21	**0,27**	**0,16**	0,1	0,04	0,02
Moderate	0	0	0,07	**0,2**	**0,19**	0,16	0,09	0,06
Heavy	0	0	0,05	**0,1**	**0,2**	0,19	0,16	0,13
Partial collapse	0	0	0	**0,08**	**0,16**	0,22	0,28	0,28
Total collapse	0	0	0	**0,02**	**0,15**	0,28	0,41	0,5
Average damage ratio	0,00	0,00	0,10	**0,28**	**0,51**	0,65	0,77	0,83

Number of damaged buildings of Beşiktaş district were obtained from damage distribution matrices stated above and shown in Table 3.18 through Table 3.21.

Table 3.18. Number of damaged buildings derived from MBeD for RC, steel and wooden structures on stable soil

Construction Type	**Wooden, RC and Steel (1-2 Stories)**	**Wooden (over 2 Stories) - RC and Steel (3-5 Stories)**	**RC and Steel (over 5 Stories)**
Damage level	VI_{min}	VII_{min}	$VIII_{min}$
	V_{max}	VI_{max}	VII_{max}
None	2786	2548	620
Slight	148	1027	488
Moderate	30	370	357
Heavy	0	123	225
Partial Collapse	0	41	131
Total Collapse	0	0	56
Average damage	**41**	**460**	**537**

Table 3.19. Number of damaged buildings derived from MBeD for brick masonry structures on stable soil

Construction Type	**Masonry (1-2 Stories)**	**Masonry (over 2 Stories)**
Damage level	VII $_{min}$	VIII $_{min}$
	VI $_{max}$	VII $_{max}$
None	844	30
Slight	264	25
Moderate	88	18
Heavy	63	9
Partial Collapse	0	7
Total Collapse	0	2
Average damage	**125,90**	**25,58**

Table 3.20. Number of damaged buildings derived from MBeD for RC, steel and wooden structures on unstable soil

Construction Type	**Wooden, RC and Steel (1-2 Stories)**	**Wooden (over 2 Stories) - RC and Steel (3-5 Stories)**	**RC and Steel (over 5 Stories)**
Damage level	VII $_{min}$	VIII $_{min}$	IX $_{min}$
	VI $_{max}$	VII $_{max}$	VIII $_{max}$
None	190	281	28
Slight	77	221	34
Moderate	28	162	38
Heavy	9	102	38
Partial Collapse	3	60	34
Total Collapse	0	26	28
Average damage	**34**	**243**	**100**

Table 3.21. Number of damaged buildings derived from MBeD for brick masonry structures on unstable soil

Construction Type	**Masonry (1-2 Stories)**	**Masonry (over 2 Stories)**
Damage level	VIII_{min}	IX_{min}
	VII_{max}	VIII_{max}
None	34	5
Slight	28	5
Moderate	21	6
Heavy	10	7
Partial Collapse	8	5
Total Collapse	2	5
Average damage	**28,63**	**16,70**

3.4.4. The Results

The results of this assessment are obtained by using population and number of stories (Table 3.22).

Table 3.22. Number of people in terms of number of stories

Building Structure Type	**Unstable Soil**				**Stable Soil**			
	Groups of Stories	**Number of Buildings**	**Number of Stories**	**Population**	**Groups of Stories**	**Number of Buildings**	**Number of Stories**	**Population**
RC	1 - 2 stories	265	397,5	**1709**	1 - 2 stories	2753	4129,5	**17752**
	3-5 stories	795	2782,5	**11961**	3-5 stories	3899	13646,5	**58664**
	5 stories and over	200	1500	**6448**	5 stories and over	1858	13935	**59904**
Steel	1 - 2 stories	0	0	**0**	1 - 2 stories	12	18	**77**
	3-5 stories	7	24,5	**105**	3-5 stories	3	10,5	**45**
	5 stories and over	0	0	**0**	5 stories and over	20	150	**645**
Wooden	1-2 stories	41	61,5	**264**	1-2 stories	199	298,5	**1283**
	3 stories and over	49	171,5	**737**	3 stories and over	207	724,5	**3114**
Brick masonry	1-2 stories	103	154,5	**664**	1-2 stories	1259	1888,5	**8118**
	3 stories and over	33	115,5	**497**	3 stories and over	92	322	**1384**

Firstly RC, steel and wood structures on stable soil are analyzed. The results of this analysis are;

- One - two stories: neither buildings collapsed nor people injured.
- Three five stories: Some poor constructed buildings (41 buildings) may collapse partially. Approximately 620 people would be slightly injured.
- Over five stories: 225 buildings are heavily damaged and 187 buildings are partially and totally collapsed. Approximately 7250 people would be slightly injured and 6060 of them are seriously injured or casualties.

Secondly brick masonry structures on stable soil are evaluated.

- One - two stories: Some poor constructed buildings (63 buildings) may collapse partially. Approximately 400 of people would be slightly injured.
- Over two stories: nine buildings are heavily damaged and 9 buildings are partially and totally collapsed. Approximately 135 people would be slightly injured and 135 of them are seriously injured or casualties.

Thirdly, RC, steel and wood structures on unstable soil are investigated. The results of these analyses are;

- One - two stories: nine buildings are heavily damaged and three buildings are partially and totally collapsed. Approximately 58 people would be slightly injured and 20 of them are seriously injured or casualties.
- Three five stories: 102 buildings are heavily damaged and 86 buildings are partially and totally collapsed. Approximately 1535 people would be slightly injured and 1290 of them are seriously injured or casualties.
- RC and Steel over five: 38 buildings are heavily damaged and 62 buildings are partially and totally collapsed. Approximately 1225 people would be slightly injured and 2000 of them are seriously injured or casualties.

Lastly, brick masonry structures on unstable soil are evaluated. The results of these analyses are;

- One - two stories: 10 buildings are heavily damaged and 10 buildings are partially and totally collapsed. Approximately 65 people would be slightly injured and 65 of them are seriously injured or casualties.
- Over two stories: seven buildings are heavily damaged and 10 buildings are partially and totally collapsed. Approximately 105 people would be slightly injured and 150 of them are seriously injured or casualties.

The same results are also obtained by using different assumptions such as determination of number of buildings, number of housing units and population.

4. FUTURE ASPECTS AND CONCLUSIONS

The aim of this study is to analyze whether or not Beşiktaş is ready for the earthquake risk, to investigate its potential of response to it and to perform analysis on which the comprehensive damage mitigation plans will be based. In other words, this study comprise testing of getting ready against earthquake risk of urban areas and analyzing of parks in a sufficient amount. In the result of this study, one can easily find the meeting points and tenting areas in Beşiktaş district.

Geographic Information System, GIS, also provides us some very useful options such as more data can be added on this study, updating is very easy, analyses can be performed quickly using inquiries, and it is easily understood because of its powerful visualization tools. Since every structure has attribute table and multimedia information of these structures can be visualized function of hyperlink, it can be used as an urban information system.

The software used in this study has various functions. For instance; the type of features that are stored in database can be changed by using the data management tools under Arc Toolbox. Features can be buffered by using Euclidian distance under spatial analyst tools or straight line tab under spatial analyst toolbar. This software is also providing statistical tools to analyze more than one or two features at the same time (Zonal statistics under spatial analyst tools or cell statistics under spatial analyst toolbar). Moreover sloped areas can be obtained by using surface analyst tab under spatial analyst toolbar or slope tab under spatial analyst tools.

Considering all the obtained data and analyses studies total number of slightly injured people would be 10373, total number of seriously injured people or casualties would be 10120, total number of heavily damaged buildings would be; 400, total number of partially and totally collapsed buildings would be; 471. Since the population reaches over two million in Beşiktaş on day times, it is obvious that these numbers will dramatically increase. Within this study, parks, appropriate campuses (American Robert

College, Boğaziçi University, İstanbul Technical University and Yıldız Technical University), stadiums and other suitable areas are cited as alternatives for current tenting areas and meeting points, thus, approximately total area is evaluated as 20 hectare. Besides, total number of tents are determined as 8000.

In this study any scenario earthquake is not created. KOERI Earthquake Engineering Department scenario earthquake studies are used.

All the buildings (schools, hospitals, *etc.*), transportation structures (bridges, viaduct, *etc.*) and the infrastructure (pipeline, waterline *etc.*) could not be analyzed in this study because of the lack of data. However, for an adequate earthquake risk assessment all these data should be put into consideration.

As the planning before an earthquake, Directorate of Real Estate and Expropriation of the Beşiktaş Municipality has investigated the district and determined the meeting and tenting areas for every street. This effort has been shown in related maps. In addition to these studies, these areas have been visualized and analyzed in GIS environment using more data and shown basing on analyze of geological formation and various queries.

The number of health center's located in Beşiktaş district is 49. However most of them are polyclinics and branch clinics that have one or two doctors and no beds. The only hospital serving advanced health care in Beşiktaş district is the Florence Nightingale Hospital. Although there are some other hospitals like Hattat Hospital, Dünya Göz Hospital and Dent İstanbul that can be used in emergency situations, these do not serve advanced health care. In case of an earthquake the nearby hospitals serving advanced health care are Taksim İlkyardım Hospital in Beyoğlu district, İstinye Devlet Hospital in Sarıyer district and Şişli Etfal Hospital in Şişli district.

Beşiktaş district is divided into four separate plans. One of them is the Bosporus frontal view area which is directed by IMM, Directorate of Bosporus Housing. Another one is the site plan including Yıldız Palace, Yıldız Grove, Yıldız Technical University and military zone which is on preparation phase right now and is directed by IMM, Directorate of City Planning. The last two plans are directed by the Beşiktaş Municipality Beşiktaş – Dikilitaş - Balmumcu implementary development plan (09.08.2007) and Bosphorus back view area implementary development plan (10.12.1993). Because of this situation Beşiktaş Municipality has limited authority for all quarters of Beşiktaş and this can lead to chaos in an emergency situation.

Decision makers can use the results provided in this study for planning and mitigation of the earthquake risk. In addition to this, following outcomes obtained from personal researches should also be considered for mitigation of earthquake risk.

In order to obtain a detailed earthquake risk analysis, a study involving a very wide range of disciplines like civil engineering, geodesy and photogrammetry engineering, city planning, geology and *etc.* is really crucial.

When organization schematics about disaster management for both Turkey and other countries are examined, it is obviously seen that Turkey has a multiple headed. A lot of public organizations and ministries such as Ministry of Public Works and Settlement, Ministry of Internal Affairs, Ministry of National Defense, Ministry of Health, Ministry of Transportation, Ministry of Environment and Forestry, Ministry of Energy and Natural Sources, Ministry of Industry are involved in the management of disasters by their foundational codes system. Compatible and collateral units working under a centralized management should be formed. The involvement of so many organizations and the distribution of functions and powers over all these groups cause a serious coordination and synchronization problem in applications. This results in repetition of effort and data and waste of important resources.

After the Kocaeli (Izmit), Turkey Mw 7.4 Earthquake (17.08.1999); construction quality, construction stability and construction controls have been considered mostly as pre-caution factors. However the property and formation of urbanization and the increasing of population within the centers of metropolitan cities are more important problems.

Local administrations, municipalities, should be supported with adequate man power, resources and authority in order to obtain a competent readiness for earthquakes and natural disasters. Such a support will not only provide a better city planning and building inspection for municipalities, but also will help them carry out their authority during disasters. Using these authority municipalities can form adequate disasters mitigation plans and organize necessary man power for protection from natural disasters and mitigation of damage.

Municipalities have to use their authority in order to inhibit illegal or insufficient constructions on areas that have a high risk potential and restore damaged buildings.

Disasters are closely related to the socio-political factors. It should not be forgotten that risk mitigation is not only about social factors, that are defining the vulnerabilities, but also about resistance of individuals. Therefore appropriate political changes should be considered such as public education to increase awareness of earthquake loss.

Observations and experiences show that individuals should have an active role in risk mitigation for more successful applications. Researches and applications should be focused on more attractive topics for community and should be performed with their participation.

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