GIS-BASED MICROZONATION MAP OF NIKSAR (TOKAT) SETTLEMENT AREA FOR THE PURPOSE OF URBAN PLANNING

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ABSTRACT

GIS-BASED MICROZONTION OF NIKSAR (TOKAT) SETTLEMENT AREA FOR THE PURPOSE OF THE URBAN PLANNING

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Niksar (Tokat), is an urban area located in a seismically active zone of Turkey. The aim of this thesis is to prepare GIS-based microzonation map of Niksar settlement area for the purpose of urban planning. Liquefaction, activity, slope, aspect, fault proximity, ground amplification and lithology are considered during the overlay analysis by using Multicriteria Decision Making Analysis (MCDA) of Simple Additive Weighing (SAW) and Analytical Hierarchical Process (AHP) methods. Based on the evaluations, the study area is divided into four different zones, namely, (1) areas suitable for settlement; (2) provisional settlement areas; (3) areas requiring detailed geotechnical investigation; (4) unsuitable areas. Two microzonation maps obtained from analyses are compared. Maps prepared by SAW and AHP methods are found to be consistent with each other. However, the microzonation map prepared by AHP method is recommended for the purpose of urban planning because it has the ability to check consistency itself.

Keywords: Engineering Geology, GIS, Microzonation, Analytical Hierarchical Process, Simple Additive Weighing, Niksar

ÖZ

NİKSAR (TOKAT) YERLEŞİM BİRİMİNİN ŞEHİR PLANLAMASI AMACIYLA CBS TABANLI MİKROBÖLGELEMESİ

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Yüksek Lisans, Jeoloji Mühendisliği Bölümü
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Niksar (Tokat) ilçesi yerleşim merkezi, Türkiye'nin aktif sismik bölgelerinden birinde kuruludur. Bu tezin amacı Niksar yerleşim alanının şehir planlamasına esas olmak üzere CBS tabanlı mikrobölgeleme haritasını hazırlamaktır. Sıvılaşma, aktivite, eğim, bakı, faya uzaklık, zemin büyütmesi ve litoloji faktörleri; Çok Ölçütlü Karar Verme (MCDA) metotları olan Basit Eklemeli Ağırlık (SAW) ve Analitik Hiyerarşi Yöntemi (AHP) analizleri uygulanırken, göz önüne alınmıştır. Yapılan değerlendirmelere göre çalışma alanı dört bölgeye ayrılmıştır; (1) yerleşime uygun alanlar, (2) Önlemli Alanlar, (3) detaylı jeoteknik inceleme gerektiren alanlar, (4) yerleşime uygun olmayan alanlar. Bu iki yöntemle elde edilen mikrobölgeleme haritaları, birbirleriyle karşılaştırılmıştır. SAW ve AHP ile hazırlanan haritalar birbirleriyle tutarlıdır. Ancak kendi kendini denetleme imkanına sahip olan AHP yöntemi ile hazırlanmış harita şehir planlamasına esas olmak üzere önerilmektedir.

Anahtar Kelimeler: Mühendislik Jeolojisi, CBS, Mikrobölgeleme, Analitik Hiyerarşi Yöntemi, Basit Eklemeli Ağırlık, Niksar

to my family

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CHAPTER 1

INTRODUCTION

A city is an advent of the human kind. It has been developing since the first appearance of the communities. It is the evidence of the civilization; meaning that, whole civic activities are carried out, there. Indeed, the target of the city development is not to improve civilization. Instead of this, improving civilization creates a higher quality habitat for the human kind, giving rise to longer life expectancy and more peace. In such a case, the city should satisfy requirements of people, such as; the resident to flourish, the job to gain income, the security against threads, the infrastructure for every utility, the safety toward every danger and the health (Coch, 1995; Waltham, 1994). If the history is searched superficially, it will easily be grasped that all cities and nomad’s cantonments have been established to fulfill these needs. Nevertheless, past times show that the nature is decisive for the survival of cities. Particularly, our country exhibits ancient and recent evidences of the nature’s fatal defects (Altunel, 1997).

Harms caused by the nature occupy an important part of subjects of geological engineering in the city planning concern. Engineering geology investigates the relationship between the ground and all engineering projects. As a branch of engineering science and application to some economic sectors, it seeks for early events, prevailing conditions and cautions for predictable dangers, at/near the Earth’s surface and the rest of the natural forces. Consequently, the city planning must have the basis determined by geological studies including, geotechnics, geophysics and natural hazard inspection (Coch, 1995; Maantay and Zieger, 2006).

The earthquake phenomenon is a specific subject. Especially, the public is aware of this, but not consciously. One of the world’s most active tectonic systems, which produce devastating earthquakes, jeopardizes today’s Turkish cities, which show rapid growth rates in enlargement. However, Irtem et al (2004) stated that the construction quality is suspicious. Therefore, the influence of seismicity on cities appears with great importance with increasing rate of threat. Then, it is one of the aspects in the field of geological engineering (Coch, 1995; Ciftci, 2005; De Mulder, 1996).

Niksar city, which is an improving urbanization in the North Anatolian Fault Zone, is the study area to investigate. It is required to define which part of the city is more convenient for settlement. At the same time it is an ancient city and community like to convey the heritage to next generations, without being lost.

1.1. Purpose and scope

The aim of this study is to prepare a microzonation map covering the municipality service border of Niksar (Tokat). This map is planned to be composed of geographical, geological, geotechnical and geophysical data, in a systematical contribution to determine classified safe zones for settlement. The result will certainly include a relative correlation among different locations of the study area. It means that the microzonation classification will be peculiar to Niksar, only. On the other hand, base data producing the output will be consistent with the general laws of related branches of science.

The main problems faced within the city are the fault activity and the landslide. The study area lies on one of the most active tectonic regions of world so called the North Anatolian Fault Zone. Niksar witnessed two high magnitudes and two medium magnitudes of ground shaking near the city, last century (ref. koeri.boun.edu.tr, last visited on August 2009). Particularly, the ground rupture of

1942 Erbaa Earthquake reached the city. Other problems related with urbanization are evaluated as a consequence of the earthquake investigation.

This thesis is a GIS (Geographical Information Systems) based study. Whole data, including parts of surveys, maps, calculations, databases and representations are stored digitally, in digital elevation models.

The classification of the lithology observed on the ground surface, such as soil, rock, is derived from the geological map, including the stratigraphic section, of the study area and related geotechnical data (Canik and Kayabali, 2000; Danakol and Gedik, 2003). The study area is mainly divided into three zone with respect to the ground material, which are young alluvium, volcanic material of Eocene epoch and relatively older formations. Moreover, the same geological map defines the positions of the fault, which are parts of the North Anatolian Fault Zone. This information directs the precautions with existence of this fault.

Topographic relief of the study area is derived from the geographical data stored in cartographic maps (source Niksar Municipality). These maps supply altitude values at definite locations indicated with contour lines. Then, slope and aspect maps are produced from these base maps.

Geotechnical data cover the plasticity variation and liquefaction susceptibility depending on the borehole logs and in-situ tests within boreholes. Plasticity is considered using the Unified Soil Classification System (Wagner, 1957). Geophysical data are supplied from the microtremor measurements, which yield the ground amplification map.

1.2 Geographical setting, accessibility and climate

The study area, Niksar settlement area, is located in the central northern Anatolia. It is just behind the Black Sea Coastal Region. It is a small but important city flourished in/near the long Kelkit Valley. There is a main road D-100 passes through this valley. Lots of enclave and greater urbanizations, such as; Amasya and Erbaa at west, Resadiye, Susehri, Erzincan and Erzurum at the north, are found in / around the route of this main road. Niksar becomes easily accessible via Amasya from Istanbul or Ankara (Figure 1.1). This road continues eastward until Erzurum in northeastern Anatolia. The position of Niksar is convenient for accessing neighboring cities such as; Amasya (at west), Tokat (at south), Sivas (at east) and Black Sea coastal cities of Samsun and Ordu (at north). Nevertheless, transit roads, especially new highway keeping the route parallel to the shoreline of the Black Sea, are preferred for transportation, causing reduction in the economic potential of Niksar.

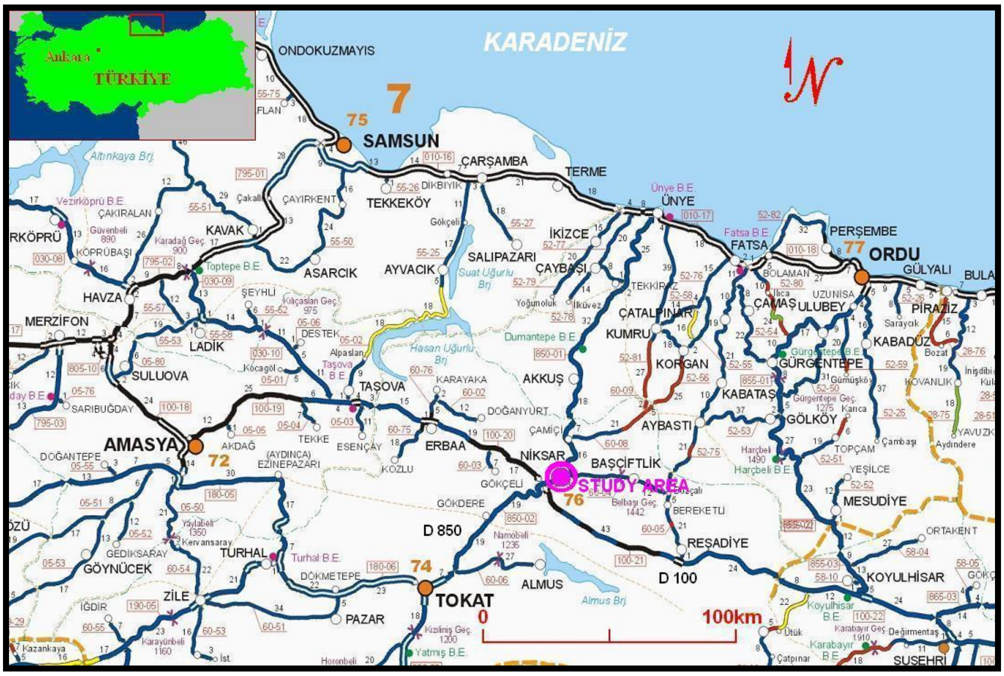

Figure 1.1. Location map of the study area (Source: State higway map, 2009).

The North Anatolian Fault Zone controls the topography of the region adjacent to Niksar. Whole Kelkit Valley is formed as a result of the movement along numerous fault segments over the North Anatolian Fault Zone. It divides the long mountain range system of central Black Sea region into two parallel mountain range series. The Kelkit River flows between them (Figure 1.2). The Kelkit Valley is deeply incised between the two adjacent highlands. For example, the elevation is about 250m near the channel of Kelkit River in Niksar while it approaches 1500 meters at the top of the mountains both at the north and the south. This distinct altitude difference produces drastic changes in the annual average temperatures of the valley and the adjacent highland. Moreover, complexities of the fault system reshape the terrain with pull-apart basins and pressure ridges. Pull-apart basins result in plain while pressure ridges separate these (Blumnethal, 1945; Aktimur et al., 1992; Barka and Kadinsky-Cade, 1988). Niksar has such a plain at the west and the southwest of the city center.

This special relief property of the terrain creates a huge and important watershed area. Snow accumulated in both mountainous regions at the north and the south melts in spring and high groundwater table levels are observed. Consequently, there is a fluvial system consisting of numerous brooks feeding the Kelkit river. At the same time, the relative humidity is high due to existence of the abundant shallow groundwater and streams.

The terrain characteristic produces special climatic conditions, under the influence of the relative humidity and temperature at any level of altitude. The annual mean temperature ranges between 12.6 and 14.4 ^{o}C, and the annual average precipitation between 541 and 691mm. The relative humidity is observed within limits of %71-74 (Sensoy et al., 2009). It is a transitional climate property from the northern coastal and southern inner land regions and very convenient for agriculture. Especially, plains of Kelkit Valley, which have been formed by NAFZ, provide ample space for cultivation.

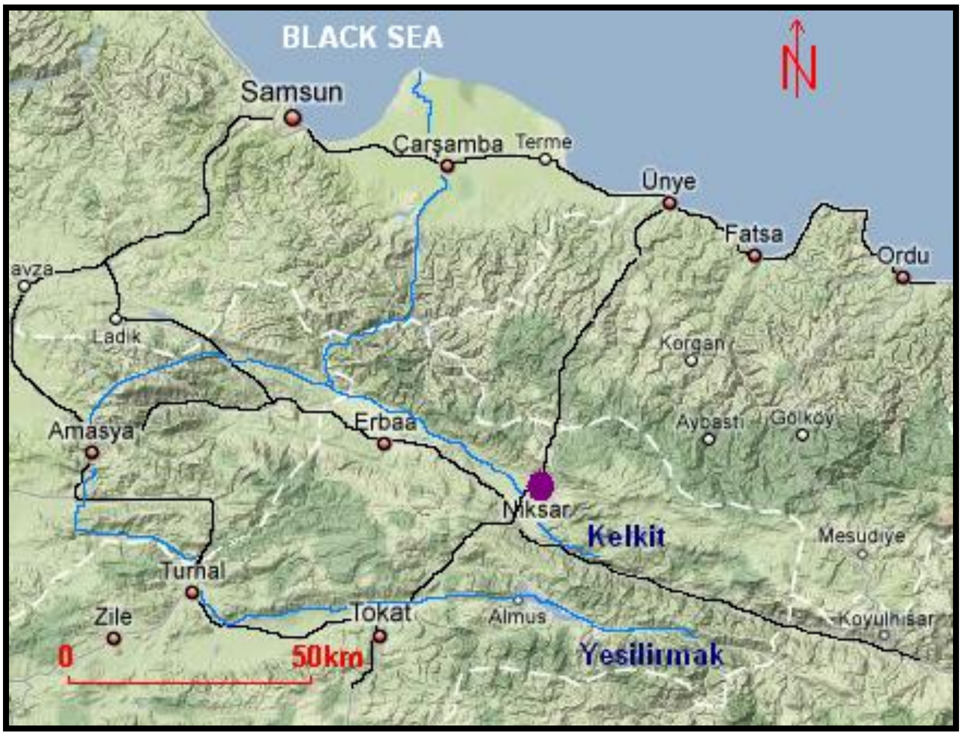

Figure 1.2. Geographical location of Niksar (modified from earth.google.com, last visited on August 2009).

Fortunately, in special climatic and geographic conditions with the existence of its plain covered by alluvium, Niksar city has a great facility for many types of agricultural activities. Many kinds of vegetables and fruits are produced with considerable amount. Simply, the economy is dependent of agriculture.

Niksar has a potential to attract tourists. It is a historical city dated back to six thousands years. Even its name originated from Latin phrase ‘Nicaseria’; meaning ‘New Citadel’, after the reconstruction by governors of Roman Empire (Akdamar, 2008).

The population of Niksar city is 34000. This number includes all villages and small towns, having the area of 1072 square kilometers.

Today's Niksar city has flourished around the old town. The city development has been kept in the northwest-southeast direction. Old town is found in banks of the Canakci Brook (Figure 1.3). It is still the city center, where the municipality building is located. The city has an industrial district on the main roads of D-100 and D-850 crossing 2km southeast of the city center (Figure 1.1), near the Kelkit River.

Rest of the land except from districts shown in Figure 1.3 is used for residential purposes and small stock shops. There are also mills, farms and cultivation gardens around the city center. Majority of the buildings lacks of efficient geotechnical control before the construction.

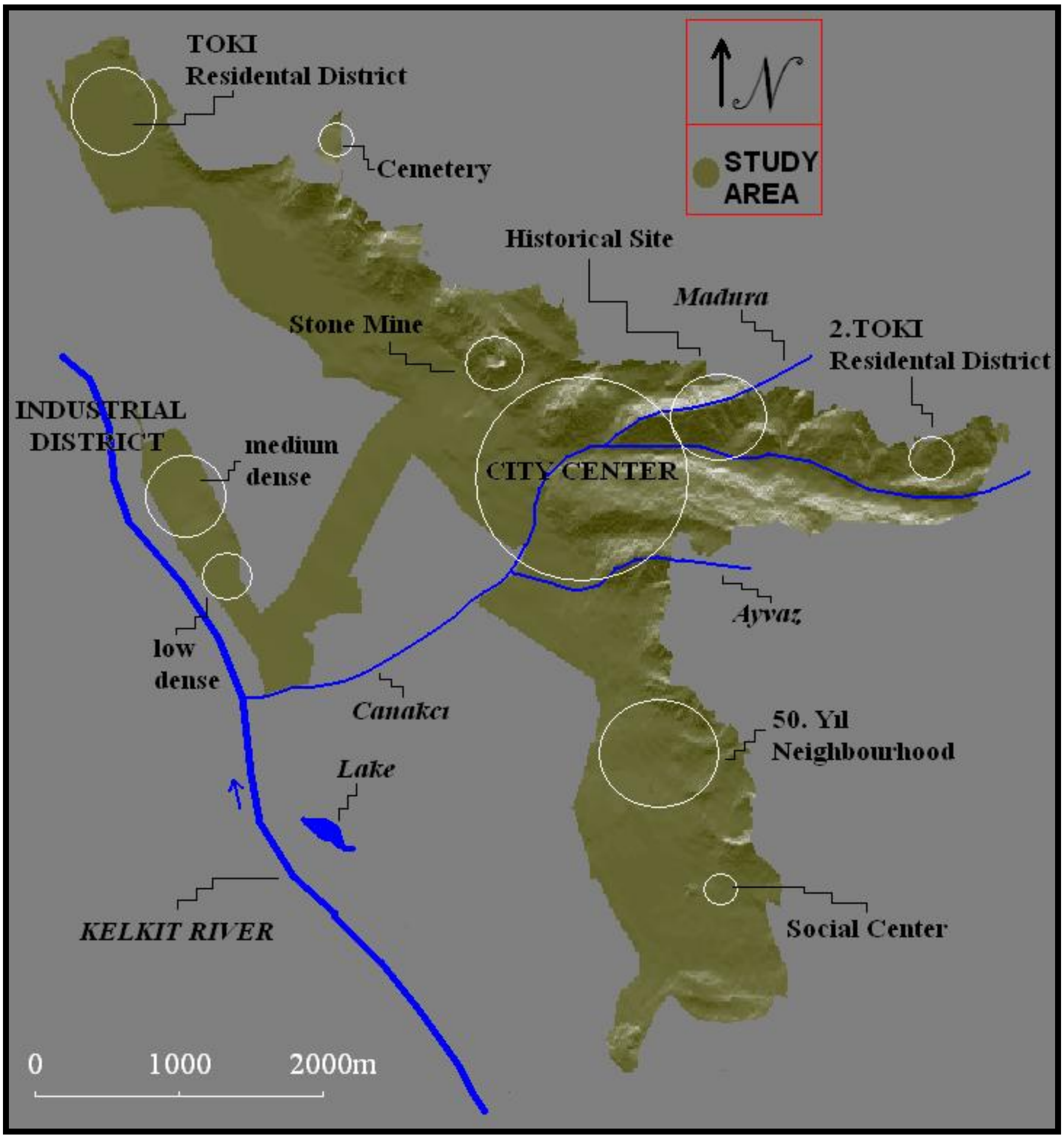

Figure 1.3. The study area and some definite locations of Niksar.

1.3. Methodology

The microzonation for the suitability of Niksar settlement is the major aim for this thesis. The resultant microzonation map will be the guideline for the urban planning of Niksar. There are seven different data to fulfill this aim. These are, the liquefaction susceptibility and the activity of the soil, the ground amplification from microtremor measurements, the slope and the aspect from cartographic maps, the lithology and fault proximity derived from geological maps and field surveys.

The second phase of the study is the decision making. Simple Additive Weighing (SAW) and Analytical Hierarchical Process (AHP) methods of the Multi Criteria Decision Making Analysis (MCDA) techniques are preferred. Contributions of all seven parameters on the microzonation for the settlement are decided. At the same time, some of them show reciprocal interactions. Except from the inversely proportional liquefaction and plasticity with respect to the soil type, the others are limited to the study area. The alluvium cannot form the high sloping angles. Ilicaktepe formation (explained in the next chapter) exhibits slope instability on north facing slopes of the study area.

At the GIS application phase, all these parameters are mapped throughout the study. All of them have a base map with certain dimensions and unit cell size to satisfy consistency. After that, the layer analysis is performed and the raw microzonation map is produced from DEMs of seven parameters according to the statistical model.

The last phase includes GIS application, too. Here, the raw microzonation maps are classified to indicate convenience for settlement, which is the classification proposed by the General Directorate of Disaster Affairs.

1.4. Previous studies

The study area has been investigated before to evaluate geological and geotechnical properties of the ground. Nevertheless, there has not been any study carried out to prepare a microzonation map. The previous studies, which are included within this thesis, are tabulated in Table 1.1.

Table 1.1. Previous studies included in this thesis

Date	Author	Title	Description
1945	Blumenthal, M.	Niksar Güneyindeki Kelkit Dislokasyonu ve Tektonikle İlgisi	Article: Geological Evidences for Tectonism around Niksar
1969	Ketin, I.	Features and Main Earthquake Regions of Turkey	Article: Detailed Properties of the Turkish Tectonism
1980	Terlemez and Yılmaz	Ünye, Ordu, Koyulhisar ve Reşadiye Arasında Kalan Yörenin Stratigrafisi	Article: Geological Description about the Kelkit Region
1992	Aktimur et al	Niksar, Erbaa ve Destek Dolayılarnın Jeolojisi	Article: Geological Evaluation of Study Area
1995	Tatar et al.	Paleomagnetic Study of Block Rotations in the Niksar Overlap Region of the North Anatolian Fault Zone, Central Turkey	Article: Geological Evolution just on the study area
1999	Sakinc et al.	Thrace Basin and the Tethys-Paratethys Relations at Thrace	Closure of the Ancient Tethys Ocean
2000	Barka et al.	Taşova, Erbaa pull-apart basins, North Anatolian Fault Zone: their significance for the motion of the Anatolian block	Article: Geological Evaluation of Study Area related with the tectonism of whole NAFZ
2000	Canik and Kayabalı	Niksar (Tokat) Zeminlerinin Depremsellik Açısından Değerlendirilmesi	Report: a Geotechnical Investigation Project in Niksar
2006	Faccene et al.	Slab Detachment beneath the Eastern Anatolia: a Possible Casue for the Formation of the North Anatolian Fault	Article: Geological History of the NAF zone Consequently of Niksar
2006	Tatar et al.	Kuzey Anadolu Fay Zonu – 1942 Erbaa-Niksar Depremi Yüzey Kırğı: Yeni Gözlemler	Proceeding: Recent Observations on the tectonidm around the study area
2007	Tatar et al.	Intercontinental Quaternary Volcanism in the Niksar Pull Apart Basin, North Anatolian Fault Zone	Article: Opinions about the Volcanic Lithologies exposed in the study Area

The oldest reference for the geology of the study area is Blumenthal (1945). This is an earthquake investigation based on the geology of the Kelkit Valley after the devastating ground shaking of 1942 Erbaa (Table 1.1).

Study of Ketin (1969) did not focus on Niksar, directly but; the paper evaluate the tectonism in whole country and consequently the North Anatolian Fault Zone. Moreover, tectonism induced topographical morphology were also defined. The other similar study is Barka et al. (2000). This paper tried to evaluate the relationship between the strike slip faulting properties around the study area to define the major tectonic activity of the northern Anatolia (Table 1.1).

Terlemez and Yilmaz (1980) carried a geological survey just north of the study area, covering Ordu Province, Unye, Koyulhisar and Resadiye settlements. And, the study of the Aktimur et al. (1992) is a geological investigation of the study area. It puts the fundamental characteristics of stratigraphy and structural geology of the study area.

There are some other references contributing the thesis to present the brief geological history of the study area. These are turned to explain general geological history of Anatolia and the North Anatolian Fault Zone. Sakinc et al. (1999) dealt with the closure of Tethys Ocean. Facenna et al. (2006) put an idea forward that the reason of the NAFZ and EAFZ (East Anatolian Fault Zone) is the slab detachment around Eastern Anatolia.

Tatar et al. (1995), in addition to the geological investigation, the paleo-magnetic data are used for evaluating the geological history of the study area. Tatar et al. (2006) presented a field study tracing the exposure of the main fault, which produced 1942 Erbaa earthquake, passing through the study area. Tatar et al. (2007) is a study about the Niksar plain and its volcanic material after the young Quaternary activities.

Canik and Kayabali (2000) have prepared a report evaluating the situation of Niksar city toward earthquake hazard. It includes a precise geological map and 36 boreholes of which there are 26 with logs, in situ and laboratory tests results. The text includes also natural periods of the ground whereby the seismic refraction technique.

Another project, which is carried out in the study area, is the drains project of Niksar Municipality carried by Danakol and Gedik (2003). This study focused on the water head levels for the sewage system. Boreholes given with it is for the level of the groundwater table. Additionally, there is a geological map, which is used, for this thesis, to complete the lithological distribution at the southern parts of the study area.

CHAPTER 2

GEOLOGY

2.1. Regional Geology

The study area is located in the Northern Anatolia where activities of the North Anatolian Fault Zone (NAF) are in progress (Blumenthal, 1945; Aktimur et al., 1992; Barka et al., 2000). Similar to the rest of Anatolia, there is a complex geological history giving the modern shape to the environment. Especially, dextral (right lateral) displacing strike-slip faults and their complexities cause highly involved boundary pattern in the distribution of geological formations (Barka and Kadinsky-Cade, 1988).

Blumenthal (1945) performed the first study of Kelkit dislocation over the North Anatolian Fault Zone. The geological characteristics of the whole Kelkit Valley Region have the same origin and geological history. The study proved that, the Kelkit Valley and division of the Northern Mountain Ridges of Anatolia into two slices as northern and southern is the result of the tectonic activity along the North Anatolian Fault Zone.

The regional geology (Figure 2.1) exhibits transition from the oceanic environment to the continental environment. Ultimately, the tectonic activity along the NAF has prevailed for almost 11 million years. The end of the oceanic environment is related with the closure of the Tethys Sea. (Aktimur et al., 1992; Blumenthal, 1945; Barka et al., 1992; Barka et al., 2000; Facenna et al., 2006).

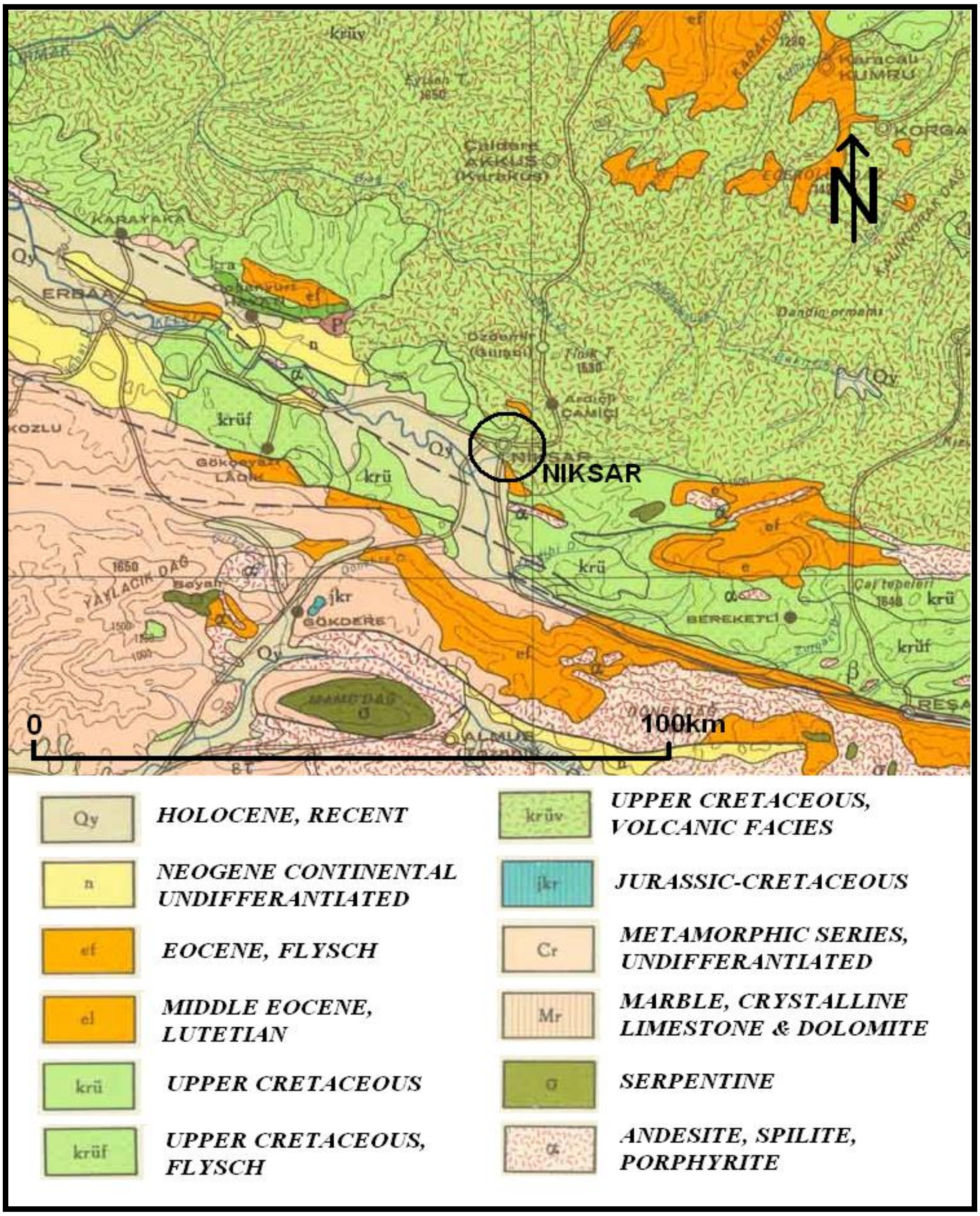

Figure 2.1. Regional geological map of the study area, taken from 1/500000 scale of MTA public maps (www.mta.gov.tr, last visited on August 2009)

Aktimur et al. (1992) have carried a geological survey just around the study area on the route of the North Anatolian Fault Zone. The basement is indicated to be

Turhal Metamorphic Zone of Permian to Triassic age (which is not observed in the study area). It has an unconformable boundary with younger units.

Figure 2.1 exhibits geological divisions of the study area and surroundings, concisely with respect to the geological age. Metamorphic Turhal group, aged Permo-Triassic, constitutes the basement rocks. Over this, carbonate dominant oceanic rocks of Jurassic age take place. Especially, Late Jurassic-Early Cretaceous exhibit continental sediment influx, which is concluded as uplifting of Anatolian Plate, with existence of carbonates (limestone) including clay, turning into claystone-limestone sequence. Upper Cretaceous rocks belong to active continental margin, especially, near shore. Harmankaya and Tersakan Formations, which are respectively turbiditic flysch and volcanogenic flysch, are indicators for this (Aktimur et al., 1992). The basaltic volcanism continued until the end of Eocene. A lacustrine sedimentation occurred during Pliocene. Quaternary period until today has witnessed sediment transportation to the tectonical pull-apart basins, which are formed due to the complexities of master faults of NAF (Aktimur et al., 1992; Blumenthal, 1945; Barka et al., 2000; Barka, 1992; Kiratzi, 1993; Tatar and Park, 1992; Inan and Temiz, 1992; Rojay and Goncuoglu, 1998; Facenna et al., 2006; Tatar et al., 2007).

2.2. Site Geology

Some of the previous geological surveys carried out in the study area include Barka et al. (2000), Aktimur et al. (1992). In this thesis, however, the geological map of Canik and Kayabali (2000) is adopted. This geological map covers the study area completely except the southern part of the city. The geology of this section is compiled with the geological map of Danakol and Gedik (2003). The compiled geological map of the study area is given in Figure 2.2 and the stratigraphic column is given in Figure 2.3.

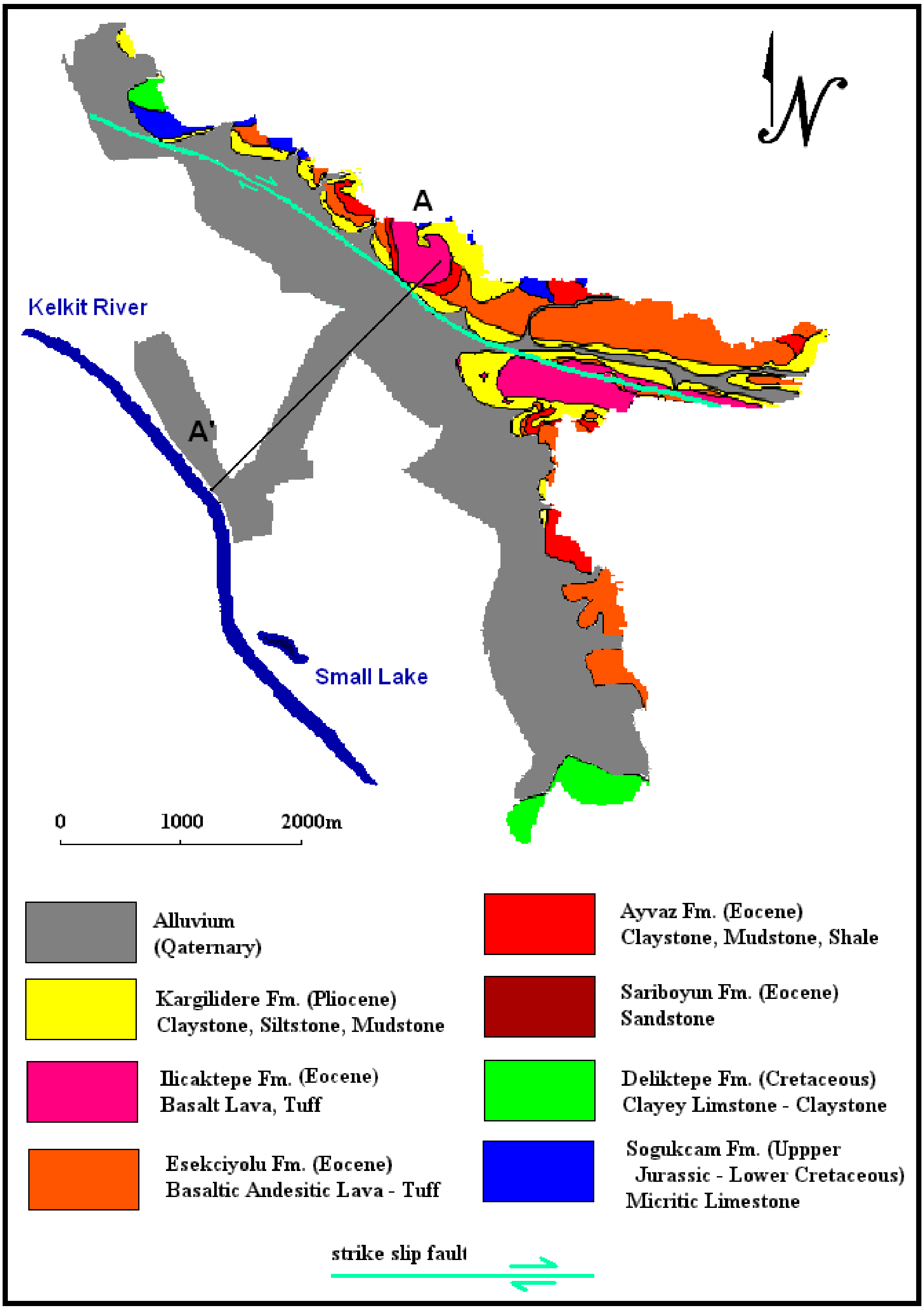

Figure 2.2 Geological map of the study area within boundaries only (modified from Canik and Kayabali, 2000; Danakol and Gedik, 2003)

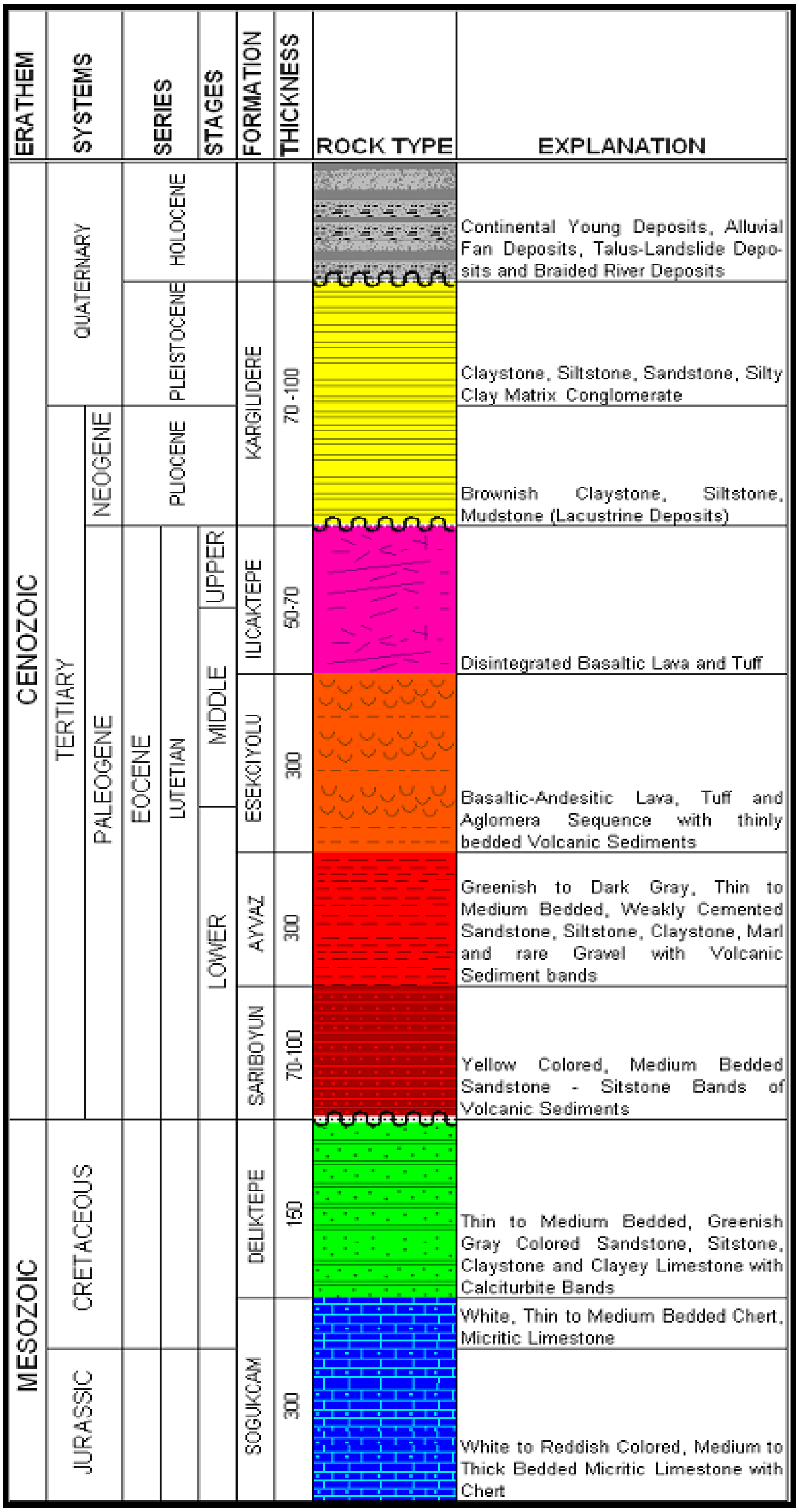

Figure 2.3. Stratigraphic section of the study area (not to scale) (modified from Canik and Kayabali, 2000)

2.2.1. Sogukcam formation

This formation exposes at the north and northwestern part of the study area. The observable color is white to bright gray. It is a distinct micritic limestone body. Upward direction exhibits clay inclusion. Then, claystone sequences occur. The thickness reaches 300m in the study area. Because it is the oldest unit observable in the study area, the lower boundary does not exist. However outside the study area, there are older formations dating back to Permian (Aktimur et al., 1992). It contacts with Deliktepe formation above, conformably. The age of the formation is Late Jurassic-Early Cretaceous.

2.2.2. Deliktepe formation

Its exposures are observed at the southern part of the study area in addition to some smaller exposures at the north. Yellowish gray color changes into greenish gray from lower to upper levels. Clayey limestone, siltstone and sandstone are dominant sedimentary rocks for the formation. Sequences of limestone disappear in the same direction of the color change. It is generally thinly bedded. The observed thickness is 150m, in the study area. It is diversified from upper levels of the Sogukcam formation then its lower boundary is conformable. However, it contacts with the overlying Sariboyun, unconformably. The age of the formation is Cretaceous, Valanginian stage (Canik and Kayabali, 2000).

2.2.3. Sariboyun formation

Its exposures are rare and distributed among the northeastern rocky part of the study area. Poorly sorted sandstone with the calcium carbonate cement constitutes thick to medium bedding with intermediate thin siltstone beds. The thickness ranges from 70 to 100m. Its color changes yellow to bright gray. It overlies Deliktepe formation, unconformably. The boundary with Ayvaz formation above is conformable. Its age is Eocene-Early Lutetian as the lowest Cenozoic unit of the study area (Canik and Kayabali, 2000).

2.2.4. Ayvaz formation

This formation exposes at the southeast of the city center and rarely eastern parts of the study area. The common color is bright yellow to bright gray. It is observed as frequent bedding of sandstone alternating with siltstone and shale layers. Upper sections contain sediments of volcanic origin. Sandstone exhibits two types of bedding. Thick beds are well cemented while thinner intermediate beds are weak and ready to break down, easily. The thickness of the Ayvaz formation is around 300m. It bounds with Sariboyun formation below and Esekciyolu formation. above, both conformably. The age of this unit is Eocen-Early Lutetian (Canik and Kayabali, 2000).

2.2.5. Esekciyolu formation

It has the greatest exposures among other formations observed in the study area. It differs from Ayvaz with beginning of volcanic sedimentation. It is sandstone composed of both volcanic and other types of continental clastics. Upper levels of the formation show andesite, tuff and agglomerate layers. The thickness is about 300m. It overlies the Ayvaz formation, conformably. Its boundary with overlying Kargilidere formation is unconformable with exhibiting time gap until Pliocene. This formation is aged Eocene-Middle to Late Lutetian (Canik and Kayabali, 2000).

2.2.7. Ilicaktepe formation

Its exposure is found at the southern banks of Canakci brook, at the eastern parts of the study area. Although it is indicated as a unit of the Esekciyolu formation by Canik and Kayabali (2000), it is observed as different formation from Esekciyolu formation (Eocene) in the field. Its relative age and lithology are consistent with Tekkekoy formation of Aktimur et al. (1992). It contains basalt and andesitic tuff. The observed thickness of the formation is 60 to 70m. The unit is aged Eocene-Late Lutetian.

2.2.7. Kargilidere formation

It exhibits several large exposures distributed over eastern parts of the study area. The formation is composed of brownish claystone, siltstone and mudstone, at the bottom. Then it turns into claystone, siltstone, sandstone and silty clay matrix conglomerate, to the top. The thickness ranges from 70 to 100m. Its contact with underlying the Esekciyolu formation is unconformity. It exhibits conformable boundary with Ilicaktepe fm., above. The age of the unit is Pliocene (Canik and Kayabali, 2000).

2.2.8. Alluvium

The Quaternary alluvium overlies the older formations, unconformably. Western part of the study area, which is on the Niksar pull-apart basin, is covered with alluvium. There are four sources of the material defined in the field. Alluvial fan deposits (1) are observed along foothills. Landslide deposits (2) are composed of materials as fragments of the closest rocks at uphill direction. Braided river deposits (3) are observable around the Channel of Kelkit River. The flood plain deposits (4) are spread throughout the flat parts of the study area, which are composed of fine-grained material (silt and clay) (Canik and Kayabali, 2000).

2.3. Seismicity of the region

As it is mentioned in the previous section, the Anatolian peninsula is one of most tectonically active regions. Devastating earthquakes occur frequently. According to the data published in the website of Kandilli Research Center (last visited on August 2009), there are 90 important earthquakes recorded from 1900 to 2005. Most of them were produced by the North Anatolian Fault Zone, along which Niksar is settled. Table 2.1 tabulates these earthquakes and those occurred around the study area are indicated with yellow brushing. These earthquakes are shown in Figure 2.4. These earthquakes produced considerable ground ruptures. The Anatolian plate moves westward along fault segments having total length of 900km (Barka et al., 2000; Ketin, 1969).

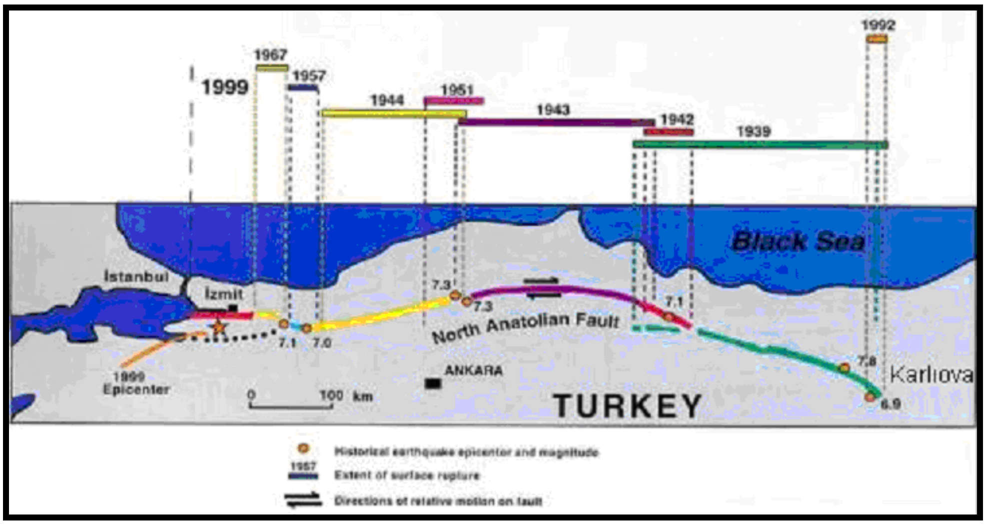

Figure 2.4. Earthquakes of large magnitudes around the study area from 1900 to 2000 (www.mta.gov.tr, last visited on August 2009)

Table 2.1. Devastating earthquakes of last century recorded in Anatolia (ref. Kandilli Research Center, Bosphorus University website, last visited on March 2009). Ones occurred around the study area are shaded.

	Date	**Epicenter**	**Mw**		**Date**	**Epicenter**	**Mw**
1	29.04.1903	Malazgirt, MUŞ	6,7	***46***	30.01.1964	Tefenni, BURDUR	5,7
2	09.08.1912	Mürefte, TEKİRDAĞ	7,3	***47***	14.06.1964	MALATAYA	6,0
3	04.10.1914	BURDUR	6,9	***48***	06.10.1964	Manyas, BALIKESİR	7,0
4	13.09.1924	Horasan, ERZURUM	6,8	***49***	13.06.1965	DENİZLİ	5,7
5	07.08.1925	Dinar, AFYON	5,9	***50***	07.03.1966	Varto, MUŞ	5,6
6	22.10.1926	KARS	6,0	***51***	19.08.1966	Varto, MUŞ	6,9
7	31.03.1928	Torbalı, İZMİR	6,5	***52***	22.07.1967	Mudurnu, ADAPAZARI	6,8
8	18.05.1929	Suşehri, SİVAS	6,1	***53***	26.07.1967	Pülümür, TUNCELİ	5,9
9	07.05.1930	İran Sınırı	7,2	***54***	03.09.1968	BARTIN	6,5
10	19.07.1933	Çivril, DENİZLİ	5,7	***55***	23.03.1969	Demirci, MANİSA	5,9
11	04.01.1935	Erdek, BALIKESİR	6,4	***56***	06.04.1969	Karaburun, İZMİR	5,9
12	19.04.1938	KIRŞEHİR	6,6	***57***	28.03.1970	Alaşehir, MANİSA	6,5
13	22.09.1939	Dikili, İZMİR	6,6	***58***	28.03.1970	Gediz, KÜTAHYA	7,2
14	21.11.1939	Tercan, ERZİNCAN	5,9	***59***	19.04.1970	Gediz, KÜTAHYA	5,8
15	27.12.1939	ERZİNCAN	7,9	***60***	23.04.1970	Demirci, MANİSA	5,6
16	13.04.1940	YOZGAT-KAYSERİ	5,6	***61***	12.05.1971	BURDUR	5,9
17	23.05.1941	MUĞLA	6,0	***62***	22.05.1971	BİNGÖL	6,8
18	10.09.1941	Erciş, VAN	5,9	***63***	06.09.1975	Lice, DİYARBAKIR	6,6
19	12.11.1941	ERZİNCAN	5,9	***64***	24.11.1976	Muradiye, VAN	7,5
20	15.11.1942	Bigadiç, BALIKESİR	6,1	***65***	05.07.1983	Biga, ÇANAKKALE	6,1
21	21.11.1942	Osmancık, ÇORUM	5,5	***66***	30.10.1983	ERZURUM-KARS	6,9
22	20.12.1942	Erbaa, TOKAT	7,0	***67***	18.09.1984	Balkaya, ERZURUM	6,4
23	20.06.1943	Hendek, ADAPAZARI	6,6	***68***	05.05.1986	Doğanşehir, MALATYA	5,9
24	27.11.1943	Ladik, SAMSUN	7,2	***69***	06.06.1986	Doğanşehir, MALATYA	5,6
25	01.02.1944	Gerede, BOLU	7,2	***70***	07.12.1988	KARS	6,9
26	25.06.1944	Gediz, UŞAK	6,0	***71***	13.03.1992	ERZİNCAN	6,8
27	06.10.1944	Ayvalık, BALIKESİR	6,8	***72***	15.03.1992	Pülümür, TUNCELİ	5,8
28	20.03.1945	Ceyhan, ADANA	6,0	***73***	06.11.1992	Doğanbey, İZMİE	6,0
29	21.02.1946	Ilgın, KONYA	5,5	***74***	28.01.1994	MANİSA	5,1
30	31.05.1946	Varto, MUŞ	5,9	***75***	01.10.1995	Dinar, AFYON	6,1
31	23.07.1949	Karaburun, İZMİR	6,6	***76***	05.12.1995	Kığı, TUNCELİ	5,7
32	17.08.1949	Karlıova, BİNGÖL	6,7	***77***	14.08.1996	Mecitözü, AMASYA	5,6
33	08.04.1951	İskenderun, ANTAKYA	5,8	***78***	22.01.1997	ANTAKYA	5,4
34	13.08.1951	Kurşunlu, ÇANKIRI	6,9	***79***	13.04.1998	Karlıova, BİNGÖL	5,0
35	03.01.1952	Hasankale, ERZURUM	5,8	***80***	27.06.1998	Ceyhan, ADANA	6,2
36	22.10.1952	Ceyhan, ADANA	5,6	***81***	17.08.1999	Gölcük, KOCAELİ	7,8
37	18.03.1953	Yenice, ÇANAKKALE	7,2	***82***	12.11.1999	DÜZCE	7,5
38	07.09.1953	Kurşunlu, ÇANKIRI	6,0	***83***	06.06.2000	Orta, ÇANKIRI	6,1
39	16.07.1955	Söke, AYDIN	6,8	***84***	15.12.2000	Sultandağı, AFYON	5,8
40	20.02.1956	ESKİŞEHİR	6,4	***85***	25.06.2001	OSMANİYE	5,5
41	25.04.1957	Fethiye-Rodos Hattı, MUĞLA	7,1	***86***	03.02.2002	Çay - Sultandağı, AFYON	6,4
42	26.05.1957	Abant, BOLU	7,1	***87***	27.01.2003	Pülümür, TUNCELİ	6,2
43	25.04.1959	Köyceğiz, MUĞLA	5,9	***88***	01.05.2003	BİNGÖL	6,4
44	23.05.1961	Fethiye-Rodos Hattı, MUĞLA	6,3	***89***	25.03.2004	Kandilli - Aşkale, ERZURUM	5,6
45	18.09.1963	Çınarcık, İSTANBUL	6,3	***90***	02.07.2004	Doğubeyazıt, AĞRI	5,1

The area around the city of Niksar witnessed 57 earthquakes of magnitudes greater than 4 (Figure 2.5). It proves that earthquake activity is the main thread for the city. Particularly, Erbaa Earthquake of 1942 wiped out the city located at the epicenter. It was also strongly felt in Niksar. A future earthquake will be very hazardous for the city. The list of earthquakes, which are shown in Figure 2.5, around Niksar is given in Table 2.2.

There are two proximal and important ground rupture observed in both Figure 2.5 and Table 2.2. These are westward 1942 Erbaa and 1917 Almus earthquakes. In addition to these, 1923 Artova and 1929 Koyulhisar cannot be excluded. These were powerful earthquakes and their reoccurrence are probable depending on the information that the activity of NAF has continued for 11 million years (Facenna et al., 2006).

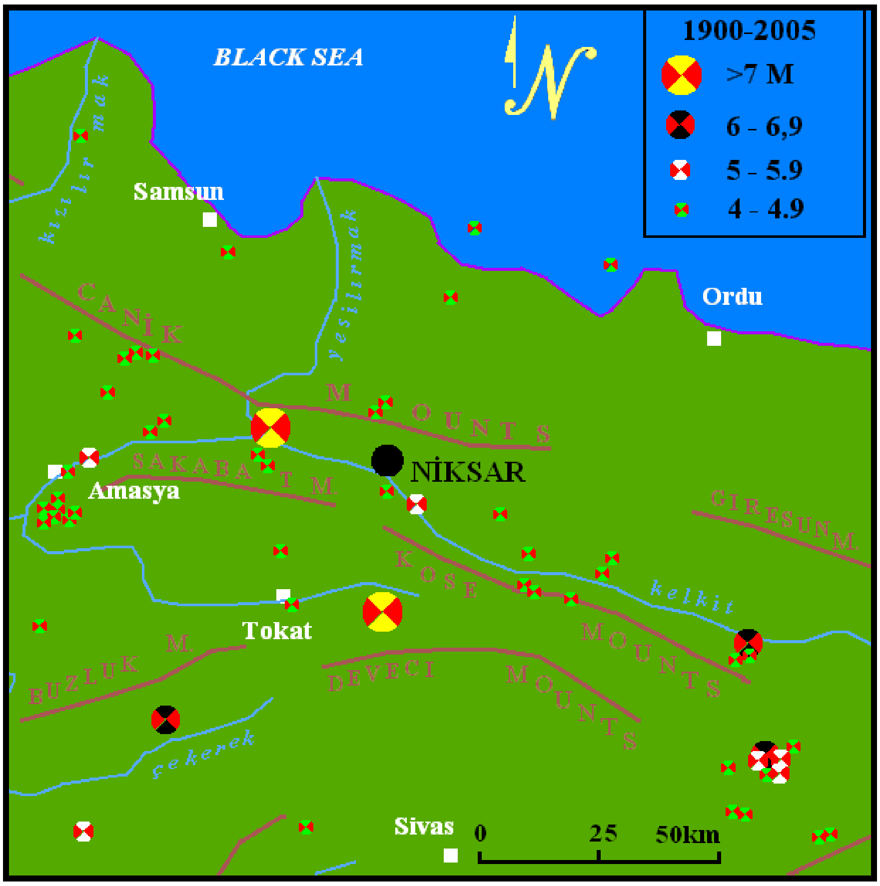

Figure 2.5. The map showing the earthquakes ($M_w \geq 4$) around Niksar recorded last century. (http://koeri.boun.edu.tr, last visited on March 2009).

Table 2.2. Details of the earthquakes exhibited in Figure 2.3. (data from Kandilli Research Center, University of Bosphorus website, last visited on March 2009)

No	Date	Latitude	Longitude	Location	M_w	UTM N	UTM E	ZN.
1	Jun 21, 1908	40,60	35,90	Sazköy, Amasya	5,2	4498397,50	745379,30	36T
2	Feb 9, 1909	39,98	38,00	Kumoğlu, Zara, Sivas	6,3	4426016,00	414614,62	37S
3	Sep 9, 1909	40,00	38,00	Kumoğlu, Zara, Sivas	5,8	4428236,00	414639,53	37T
4	Feb 9, 1909	40,05	38,00	Kumoğlu, Zara, Sivas	5,7	4433785,50	414701,84	37T
5	May 28, 1914	39,84	35,80	Akdağmadeni, Yozgat	5,4	4413751,00	739581,25	36S
6	Jan 24, 1916	40,27	36,83	Almus, Tokat	7,1	4459984,50	315493,88	37T
7	Apr 29, 1923	40,07	36,43	Çubuklu, Artova, Tokat	6,9	4438692,00	280837,03	37T
8	May 18, 1929	40,21	37,92	Akseki, Koyulhisar, Sivas	6,1	4451624,50	408093,47	37T
9	19 May 1929	40,19	37,88	Günışık, Koyulhisar, Sivas	4,5	4449447,00	404661,70	37T
10	Jun 28, 1929	40,20	37,91	Günışık, Suşehri, Sivas	4,5	4450525,50	407229,00	37T
11	Feb 25, 1934	40,31	36,56	Tokat Merkez	4,5	4465022,50	292657,03	37T
12	Dec 27, 1939	39,99	38,14	Kumoğlu, Zara, Sivas	5,5	4427001,50	426579,40	37S
13	Dec 27, 1939	40,80	36,80	Alanköy, Akkuş, Ordu	4,5	4518884,00	314411,66	37T
14	Dec 27, 1939	40,83	36,80	Alanköy, Akkuş, Ordu	4,9	4522215,00	314495,28	37T
15	Dec 28, 1939	41,05	37,01	İkizce, Ordu	4,5	4546215,00	332759,66	37T
16	Dec 28, 1939	40,47	37,00	Muhtardüzü, Niksar, Tokat	5,7	4481846,00	330451,34	37T
17	Feb 2, 1940	39,60	38,10	Aşağımescit, Zara, Sivas	4,5	4383749,50	422729,16	37S
18	Jun 7, 1940	40,06	37,82	Büyükgüney, Zara, Sivas	4,6	4435084,00	399362,50	37T
19	Dec 20, 1942	40,87	36,47	Narlıdere, Erbaa, Tokat	7,0	4527407,00	286795,62	37T
20	Aug 19, 1954	41,21	36,41	Kutlukent, Tekkeköy, Samsun	4,8	4565304,00	282859,94	37T
21	Jul 26, 1960	40,56	37,25	Hatipli, Başçiftlik, Tokat	4,6	4491386,50	351844,34	37T
22	Apr 1, 1962	40,80	36,10	Durucasu, Taşova, Amasya	4,7	4520603,00	255354,23	37T
23	Sep 21, 1964	41,10	37,60	Yalıköy, Fatsa, Ordu (Deniz)	4,2	4550802,50	382434,25	37T
24	Jul 10, 1970	40,99	35,91	Çadırkaya, Ladik, Samsun	4,5	4541726,50	744787,30	36T
25	Oct 17, 1970	40,61	35,79	İpekköy, Amasya	4,3	4499207,00	736035,40	36T
26	Apr 17, 1971	41,24	37,08	Sivaslılar, Terme, Samsun (Deniz	4,7	4567177,50	339108,38	37T
27	Jul 15, 1975	40,93	36,08	Hızarbaşı, Ladik, Samsun	4,6	4535092,50	254148,80	37T
28	Jul 15, 1975	40,91	36,06	Hızarbaşı, Ladik, Samsun	4,7	4532928,50	252389,92	37T
29	Jun 23, 1981	40,02	38,05	Kumoğlu, Zara, Sivas	4,3	4430409,50	418931,22	37T
30	Dec 7, 1981	40,66	36,00	Yassıçal, Amasya	4,3	4505343,00	246385,66	37T
31	Apr 6, 1984	40,52	36,63	Sarıtarla - Şehitler, Tokat	4,2	4488173,50	299231,47	37T
32	Jun 10, 1985	40,60	35,80	İpekköy, Amasya	4,5	4498123,50	736916,70	36T
33	Jun 10, 1985	40,56	35,81	Dadıköy, Amasya	4,2	4493710,00	737904,90	36T
34	Feb 12, 1992	40,59	35,83	İpekköy, Amasya	4,0	4497095,00	739491,30	36T
35	Feb 12, 1992	40,55	35,90	İlyas, Amasya	4,8	4492846,50	745562,20	36T
36	May 12, 1992	40,83	35,91	Eğribük, Suluova, Amasya	4,2	4523962,00	745378,70	36T
37	Jun 3, 1993	40,92	35,98	Tatlıcak, Ladik, Samsun	4,3	4534152,50	750941,56	36T
38	Jun 12, 1993	40,58	35,88	İlyas, Amasya	4,2	4496122,00	743759,44	36T
39	Jul 29, 1996	40,85	36,24	Sepetli, Taşova, Amasya	4,2	4525772,50	267341,30	37T
40	Sep 12, 1996	41,40	35,90	Dereler, Bafra, Samsun	4,0	4587221,50	742427,25	36T
41	Dec 1, 1996	40,48	37,22	Saraykışla, Reşadiye, Tokat	4,2	4482556,50	349125,20	37T
42	Dec 28, 1999	39,70	38,10	Dipsizgöl, Zara, Sivas	4,2	4394848,00	422840,40	37S
43	Dec 28, 1999	39,70	38,00	Dipsizgöl, Zara, Sivas	4,2	4394939,00	414267,12	37S
44	Apr 7, 2001	40,06	35,72	Yavıhasan, Kadışehri, Yozgat	4,2	4437962,50	731990,25	36T
45	May 3, 2001	40,58	36,66	Benli, Erbaa, Tokat	4,3	4494766,50	301949,94	37T
46	Feb 4, 2002	40,23	35,75	Küçükkarayün, Zile, Tokat	4,1	4456913,50	733964,75	36T
47	Sep 24, 2003	39,62	38,16	Aşağımescit, Zara, Sivas	4,0	4385919,00	427901,47	37S
48	Sep 27, 2003	40,54	35,81	Karaköprü, Amasya	4,3	4491489,50	737975,75	36T
49	Feb 3, 2004	40,65	36,52	Koçak, Erbaa, Tokat	4,2	4502862,50	290318,90	37T
50	Dec 14, 2004	39,77	36,73	Yıldızeli, Sivas	4,0	4404694,50	305575,56	37S
51	May 12, 2005	40,37	37,36	Yeşilyurt, Reşadiye, Tokat	4,4	4470115,50	360765,53	37T
52	May 12, 2005	40,34	37,36	Yeşilyurt, Reşadiye, Tokat	4,9	4466785,50	360703,80	37T
53	Jul 7, 2005	40,41	37,40	Karlıyayla, Reşadiye, Tokat	4,2	4474494,00	364242,10	37T
54	Jul 7, 2005	40,49	37,36	Toklar, Reşadiye, Tokat	4,2	4483436,50	361012,88	37T
55	Aug 29, 2005	40,52	36,82	Arıpınar, Niksar, Tokat	4,0	4487758,00	315328,00	37T
56	Sep 24, 2005	40,36	37,38	Yuvacık, Reşadiye, Tokat	4,0	4468974,50	362443,30	37T
57	Oct 23, 2005	40,03	37,58	Yeniköy, İmranlı, Sivas	4,3	4432052,50	378840,28	37T

There is a program called SMSIM which is a set of programs collected by David Boore, which is shared in USGS web site, that supplies a practical method to estimate artificial earthquake records, consequently, ground acceleration on rocks, at definite proximity and with the definite magnitude. A driver of the program called “a_ts_drvr” calculated that the maximum ground accelerations must have been 0.21g and 0.31g for Almus 1919 and Erbaa 1942 earthquakes, respectively.

Segments of the NAF are observable around the study area. There are long strike-slip faults passing through the study area or the close vicinity from west to east. At the same time there is another one just southwest of the study area which is the fault ruptured during 1942 Erbaa earthquake (Tatar et al., 2007).

The ground rupture of Erbaa 1942 earthquake is observable in vicinity of the study area at the west (Tatar et al., 2007). Consequently, the same magnitude of this earthquake, which is M_w of 7.0 (Table 2.2), is expected for a possible ground shaking of the future. This magnitude is also confirmed in studies of Ambraseys (1970), Saroglu et al. (1992), Barka (1996) and Ozmen et al. (1997). The expected peak ground acceleration is 0.45g on soil with respect to the attenuation relationship of Abrahamson and Silva (1996).

CHAPTER 3

DATA PREPARATION FOR THE STUDY AREA

This thesis focuses on preparation of a microzonation map of Niksar settlement area for urban planning purposes. As a consequence, geographical, geotechnical and geological information is obligatory. Contributing each type of data determines favorable and unfavorable regions for urbanization within Niksar city. Nevertheless, these are general factors related with urban planning. If it is considered locally, it will be seen that each information belonging to each discipline contributes the final output in different ways. The mission of the author is to identify the situation about the factors and resultant microzonation. Note that this study will supply a comprehensive background for further city planning projects, instead being a planning activity itself.

In this thesis, all parameters of the resultant microzonation map are defined and evaluated, individually. Each of them is the interest of different disciplines or branches, such as, geology, geotechnics, geophysics and geography.

The phenomenon of the convenience for the urban settlement covers various data, which are not usually related to each other. After they are all finished up with respect to their own criteria and analyzed, the final microzonation map is produced.

3.1. Reference data and maps

Information about geography of the study area is essential for this microzonation map for, at least, the positioning. At the same time, the relief distribution of the study area, which gives the geometry of the land shapes, is derived from the geographical information. Well-defined coordinates belonging to the Universal Transverse Mercator Sytem supplies the consistency among maps of all parameters.

3.1.1. Cartographic maps

Municipality of Niksar has supplied 46 cartographic maps having scale of 1/1000. They were prepared for city planning utilities. These maps, totally, exhibit properties in the city border and, somewhere, adjacent areas in the range of about 500m from the border. Each of the original map has the dimensions of 120cm x 100cm. Topographical map of the study area with coordinate system of UTM in meters, in Zone 37T is shown in Figure 3.1. The datum is European 1950 mean.

The assigned coordinates of the available maps were not realistic. In the beginning, existing UTM coordinates were not belonging to Niksar. True coordinates are assigned again and they are verified with GPS devices in situ, on the pre-defined measurement points.

It is not convenient to exhibit all 46 maps, here. Instead of these, a low-resolution contour map is given in Figure 3.1. This map contains contours of only ten meters altitude increment to just show conditions of the contour distribution with borehole locations. Original maps have the altitude increment as 5m, 1m and 0.5m with respect to the rate of the elevation change.

The map shown in Figure 3.1 contains locations of boreholes both drilled for this project (logs are available in Appendix A) and presented by Canik and Kayabali (2000). Coordinates, depths and other geotechnical information of new boreholes are given in Appendix B.

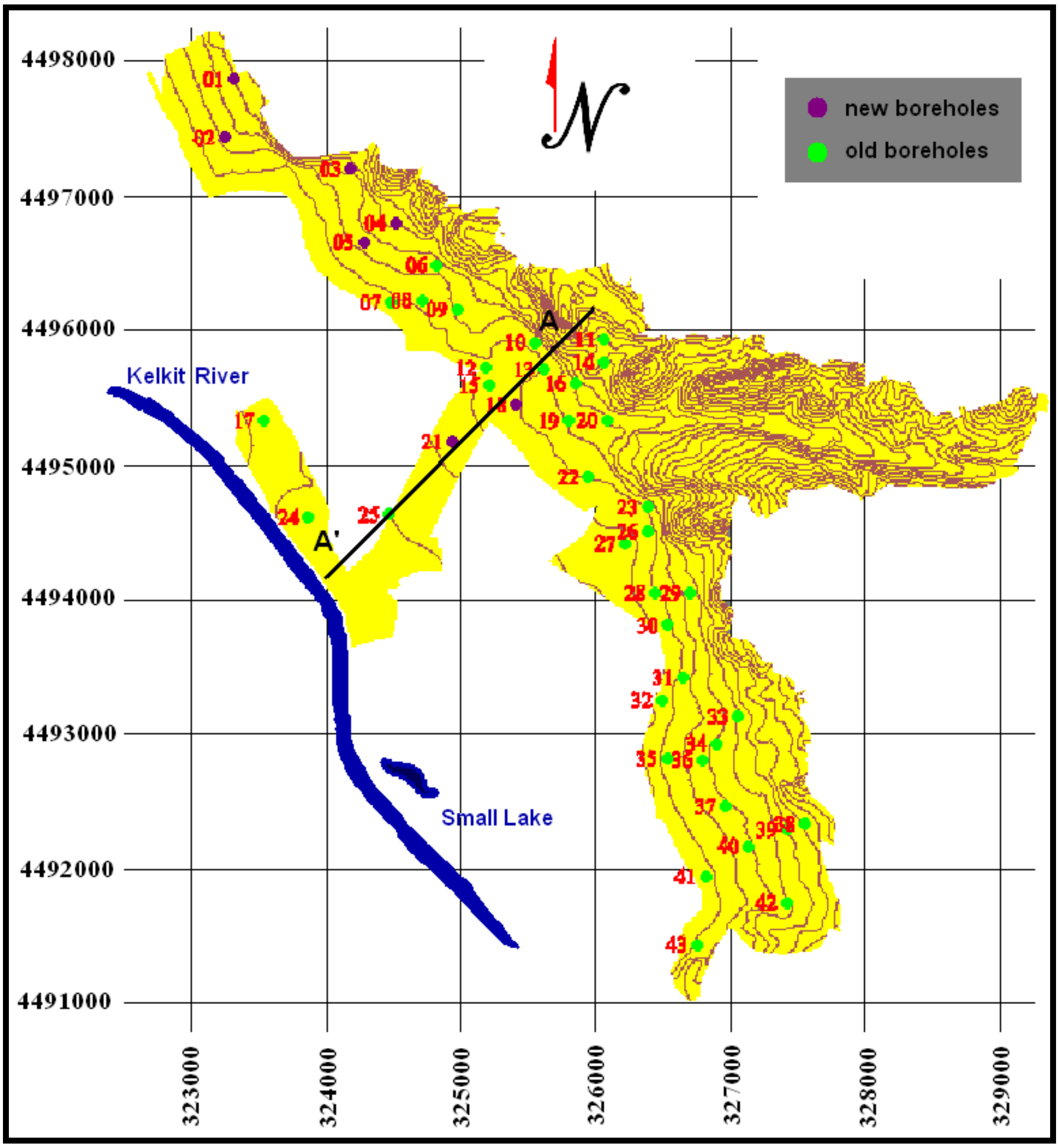

Figure 3.1. Contour map of Niksar with borehole locations.

3.1.2. Geological maps

An adequate geological reference map is supplied for this project. Primarily, the map has been prepared by Canik and Kayabalı (2000). It is updated and extended by using the map proposed by Danakol and Gedik (2003). Then, all of these are checked in the field for the verification of the lithological boundaries. The reason is that initial map covers mostly northern rock units and adjacent alluvium with respect to the city border of that date. It did not approach to the Kelkit River. The updated map (Figure 2.2) covers whole area of the city.

3.1.3. Groundwater conditions

The Kelkit Valley region on which Niksar city settles is one of the most important water shaded area of Anatolia. Even in July and August, brooks do not dry out and green plants cover everywhere. There is a depth to ground water map in Figure 3.2. It is evaluated from the altitude values of stream channels having their flowing water and some defined borehole measurements. The flat area at southwest of the city center has shallow groundwater levels, especially in sections proximal to stream channels and it is about 1m within alluvium-covered parts of the study area. Nevertheless, the eastern part of the study area is not included in Figure 3.2 because the ground is not alluvium and there is no borehole data.

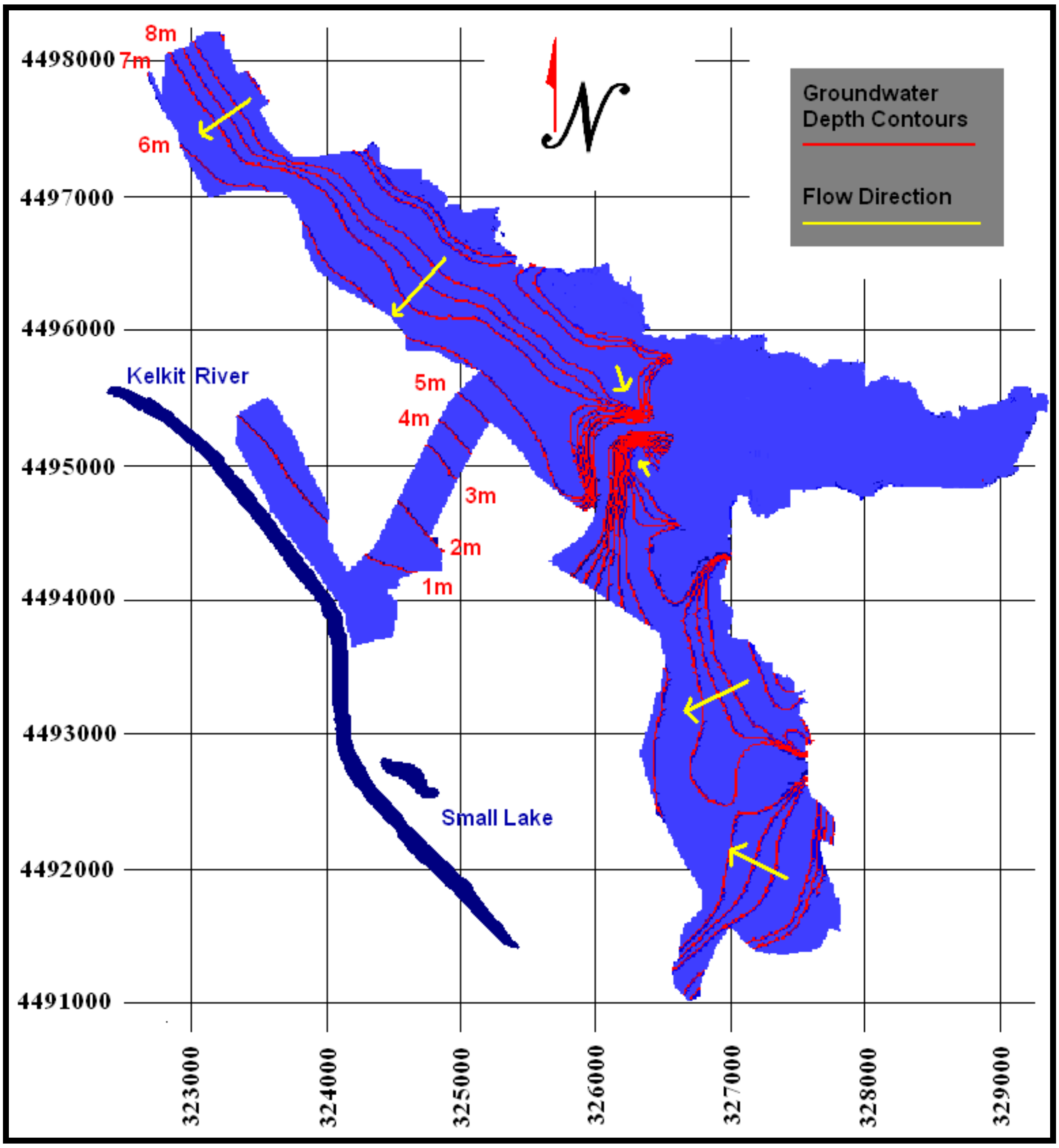

Figure 3.2. The depth to groundwater table map.

3.2. Geotechnical data

Because this microzonation study tries to evaluate the ground suitability for urbanization purposes, the ground investigation has the great importance. In addition to observations on the surface, the subsurface was investigated by means of newly drilled 7 boreholes (with SPT tests and undisturbed sampling via Shelby tube) in addition to the available 35 boreholes opened by Canik and Kayabali (2000).

The common soil type is SC (Unified Soil Classification System: Wagner, 1957; Craig, 2001) observed as grayish brown medium dense, in the study area. The cross section along the axis A-A' shown in Figure 3.1 is in Figure 3.3 (see Appendix B). The other common soil type is CL observed as grayish brown. The third type is medium dense grayish brown GC. The last type is low plastic grayish brown ML.

Disturbed and undisturbed samples test were tested in the laboratory. The laboratory tests include particle size determination by sieve analysis, water content determination, unit weight determination and Atterberg Limits tests.

Seven boreholes drilled for this thesis is not problematic (for logs please see Appendix A). Nevertheless, the rest presented with the study of Canik and Kayabali (2000) encountered with problems during drilling. Especially, the part of the alluvium originated dominantly from landslide deposits has boulder size sediments. When the drilling equipment came across such material, some of the drills had had to be ceased.

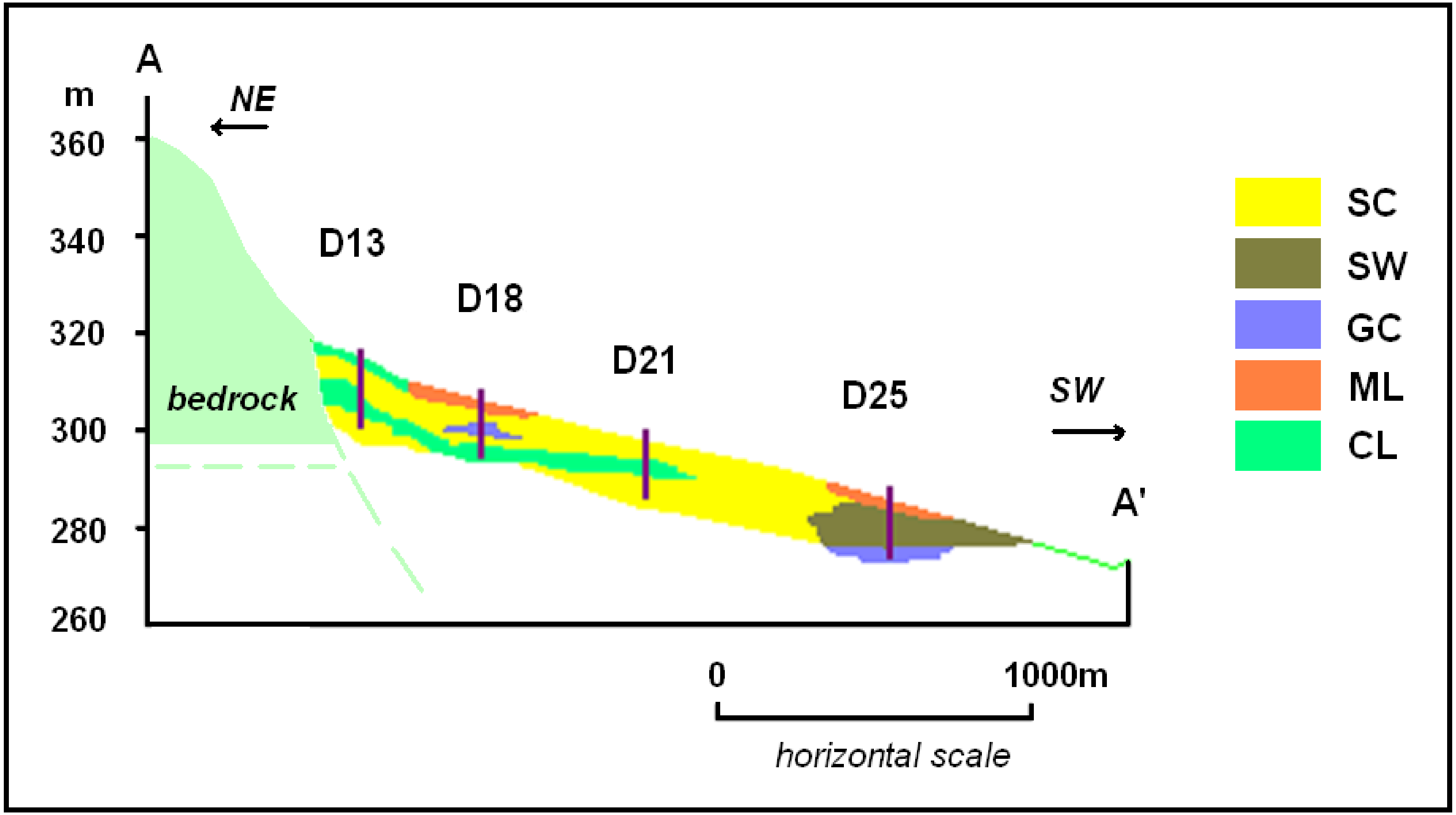

Figure 3.3. Cross-section showing soil types along A-A'

3.2.1. Plasticity of soil in the study area

Plasticity classification is necessary for fine-grained soils. The purpose for inspecting the plasticity is to evaluate the activity, which classifies the expansive behavior of the soil. The liquid limit, the plastic limit and the grain size distribution are necessary to define the activity. Then the equation (3.1) of the Plasticity is;

$$PI = LL - PL \tag{3.1}$$

where PI , LL and PL are results of Atterberg Limits Test as the plasticity index, the liquid limit and the plastic limit, respectively. The value of PI determines the water that the soil can hold until it passes to the liquid state. The plasticity chart is given in Figure 3.4. The plasticity due to clayey material in the soil and the portion of clay gives an idea how the soil behaves in the nature. It is called the Activity in Equation 3.2:

$$activity = {}^{PI}\!\big/_{Clay\_Content} \tag{3.2}$$

The result of the Equation 3.2 is plotted on the activity chart of Unified Soil Classification System. There is an example of it in Figure 3.5 containing results of activity for this thesis. The low expansion is expected dominantly for the soils of the study area. The rest is the rocky ground at the east. Nevertheless, there is a section exhibiting medium plasticity around the borehole named D-24. The medium expansion is expected at this location.

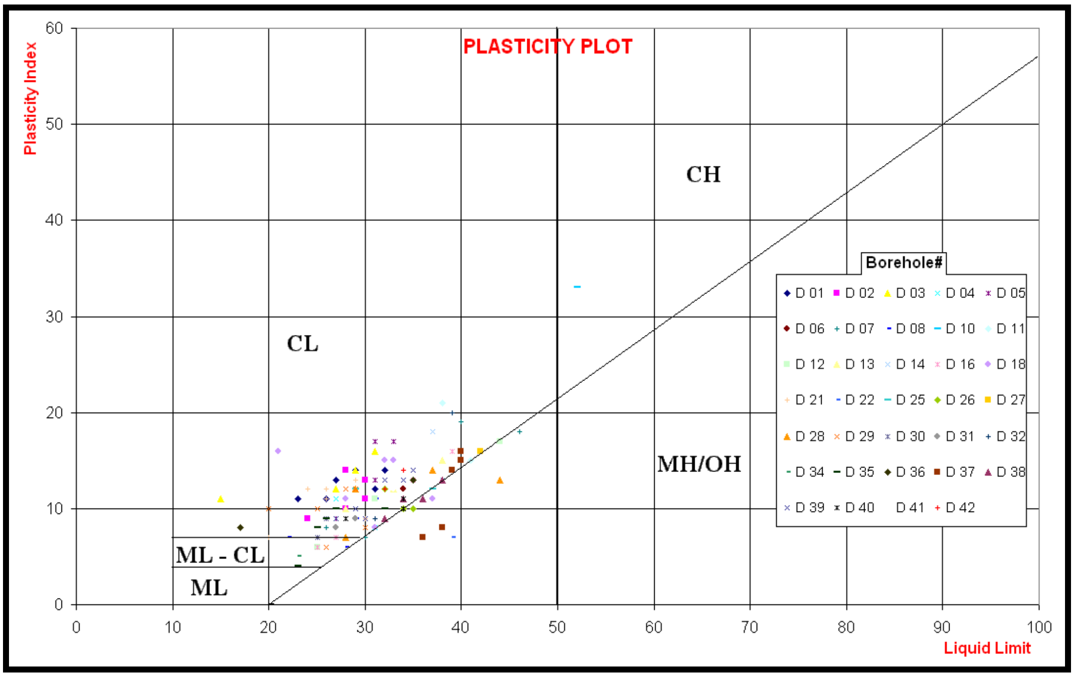

Figure 3.4. Plasticity chart of disturbed borehole samples of the study area.

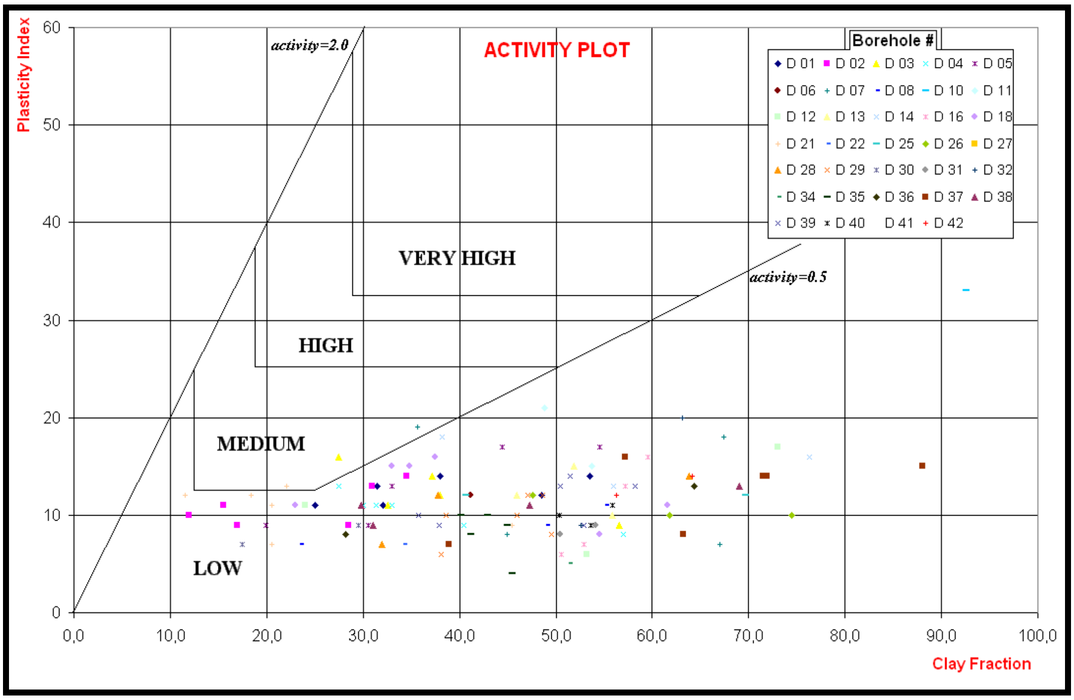

Figure 3.5. Activity chart of disturbed borehole samples of the study area.

3.2.2 Liquefaction susceptibility

Liquefaction event is a secondary effect of the earthquake causing saturated sandy layers mobilized (Cetin et al., 2004). In general, if a soil layer is said to be liquefiable; it must be low plastic (low fine content), it must contain pore spaces filled with water (or below the groundwater table), its depth must not pass 20m from the ground surface (relatively low pressure zone) and it must be thick enough according to its potential (Iwasaki et al., 1982; Iwasaki et al., 1984; Papathanassiou, 2008). Nevertheless, all of these conditions are operative for a complete liquefaction. A soil layer, which does not fulfill these at all in seismically active area, is called low potential liquefiable but it is still able to defect engineering constructions above the ground surface (Toprak and Holzer, 2003).

The data for the liquefaction susceptibility map is evaluated through the followings; the liquefaction factor of safety (Youd et al., 2001), the Chinese Criteria for fines (Woang, 1974; Derekashandi et al., 2007), the liquefaction potential index (LPI) (Iwasaki et al., 1982; Iwasaki et al., 1984; Toprak and Holzer, 2003) and the principle for the depth and thickness of the liquefiable strata (Ishiara, 1985).

First of all, the liquefaction factor of safety is evaluated for soils of each borehole. Then, the results are checked with Chinese criteria for fines. After that, LPI values are determined from these safety factors. Finally, the safety condition with respect to the liquefaction is decided by means of Ishiara (1985) method (please see Appendix B).

3.2.2.1. Factor of safety for liquefaction

Contemporarily, the factor of safety is calculated from Standard Penetration Test result of the depth interval of the test using following in Equation 3.3;

$$F = \frac{CSR}{CRR} K_{\sigma} \tag{3.3.}$$

where CSR , CRR and K_{σ} are the cyclic stress ratio, the cyclic resistance ratio and the effective overburden stress factor, respectively (Youd et al., 2001). The Equation 3.4 for CSR is;

$$CSR = 0.65 \frac{\sigma_v}{\sigma_v'} a_{\max} r_d \tag{3.4}$$

where σ_v , σ_v' , a_{max} and r_d are the vertical total stress, the vertical effective stress, maximum ground acceleration and the stress reduction factor (Equation 3.5), respectively.

$$r_d = \frac{1 - 0.4113\sqrt{z} + 0.04052z + 0.001753(\sqrt{z})^3}{1 - 0.4177\sqrt{z} + 0.05729z - 0.006205(\sqrt{z})^3 + 0.001210z^2} \tag{3.5}$$

where z is the depth of the SPT test starting point. Then the cyclic resistance ratio (in Equation 3.6):

$$CRR = \frac{1}{34 - (N_1)_{60}} + \frac{(N_1)_{60}}{135} + \frac{50}{[10(N_1)_{60} + 45]^2} - \frac{1}{200} \tag{3.6}$$

where $(N_1)_{60}$ is the corrected blow count from SPT test results (Equation 3.7).

$$(N_1)_{60} = N.C_E.C_R.C_B.C_S.C_N \tag{3.7}$$

where N, C_E, C_R, C_B, C_S and C_N are the blow count, the energy ratio correction factor, the rod length correction factor, the borehole diameter correction factor and the overburden correction factor, respectively.

The energy ratio correction factor (C_E) is taken as 1.17 because a safety hammer was used for drilling. The rod length correction factor (C_R) is taken 0.75, 0.80, 0.85, 0.95 and 1.00 for rod lengths of shorter than 3m, 3 to 4m, 4 to 6m, 6 to 10m and longer than 10m, respectively. The borehole diameter correction factor (C_B) is taken as 1 because the diameters of all boreholes are 110mm. The sampling method correction factor (C_S) is taken as 1 because a standard sampler was used. The overburden correction factor (C_N) is calculated with respect to Equation 3.8:

$$C_N = {}^{50}\!\big/_{10+\sigma'_v} \tag{3.8}$$

where σ'_v is effective overburden stress in psi (Liao and Whitman, 1986).

3.2.2.2. Chinese criteria for fines

Derakshandi et al. (2007) states that the void ratio and the plasticity due the fine content are decisive on the liquefaction susceptibility. The void ratio is important to hold water within the soil, which is pressurized during the earthquake. At the same time test results presented in the paper show that increasing void ratio gives rise to strength loss of the soil.

Prakash and Puri (2003) mentioned criteria for liquefaction. A soil, which has clay content smaller than 20%, liquid limit (LL) between 21% and 35%, plasticity index (PI) between 4 and 14, saturated water content greater than 0.90 times of the liquid limit and liquidity index greater than 0.75, is susceptible to liquefy.

In this thesis, the saturated water content, the plasticity of the soil and the liquidity of the soil samples are considered for the use of Chinese criteria (Woang, 1974; Tianqiang and Prakash, 1999).

3.2.2.3. Liquefaction potential index determination

The factor of safety implies the existence of the liquefaction and there are, commonly, more than one, different liquefiable layers at one location. Therefore, it is convenient to define liquefaction potential property of the ground and a distribution of it, throughout the study area. Liquefaction Potential Index (LPI) approach suggested by Iwasaki et al. (1982) is a logical solution to perform this, because it stands for the complete soil column below the measurement point. Then, a DEM of LPI values from multiple locations can be obtained. The equation (3.9) of LPI is;

$$LPI = \int F(z)w(z)dz \tag{3.9}$$

where *F(z)* and *w(z)* are functions of the factor of safety and the depth factor, respectively (Iwasaki et al., 1982). Actually, this approach is applicable with only SPT results, so the depth difference controlled by *dz* operator is not a regular increment. It keeps the levels of standard penetration resistance measurements. The function (Equation 3.10) of the depth factor;

$$w(z) = 10 - 0.5z \tag{3.10}$$

where *z* is the depth from the ground surface (Iwasaki et al., 1982).

3.2.2.4. Depth and thickness of the liquefiable strata

The initialization of the liquefaction needs convenient stress distribution due to the overburden composed of non-liquefiable material, if all other terms such as; the sand proportion, the fine content and the existence of the groundwater, are satisfied (Ishiara, 1985). In cases that, the depth of the liquefiable layer is more than 10m, liquefaction induced ground manifestations will not occur. On the contrary, shallow layers may produce ground deformations.

The method divides the envelope in two sections (Figure 3.6). At the right side of the curve, conditions of the thickness of the liquefiable layer and its depth will allow the liquefaction when objected to the peak ground acceleration of 0.4g, under dynamic conditions.

Borehole data of the study area shows that some of measurement points do not exhibit liquefiable material. Some of logs exhibit low liquefaction factor of safety values below the depth of ten meters. The rest is plotted (Figure 3.6) and each of them is tabulated in Appendix B. Based on Figure 3.6, it can be postulated that the whole liquefaction prone sites of the study area need at least 0.4g of ground acceleration to be liquefied.

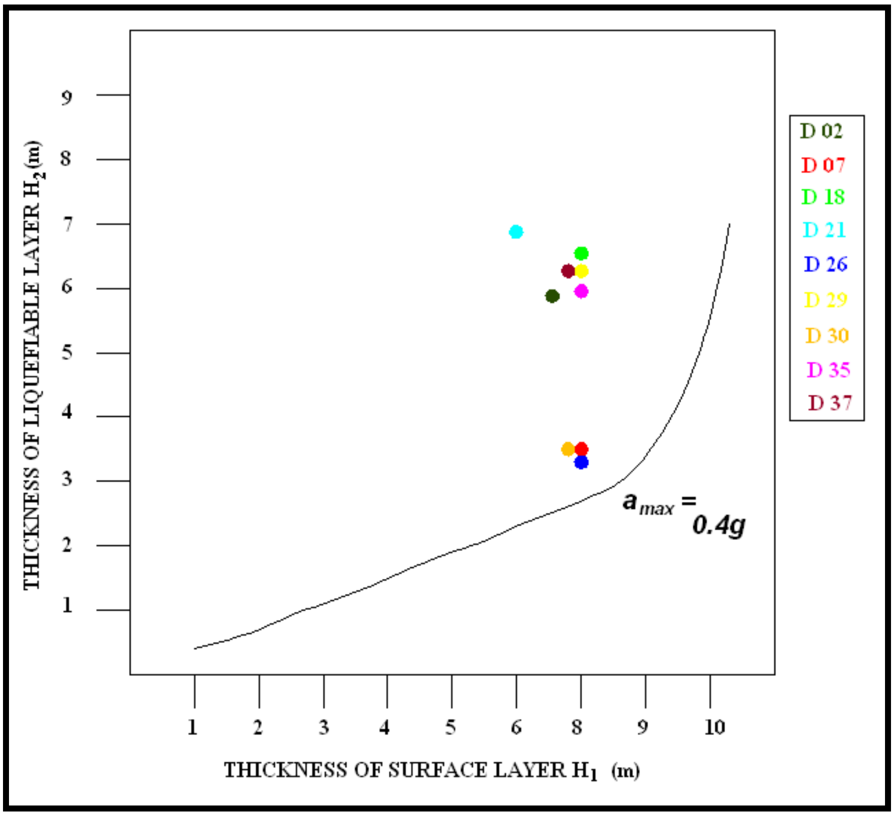

Figure 3.6. Proposed boundary curve by Ishiara (1985) relating thickness of non-liquefiable zone as a function of 0.4g peak ground acceleration required to induce ground deformations.

3.2.3. Slope instability problems in the study area

The alluvium covered western part of the study area is nearly flat. Nevertheless, the eastern part exhibits more complex topography with increasing slope amounts. In addition to these, the alluvium in foothills at some locations is originated from landslide material.

Particularly, the material of the Ilicaktepe formation is poorly consolidated volcanic sediments. An active landslide scarp is observed during the field study

(Figure 3.7) on the exposure of this formation. It is also observed that a large ancient landslide exists above the active landslide (Figure 3.8).

Figure 3.7. The scarp of an active landslide. The photograph is taken from the point having coordinates of UTM Zone 37T, 4495175N and 327627E.

Figure 3.8. Main scarps of landslides from the landslide crown. The photograph is taken from the point having coordinates of UTM Zone 37T, 4494901N and 327557E.

3.3. Geophysical evaluation

In seismically active areas, in addition to geotechnical studies, geophysical investigations are also required to decide the suitability of the area for settlement. There are two data to predict dynamic properties of the foundation, in the study area. These are microtremor measurements carried out by Dikmen et al. (2009) and seismic refraction results proposed by Canik and Kayabali (2000).

The application of the microtremor measurements is conducted by Dikmen et al. (2009), in the study area. There are 496 points recorded as the measurement stations within the city (Figure 3.9). In such a case, whole study area is covered efficiently. The output of the test is practical to distribute as a digital elevation model.

Dikmen et al. (2009) presented both the natural period of the ground and the ground amplification, while the study of Canik and Kayabali (2000) included only the natural period of the ground. They are compared to check results of Dikmen et al. (2009) in Table 3.1. There are definite differences between the values of both studies, and the results of Dikmen et al. (2009) are preferred in this thesis.

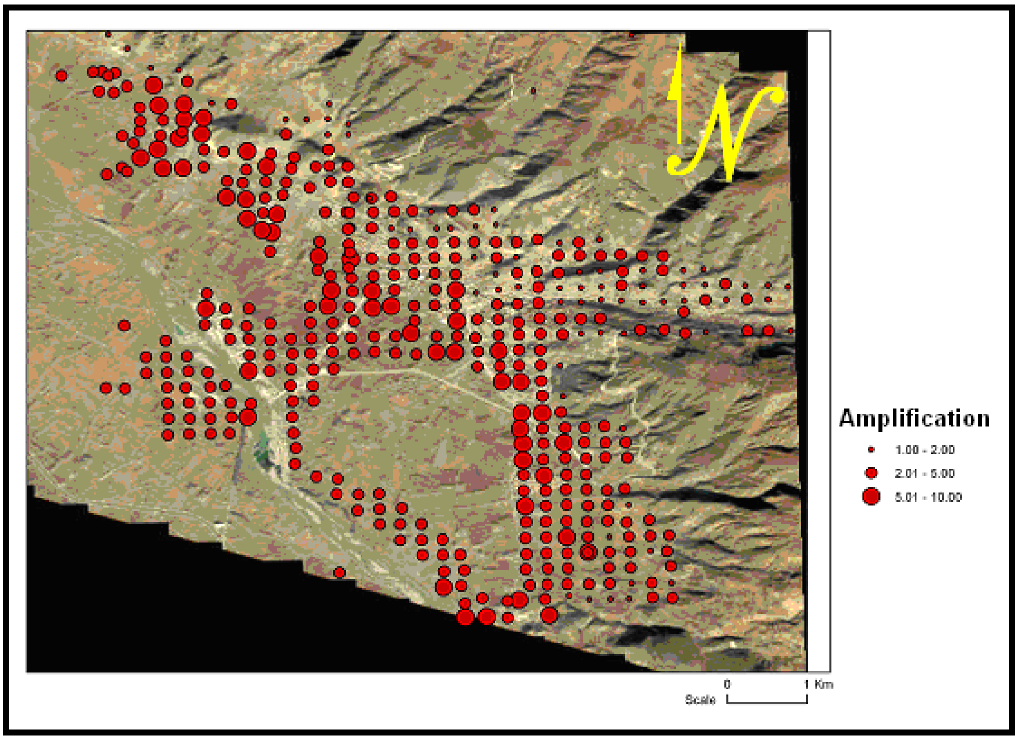

Figure 3.9. Niksar microtremor test measurement points (Dikmen et al., 2009)

Table 3.1. Comparison of natural period values, in seconds, belonging to seismic refraction testing by Canik and Kayabali (2000) and microtermor measurements by Dikmen et al. (2009)

Coordinate (UTM)			Natural Period (sn)	
Northing	Easting	Zone	Seismic Refraction	Microtremor
4496472	324817	37T	0.10	0.50
4494588	323875	37T	0.50	0.65
4495373	323574	37T	0.5	0.96
4494405	326190	37T	0.60	0.57
4492822	326779	37T	0.11	0.75
4491736	327433	37T	0.26	0.63

3.4. Properties of the city planning

Niksar is an ancient settlement. All new constructions have replaced the older ones or they are found together. Consequently, there is no systematic planning in city because older communities dwelled upon protection to fulfill security rather than the geological solicitudes. They searched for hindering topography toward enemies and easy access to water sources. In such a situation, buildings are found around several stream channels and steep slope faces (Akdamar, 2008).

Moreover, the city has lots of historical and cultural features. They are not convenient for settlement and related investigations. On the other hand, additional projects are obligatory to maintain them in the good condition. Therefore, such areas having historical importance are not handled in this study.

In addition to these, new constructions exist for different purposes and some of them are not open to the settlement. Some recreational areas and the park around the lake can be counted as the social facilities. They should be protected.

CHAPTER 4

IMPLEMENTATION OF GEOGRAPHIC INFORMATION SYSTEMS

In this chapter, all factors are distributed throughout the study area in digital elevation models. Every parameter is separately evaluated and classified into ranking groups with respect to their effects over the resultant microzonation map. The microzonation study needs a definite unit cell, which is a unit area of minimum scale of investigation. The size of the unit area is 100 m^2 as a square having side length of 10 meters. It is the half of the smallest distance between two contour lines with respect to Hengl (2006). All digital elevation models keep this size whether they are used directly for the output or they are temporal.

4.1. Topography of the study area

The topography of the study area is in three sections. The first is the digital terrain model of the study area, which is the base map for the layer analysis. The second is the slope map and the third is the aspect map. Slope and aspect maps are factors of the microzonation.

4.1.1 Digital terrain model of the study area

The digital elevation model of the topography (or digital terrain model) of the study area is produced by surface fitting technique of minimum curvature from contour lines. The curvature is preferred as linear scale because the altitude range is not very large. The initialization keeps the profiles procedure, because most of the neighboring contour lines have three or four pixels between them. The search area is circular and the search distance is 30 cells. This value is sufficient for fitting because it is the longest distance between two contour lines, approximately. The result is in Figure 4.1, which is the base map for the layer analysis producing resultant microzonation map.

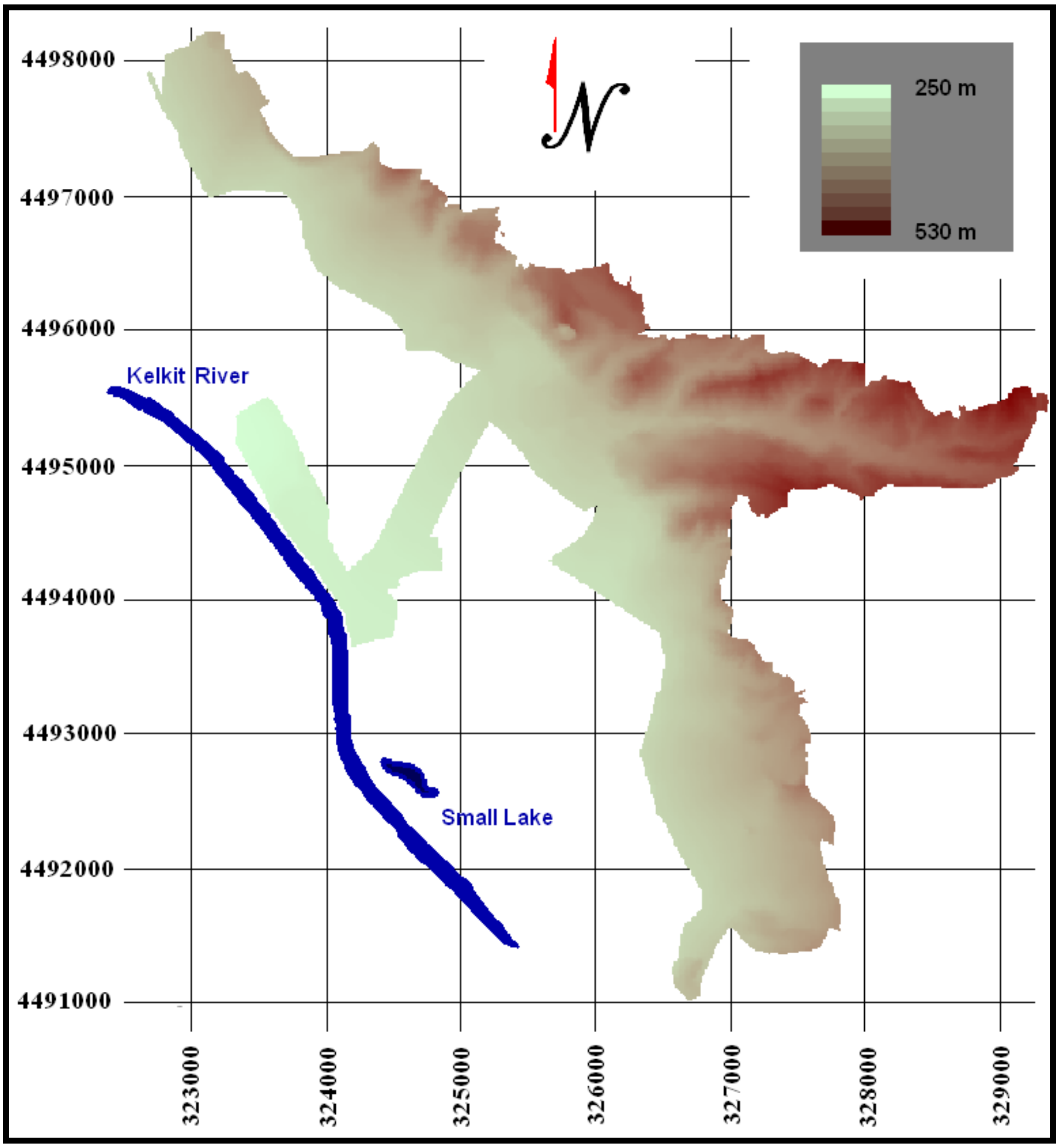

Figure 4.1. Digital terrain model of the study area.

There are other surface fitting techniques tried to fit the surface, such as; the Inverse Distance (the search area is circular, the search distance is 30 cells and the weighing power is 4), the Profiles (the search distance is 30 cells) and the Triangulation. According to digital elevation model standards of the United States Geological Surveys (USGS), the accuracy of a DEM is defined by calculating the root mean square error (RMSE) in Equation 4.1:

$$RMSE=\sqrt{\frac{(z_i - z_t)^2}{n}} \tag{4.1}$$

where z_i, z_t and *n* are elevation of DEM, true elevation at the same position and number of observation points, respectively. If difference between true elevation and the digital elevation is low, the RMSE will be small. The surface fitting technique, which will present the smallest RMSE, will be used for further processes. Table 4.1 shows RMSE values of four different surface fitting techniques mentioned in the previous paragraph. Note that digital elevation models have not been produced from point data due to lack of continuity and accuracy.

Table 4.1. RMSE chart of different surface fitting techniques

Point ID	**Point Coordinates**		**True Elevation**	**Minumum Curvature**	**Inverse Distance**	**Profiles**	**Triangulation by contours**
	Northing	**Easting**					
p1	4498064,161	322933,060	316,72	316,85900	316,78100	316,78100	316,85657
p7	4496249,304	324756,395	311,74	311,45000	311,84400	312,02800	312,28425
p11	4494067,609	324252,940	272,69	272,76200	273,02000	273,08600	273,66017
p15	4495866,162	327093,216	399,23	399,42800	399,56449	398,80648	399,91889
p19	4494990,227	327556,287	441,72	441,65300	442,04306	442,29166	440,90282
p21	4495695,128	326294,200	423,57	423,46000	423,38278	423,00045	422,57454
p24	4493081,572	326480,866	303,13	302,98800	302,99982	303,07615	303,80333
p25	4492624,353	327187,954	342,84	342,96500	343,82120	342,22711	343,50869
p28	4491809,089	325499,061	276,37	276,35200	277,24257	277,26458	276,19342
p29	4495625,643	327722,865	435,78	435,89100	436,56134	436,40298	436,70970
RMSE =				0,26687	0,54833	0,41457	0,59128

Elevation change lies in the range of 250 to 530 meters, relative to the sea level. Western and southwestern parts of the study area are almost large flat areas. They are in part of the Niksar Plain. However, in the city border, the flat area gets narrower toward both north and south. Flourishing of the city keeps the eastward direction starting from the Channel of Kelkit River. It is the same as the direction of increasing elevation. Consequently, highest points are observed eastward.

4.1.2 Slope map

The slope map of the study area is produced from the DTM of the study area. Majority of the city is on the nearly flat plains of Niksar pull-apart basin. Rest of the city has steeper slope amounts but they do not reach 50^o except the walls of the stone mine. In this study, it is preferred to divide observed topographical inclinations in 5 classes to obtain the resultant microzonation map.

The slope map in Figure 4.2 has one more division as slope angles more than 50^o. This division is also included in Table 4.2. Nevertheless, this and the division of slope angles between 30^o and 50^o are classified together in the layer analysis.

Table 4.2. Classification of slope parameter

Value - Range	0^o - 5^o	5^o - 10^o	10^o - 20^o	20^o - 30^o	30^o - 50^o	> 50^o	***Total***
Pixel Count	54251	25998	23330	10710	2033	60	*116382*
Share	46.61%	22.34%	20.01%	9.20%	1.79%	0.05%	*100%*

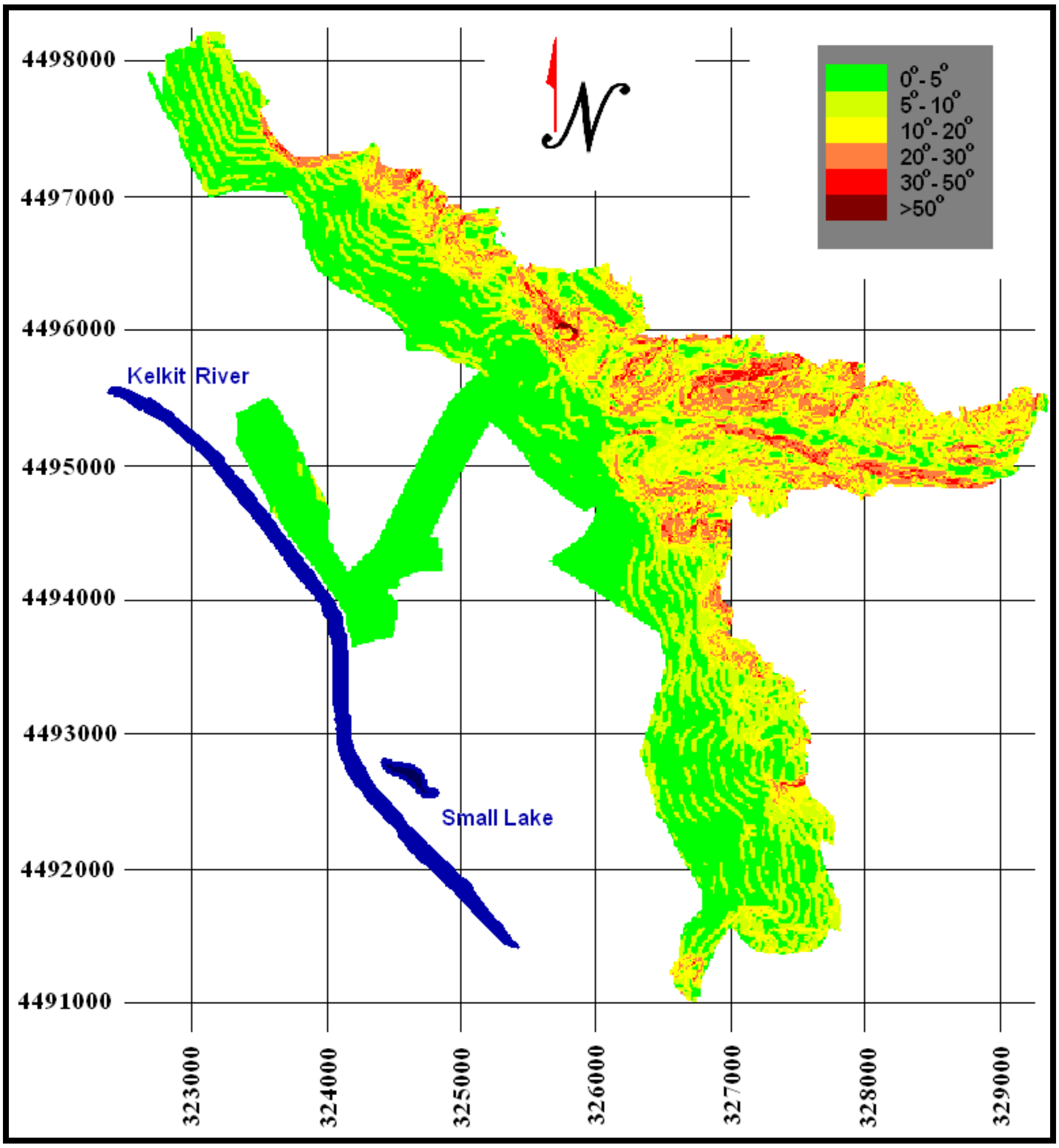

Figure 4.2. Slope map of Niksar.

4.1.3 Aspect map

The aspect map is produced from the DTM of the study area. It is in Figure 4.3 with legend of 12 divisions, which has π/6 radian slices. The details of the legend are tabulated in Table 4.3, but categories for the layer analysis depend on facing toward north, then the actual classification is given in Table 4.4.

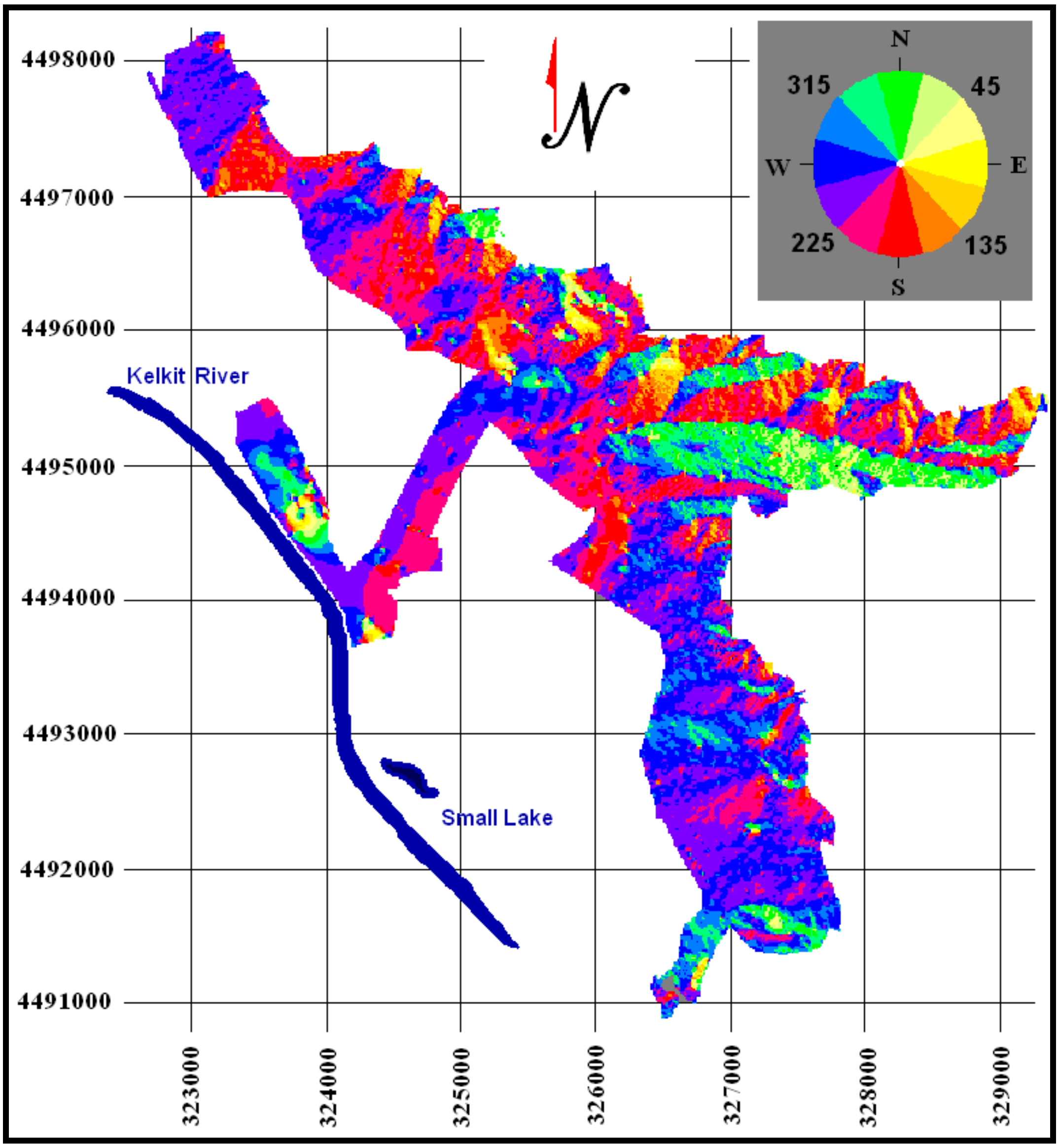

Figure 4.3. Aspect map of Niksar.

Table 4.3. Classification of the aspect parameter in the legend of Figure 4.3

Aspect Class	345° - 15°	15° - 45°	45° - 75°	75° - 105°	105° - 135°	135° - 165°	
Pixel Count	5045	2784	1242	1583	2436	4346	+
Share	4.34%	2.24%	1.07%	1.36%	2.09%	3.73%	+
Aspect Class	165° - 195°	195° - 225°	225° - 255°	255° - 285°	285° - 315°	315° - 345°	***Total***
Pixel Count	12421	21740	28321	21345	9445	5674	*116382*
Share	10.67%	18.68%	24.34%	18.34	8.11%	5.03%	*100%*

Table 4.4. Classification of the aspect parameter

Aspect Class	N	NW - NE	WNW	W - E	SW - S - SE	
Description	345^o - 360^o, 0^o - 15^o	315^o - 345^o, 15^o - 45^o	285^o - 315^o, 45^o - 75^o	225^o - 285^o, 75^o - 135^o	135^o -225^o	***Total***
Pixel Count	5045	8458	10687	53685	38507	*116382*
Share	4.34%	7.27%	9.18%	46.13%	33.08	*100%*

4.2. Data variation throughout the study area

This part of the prevailing chapter contains implementing rest of the data. Applications within the methods of the geographic information systems depend on the interpolation of the vector point data. These are borehole locations and microtremor measurement locations. Borehole samples and related laboratory tests produced geotechnical information. But the ground lithologies are derived from the polygon vector data, which divide whole study area into subdivisions of the lithology.

The liquefaction and the activity parameters of the microzonation are point data initially. Each point is the location of the borehole. The ground amplification has the similar situation, but this time, the number of points is much more and they are measurement points instead of boreholes.

4.2.1. Interpolation technique

Distribution of geotechnical and geophysical data, different from the topography of the study area, is derived from point data. Measurements are made at definite locations and the continuity cannot be tracked among the city, physically. Therefore, the necessity of the interpolation arises to estimate the value hold by the data at other unit cells. The Inverse Distance method is preferred in this study.

Interpolation choices of the point data are limited; such as triangulation, inverse distance, kriging and minimum curvature. Except from the kriging, other three gives almost same results. The kriging exhibits exaggerated anomalies in distribution, for all its techniques including different variogram models. The triangulation method has a disadvantage for this study that it covers the area inside of the linear links between outermost measurement points. It would not be a shortcoming if some of boreholes were at the margins of the study area to hold it completely. And, the minimum curvature method is more convenient for contour lines (Watson, 1992).

In the Inverse Distance Weighing method, the interpolation depends on the assumption that the definite area around the measurement point has the same value with the measurement point at the center. This area is chosen as circular for this thesis. The diameter of that circle is user-defined with respect to the distance between measurement points. It should intersect more than one of others. If this condition is satisfied, the midpoint between two measurement points has the value as the approximation of both. Then, the intermediate values are distributed exponentially (Watson, 1992). For the factors of the liquefaction and the activity, the eastern rocky ground is not included in the investigation because no borehole was drilled at this section. The search distances are chosen large because convenient boreholes to produce factor maps are sparse, far from each other and consequently there are many cells between them up to 70.

4.2.2. Ground lithology map

The ground type map is derived from the geological map of Niksar (Figure 2.2) with respect to general engineering properties of lithologies exposed at the study area. These properties are limited with observations rather than testing. Here, their joints, slope instability events, and material properties obtained from Canik and Kayabali (2000) are classified.

The main division begins with the difference between the rocky and soil ground. After that, the general properties of rocks are categorized with respect to their conditions in the study area and their types such as Limestone, Sandstone and Claystone. The final lithology map is given in Figure 4.4. This map shown in Figure 4.4 does not require any type of interpolation.

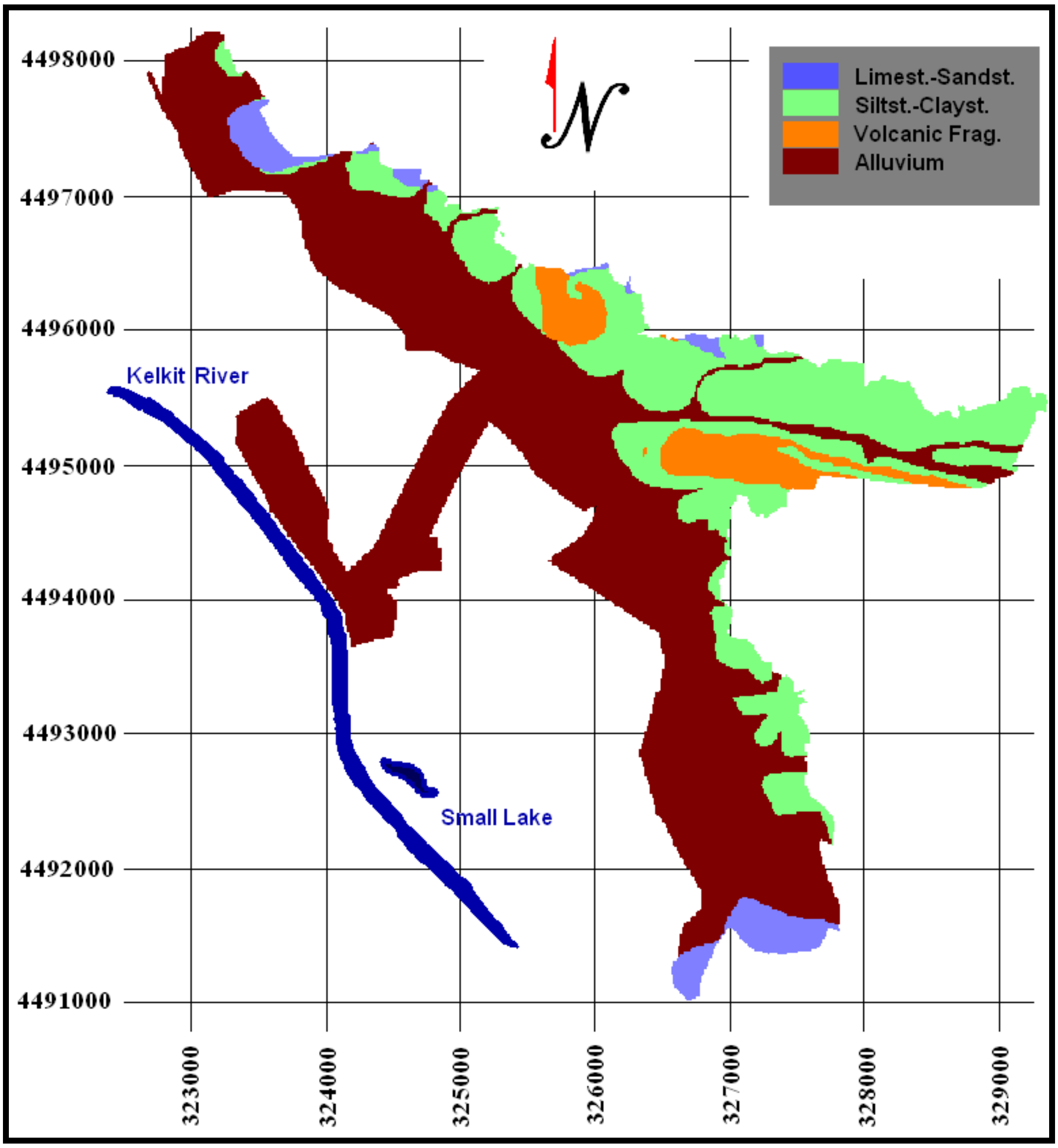

Figure 4.4. Lithology map of Niksar.

The classification shows a distinct separation between weak and strong material. Naturally, the young alluvium (Quaternary aged) is the most unsuitable material for the urban settlement. It is not found on steep slopes. In addition to this, Ilicaktepe formation is unstable in terms of the slope instability. It exhibits landslides around its exposures and also some features of scarp. The author of this thesis witnessed a landslide event at the north bank of the Canakci Brook in the Ilicaktepe formation.

On the contrary, other lithologies are convenient for settlement. Evidences of ancient slope movements or landslide deposits are not present in other lithologies. Existing constructions is not affected by any problem related with lithology. Nevertheless, joint conditions and rock type need a further subdivision. As explained in Section 2.2, older formations of Sogukcam, Deliktepe and Sariboyun with their limestone character and calcium carbonate cement of the sandstone should be counted as much stronger than Ayvaz, Esekciyolu and Kargilidere formations (Table 4.5).

Table 4.5. Classification of lithology parameter

Lithology	Limestone Sandstone	Siltstone Claystone	Fragmented Basalt	Alluvium	***Total***
Formations	Sarıboyun, Soğukçam, Deliktepe	Ayvaz, Eşekciyolu, Kargılıdere	Ilıcaktepe	Quaternary Alluvium	
Pixel Count	5354	31531	7049	72448	*116382*
Share	4.60%	27.09%	6.06%	62,25%	*100%*

The study area can be described as the area that the municipality service border of Niksar is responsible for the all-civil activities. Quaternary alluvium covers the major portion.

4.2.3. Liquefaction map

Expression of the liquefaction event throughout the study area has been completed by means of four methods as explained in Section 3.2.1. The base for the liquefaction analysis is the liquefaction factor of safety, which is the ratio of the soil's resistance to liquefy and the cyclic stress. Obtained results are checked with Chinese criteria of liquefaction for fines. After that, LPI (Liquefaction Potential Index) for each measurement point, which is borehole locations in this thesis, is calculated.

Nevertheless, the LPI is not enough to express the evaluation interacted with the soil liquefaction. The depth and the thickness of the liquefiable layer have rather importance to witness surface manifestation due to the deformation within the ground. Therefore, the method of Ishiara (1985) is applied. The resultant liquefaction susceptibility map is a combination of these.

Not all of boreholes are used to determine the liquefaction susceptibility. Some of them are ceased due to the blocky material coincided during drilling. All necessary information is available in Appendix B as for boreholes drilled for this thesis.

4.2.3.1 Distribution of liquefaction potential index

Some of boreholes could not be used for the distribution of the LPI parameter. The used boreholes are tabulated in Table 4.6. Same boreholes are added to the LPI map (Figure 4.5). The surface fitting technique is the inverse distance weighing method as it is explained in Section 4.2.1. Figure 4.5 exhibits the digital image of the LPI conditions and Table 4.7 summarizes it. According to results and the LPI method of Iwasaki et al. (1982) and Papathanassiou (2008), liquefaction induced ground deformations will probably occur during an earthquake of future. These are surface manifestations of bearing capacity loss and partial settlement when the liquefaction potential index values are greater than 3. Especially, the ground of the industrial district on the eastern bank of Kelkit River is very susceptible to liquefaction during dynamic conditions of an earthquake.

Table 4.6. LPI values in the measurement points (used boreholes)

Borehole#	**LPI**	**Borehole#**	**LPI**	**Borehole#**	**LPI**	**Borehole#**	**LPI**
D 01	0,24	***D 08***	0,00	***D 26***	1,68	***D 37***	6,88
D 02	6,00	***D 12***	0,00	***D 27***	0,00	***D 39***	0,00
D 03	3,63	***D 13***	3,13	***D 28***	6,17	***D 40***	0,00
D 04	2,23	***D 16***	0,00	***D 29***	13,83	***D 41***	0,00
D 05	0,00	***D 18***	8,95	***D 30***	3,18	***D 42***	0,00
D 06	0,00	***D 21***	4,35	***D 32***	0,00		
D 07	0,01	***D 25***	2,47	***D 35***	0,04		

Table 4.7. Classification of the liquefaction potential index values

LPI Class	> 3	1 - 3	0.2 - 1	< 0.2	rocky ground	***Total***
Pixel Count	35249	8320	10459	18417	43937	*116382*
Share	30.29%	7.15%	8.99%	15.82%	37,75	*100%*

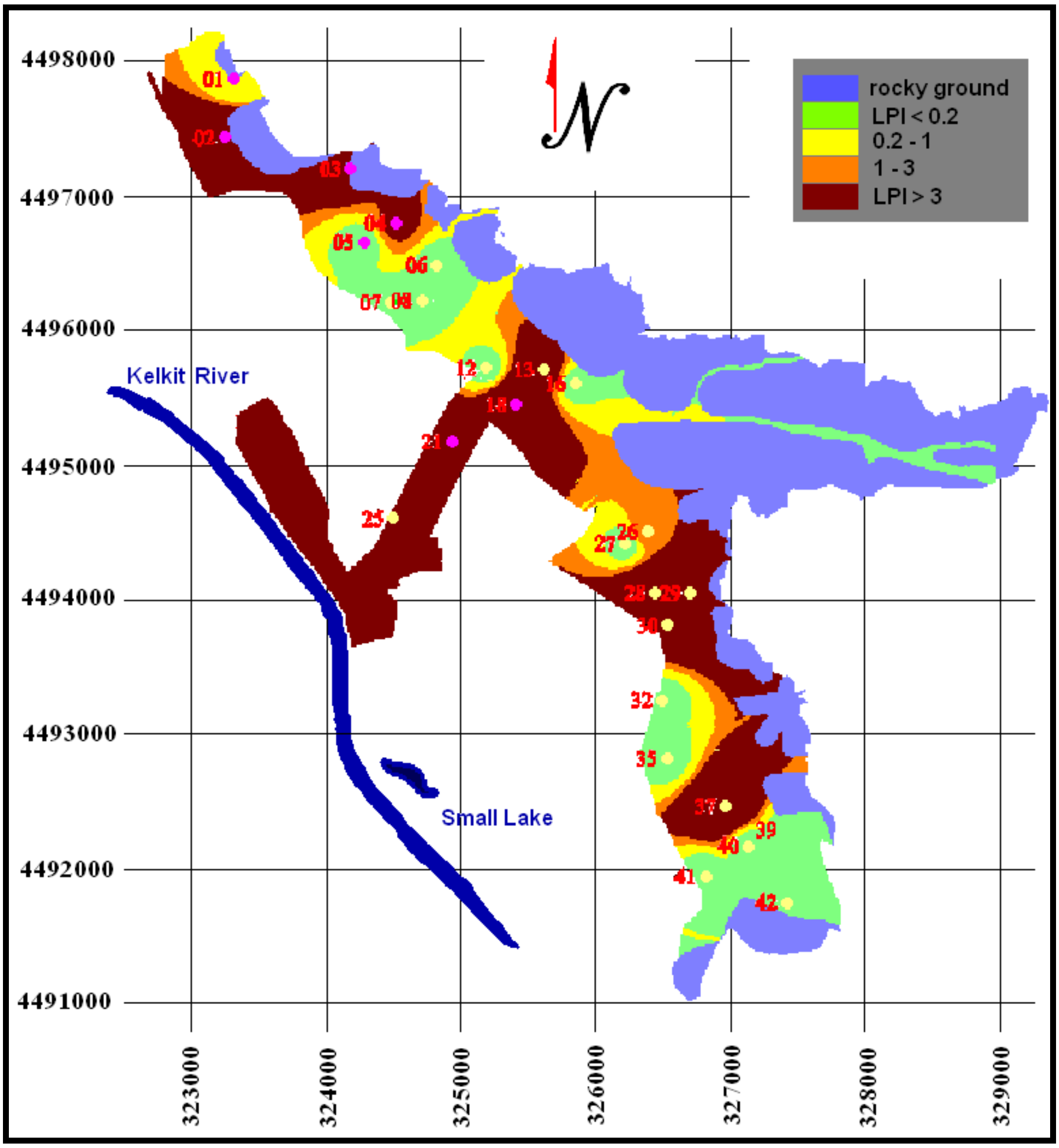

Figure 4.5. Liquefaction potential index (LPI) map of Niksar.

4.2.3.2 Distribution of liquefaction effect on the ground surface

Not all of the boreholes are used in the distribution of the variation of the liquefaction effect on the ground surface with respect to the thickness and depth of the liquefiable strata (Ishiara, 1985). Used boreholes are tabulated in Table 4.8 and they are also exhibited in Figure 4.6. In this figure, there are three divisions.

The first is liquefiable sites under the peak ground acceleration up to 0.4g on alluvium. The second is non-liquefiable sites on alluvium and third is rocky ground where the liquefaction investigation has not been carried out. This classification is tabulated in Table 4.9. The surface fitting technique is the inverse distance weighing method as explained in Section 4.2.1.

Table 4.8. Ishiara (1985) classification of liquefaction effect on the ground surface in the measurement points (used boreholes), (LIQ. = liquefaction)

Borehole#	Ish. Zone	Borehole#	Ish. Zone	Borehole#	Ish. Zone	Borehole#	Ish. Zone
D 01	SAFE	***D 08***	SAFE	***D 26***	SAFE	***D 37***	LIQ.
D 02	LIQ.	***D 12***	SAFE	***D 27***	SAFE	***D 39***	SAFE
D 03	SAFE	***D 13***	SAFE	***D 28***	SAFE	***D 40***	SAFE
D 04	SAFE	***D 16***	SAFE	***D 29***	LIQ.	***D 41***	SAFE
D 05	SAFE	***D 18***	LIQ.	***D 30***	LIQ.	***D 42***	SAFE
D 06	SAFE	***D 21***	LIQ.	***D 32***	SAFE		
D 07	LIQ.	***D 25***	SAFE	***D 35***	LIQ.		

Table 4.9. Classification of liquefaction effects with respect to the depth and the thickness of the liquefiable layer (after Ishiara, 1985)

Ishiara Lique. Class	Liquefiable	non-liquefiable	rocky ground	***Total***
Pixel Count	24791	47664	43937	*116382*
Share	21.30%	40.95%	37.75%	*100%*

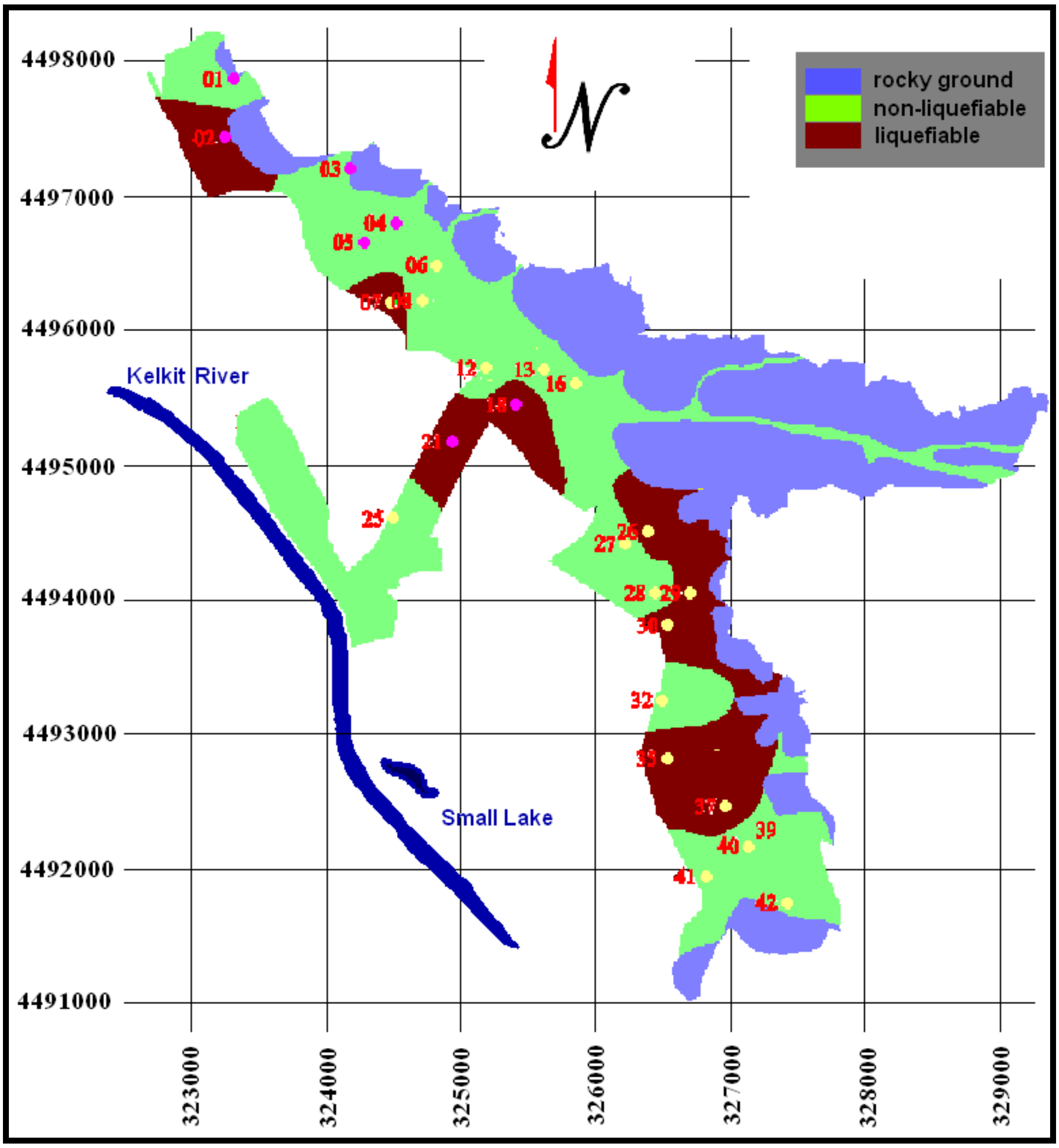

Figure 4.6. The map of liquefaction effect on the ground surface with respect to the depth and thickness of the liquefiable strata based on Ishiara (1985) method.

4.2.3.3 Map of liquefaction parameter

Because the map of the liquefaction parameter (Figure 4.7) is the combination of the two approaches of previous sections, there have to be an algorithm to constitute the output. First of all each case of two different data must be handled.

Classifications of the Liquefaction Potential Index in Table 4.6 is assigned numbers from 1 to 5 representing from the worst to the best conditions. In the Ishiara (1985) classification (Table 4.8), the unit cell takes 5 if the liquefaction is not expected, otherwise, the value will be 1. Table 4.10 explains logical relationship.

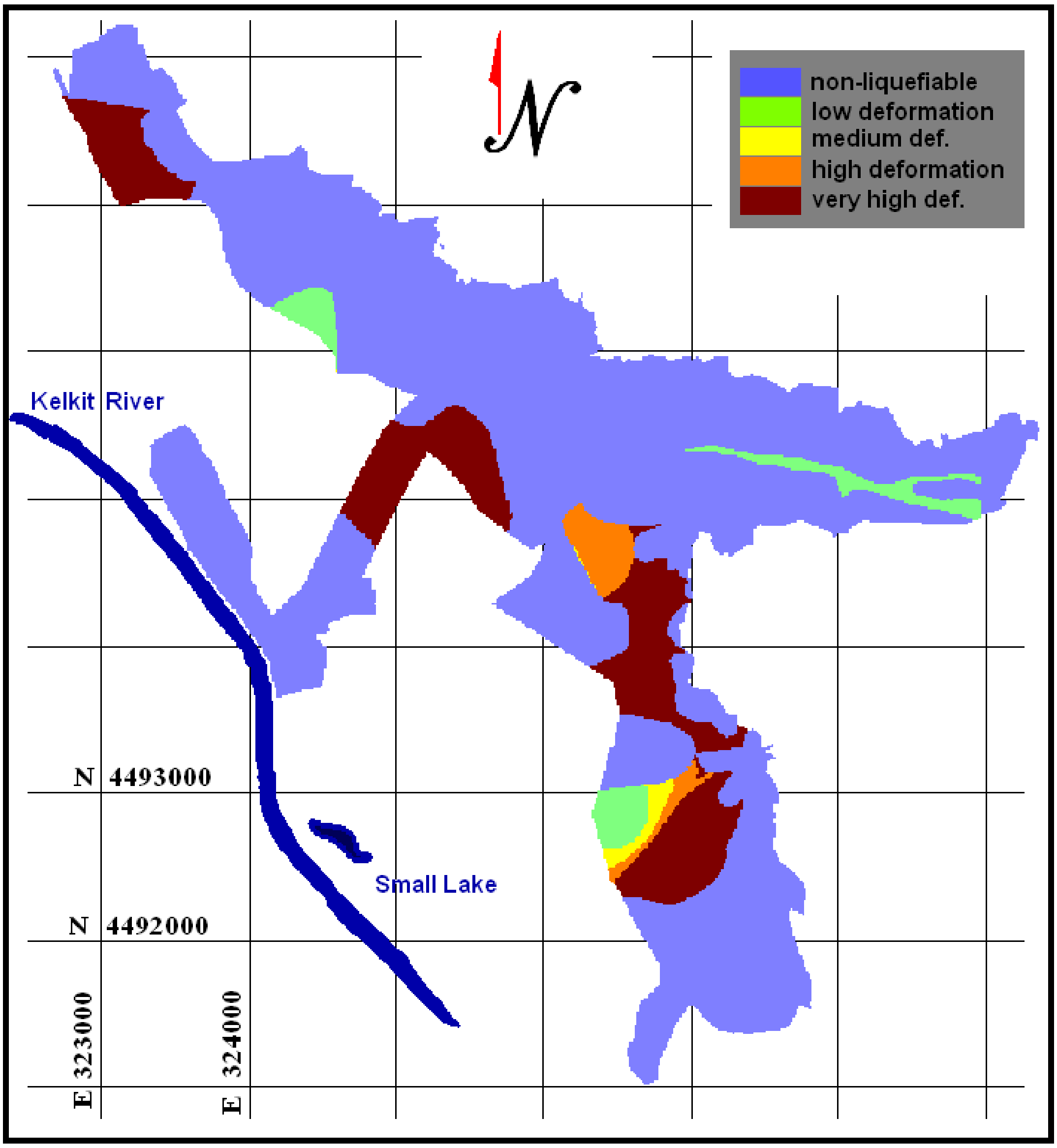

Figure 4.7. Liquefaction susceptibility map of Niksar.

A simple algorithm is applied to obtain the liquefaction susceptibility map for this thesis. Then, the map of the liquefaction induced ground deformation distribution is derived and, results are tabulated in Table 4.11.

Table 4.10 Calculation of values of the liquefaction classification

		Ishiara	
		1	***5***
LPI	***1***	1	5
	2	2	5
	3	3	5
	4	4	5
	5	5	5

Table 4.11. Classification of the liquefaction parameter

Liquefaction Class	Nonliquefiable	Low Deform.	Medium	High Deform.	Very High Def.	***Total***
Pixel Count	91775	4152	714	2496	17245	*116382*
Share	78.05%	3.57%	0.61%	2.15%	14.82%	*100%*

Each class defined for the liquefaction parameter stands for the maximum expected deformation. Non-liquefiable class is assigned to the rocky ground and there will be no observable liquefaction related event. The class named as Very High Deformation indicates possible loss of soil strength and, liquefaction induced damage is likely. According to results, more than half of the study area is not affected from liquefaction. However, the western most part of the study area, where the industrial district is found, has coarse-grained soil ground and very shallow groundwater table (around 1m deep). Then, the classified LPI map shown in Figure 4.5 is found to be more reliable when used single.

4.2.4. Map of soil activity

The activity values are derived from laboratory tests on borehole samples. It is not an occasional case for rocky parts of the study area. Boreholes are distributed among the soil part of the Niksar city and they have somehow several meters of depth at least. It helps to classify the plastic nature of the soil originated from the clay content.

Although the clay content and the overall plasticity of the soil sample are decisive on the activity, it has no direct formula to obtain a value for the activity levels of ordinal values ranging from low active to very high active. It is read from the chart shown in Figure 3.5, in the previous chapter. Database for borehole data for boreholes drilled for this thesis are available in Appendix B. The result map of activity is shown in Figure 4.8. Table 4.12 summarizes this map. The interpolation technique is the inverse distance weighing method.

Table 4.12. Classification of activity parameter

Activity Class	Medium Ex.	Low Expans.	Rocky Ground	***Total***
Pixel Count	1274	71171	43937	*116382*
Share	1.09%	61,16%	37,75	*100%*

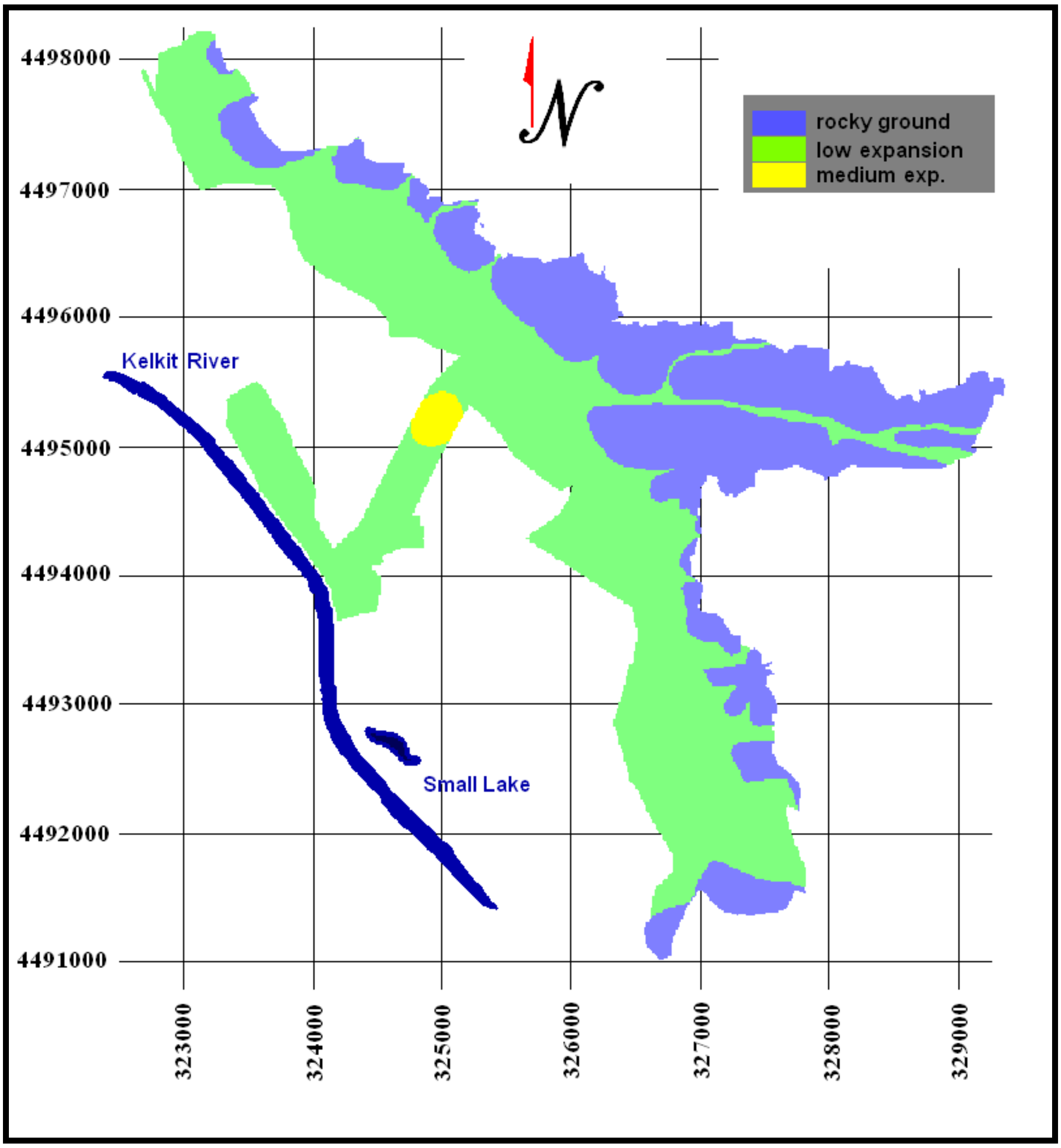

Figure 4.8. Activity map of Niksar.

Within the defined resolution of the whole project, there is no evidence of the very high or high active regions of the soil. On the other hand, the low plastic zone occupies the 64.46% of the study area. Other than that this is the general classification, therefore, all classes are included in this thesis although they are not observable in the study area.

4.2.5. Ground amplification map

The geophysical survey is done by Dikmen et al. (2009). DEM of the ground amplification map is produced (Figure 4.9). Table 4.13 summarizes the situation exhibited. The expected ground amplification is in the range of 2.0-2.5. Others are observed less comparing to this range. The greater amplifications more than 3.0 are very rare at some definite points in Figure 4.9.

The ground amplification is the function of technical parameter of the stratigraphic section including soil column above the bedrock. Therefore it is not unusual to face unexpected ground amplification values on unexpected areas. The interpolation technique is again the inverse distance weighing method, but this time the search distance is not large as much as borehole data because there are 496 measurement points, which are close to each other.

Table 4.13. Classification of ground amplification parameter

Amplification	1.5 - 2.0	2.0 - 2.5	2.5. - 3.0	3.0 -3.5	3.5 - 4.3	***Total***
Pixel Count	8439	77336	25507	4243	757	*116382*
Share	7.25%	66.45%	21.92%	3.65%	0.76%	*100%*

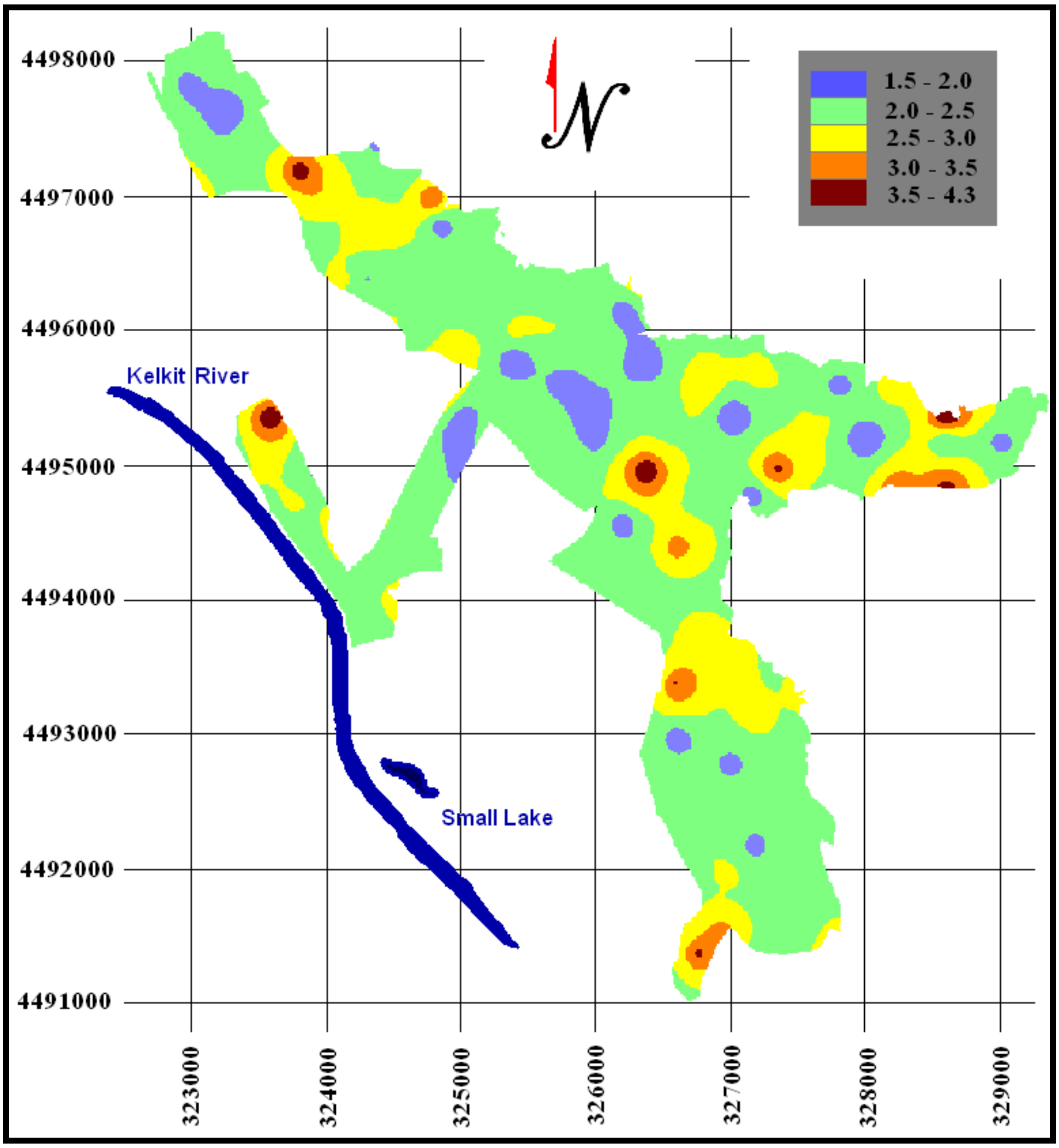

Figure 4.9. Ground amplification map of Niksar.

4.2.6. Fault proximity map

The main idea of this map is the proximity to the fault passing through the study area shown in Figure 2.2. Locations, which are far from the fault line, are safer than closer ones relatively, in the scope of urban settlement. The study area is separated into five divisions with respect to the proximity to the fault, increasing after 1000m. This map is exhibited in Figure 4.10 and the results are tabulated in Table 4.14. Buffer zone is considered for each distance level and they are converted into raster data having fault distance classification values.

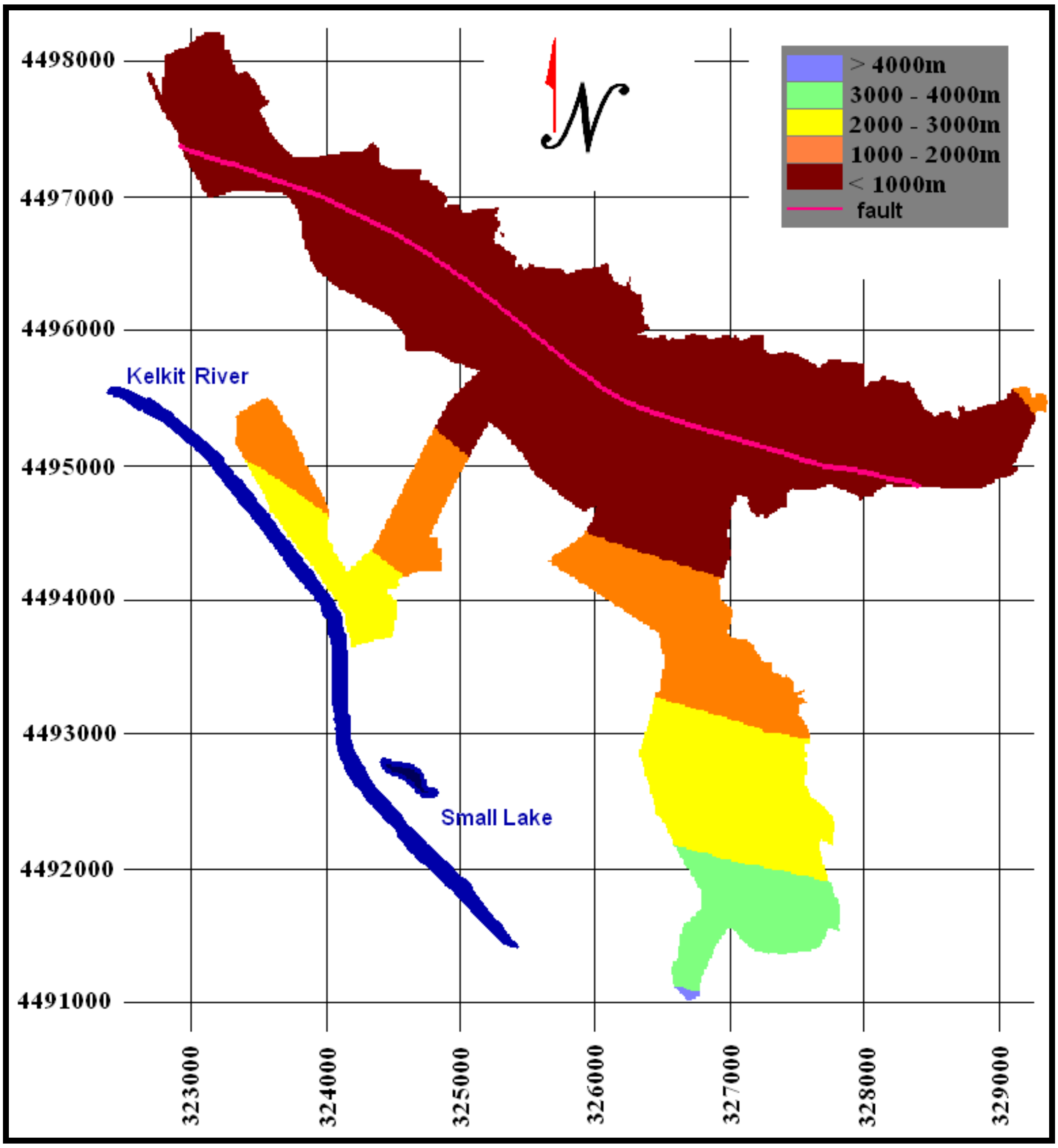

Figure 4.10. Fault proximity map of Niksar

Table 4.14. Classification of fault proximity parameter.

Fault Distance Class	< 1000m	1000-2000m	2000-3000m	3000-4000m	> 4000m	***Total***
Pixel Count	73925	17665	17577	7116	99	*116382*
Share	63.60%	15.18%	15.10%	6.11%	0.01%	*100%*

4.3 Exceptions of the study area

Niksar city has the ancient origins. It has flourished randomly or in true spelling, since times before a scientific planning. In such a situation some unrequited zones appear in the city for the purpose of urbanization. Some of them are threats toward safety such as previous landslide areas, stream channels and stone mine. Others are cultural and historical sites. In this section, they are divided into two groups with respect to method closing and excluding them from the microzonation. Some of them are coincides; especially zones of fault vicinity. Therefore, total portion of the excluded areas will be 12.67% as the union of two types; fault buffer and closed zones, which are explained next.

4.3.1. Adjacent areas to the fault passing through the study area

The study area lays on the North Anatolian Fault Zone and therefore, some of the probable main faults show their traces within the city border (Figure 2.2). In addition to these, local thrust faults, which are formed after the stress generation along major faults, are observable. Waltham (1994) states precisely that if the location of the fault is known definitely, the area having the thickness of 15m from both sides should be closed to the settlement. If the fault location is not known definitely but evidences and traces are available from faulted contacts of young lithologies, this zone should be raised up to 35m. Buffer zones surrounding the faults of the study area are shown in Figure 4.11 and the map is summarized in Table 4.15.

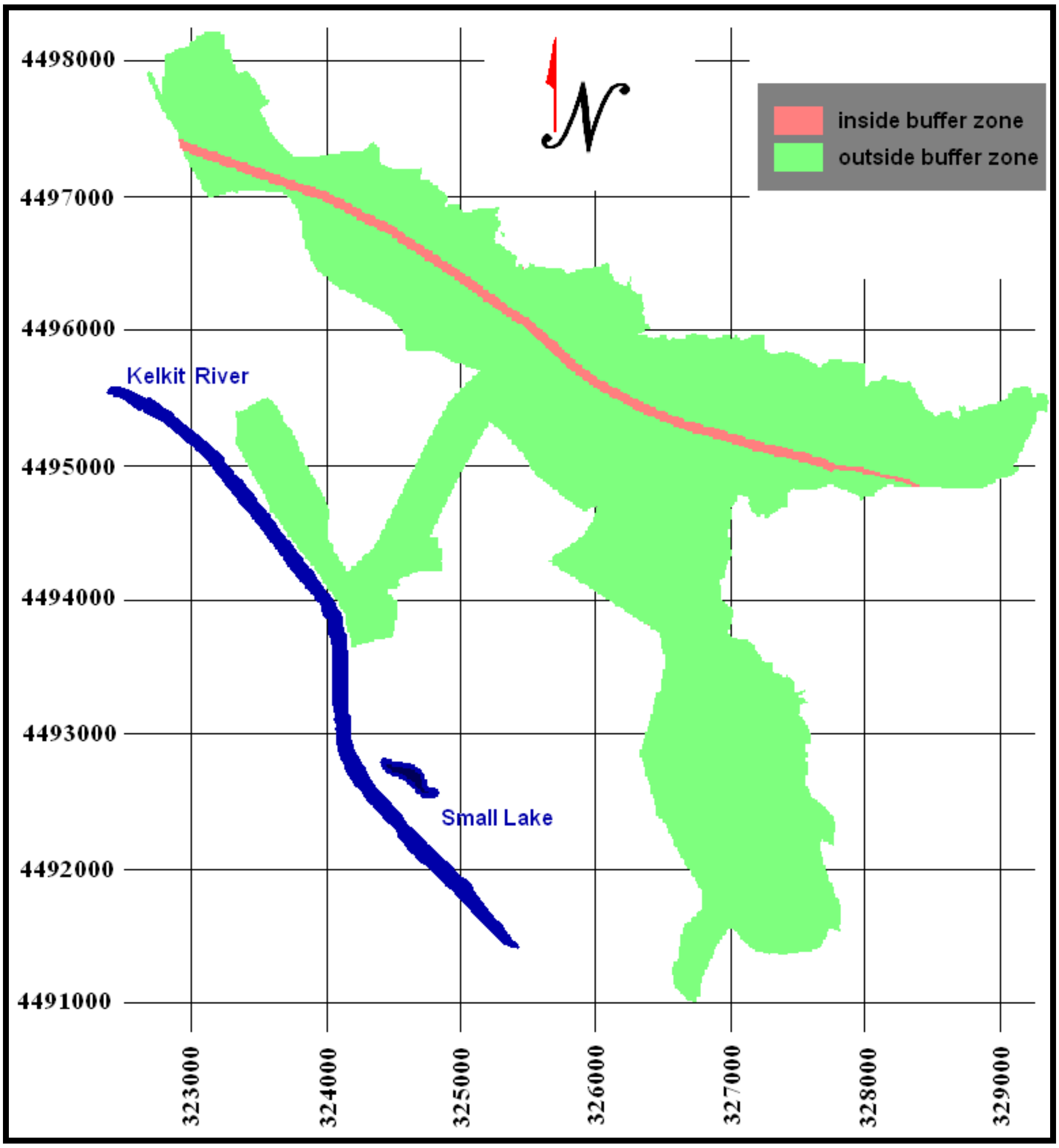

Figure 4.11. Fault buffer zone map of Niksar

Table 4.15. Proportions of fault buffer zones

Fault Buffer	Inside	Outside	***Total***
Pixel Count	4078	112304	*116382*
Share	3.50%	96.50%	*100%*

4.3.2. Closed areas

There are four types of areas, which are not allowed for settlement. These are cultural sites, stream channel, stone mine and the warning zone of a previous landslide. They are masked to separate them from other areas. All of the classification are exhibited in Figure 4.12 and tabulated in Table 4.16. Please note that, the map of masked areas is only for visual purposes. Masked zones will have the value of zero without a color for the overlay analysis.

Table 4.16. Proportions of masked zones

Masked Zone	**Pixel Count**	**Area km^2**	**Share**
Cultural	2799	0.28	2.14%
Stream Channel	6190	0.62	4.74%
Lake	0	0	-
Stone Mine	436	0.04	-
Landslide	954	0.096	0.82%
Unmasked	106003	12.07	92.06%
Total	*116382*	11,64	*100%*

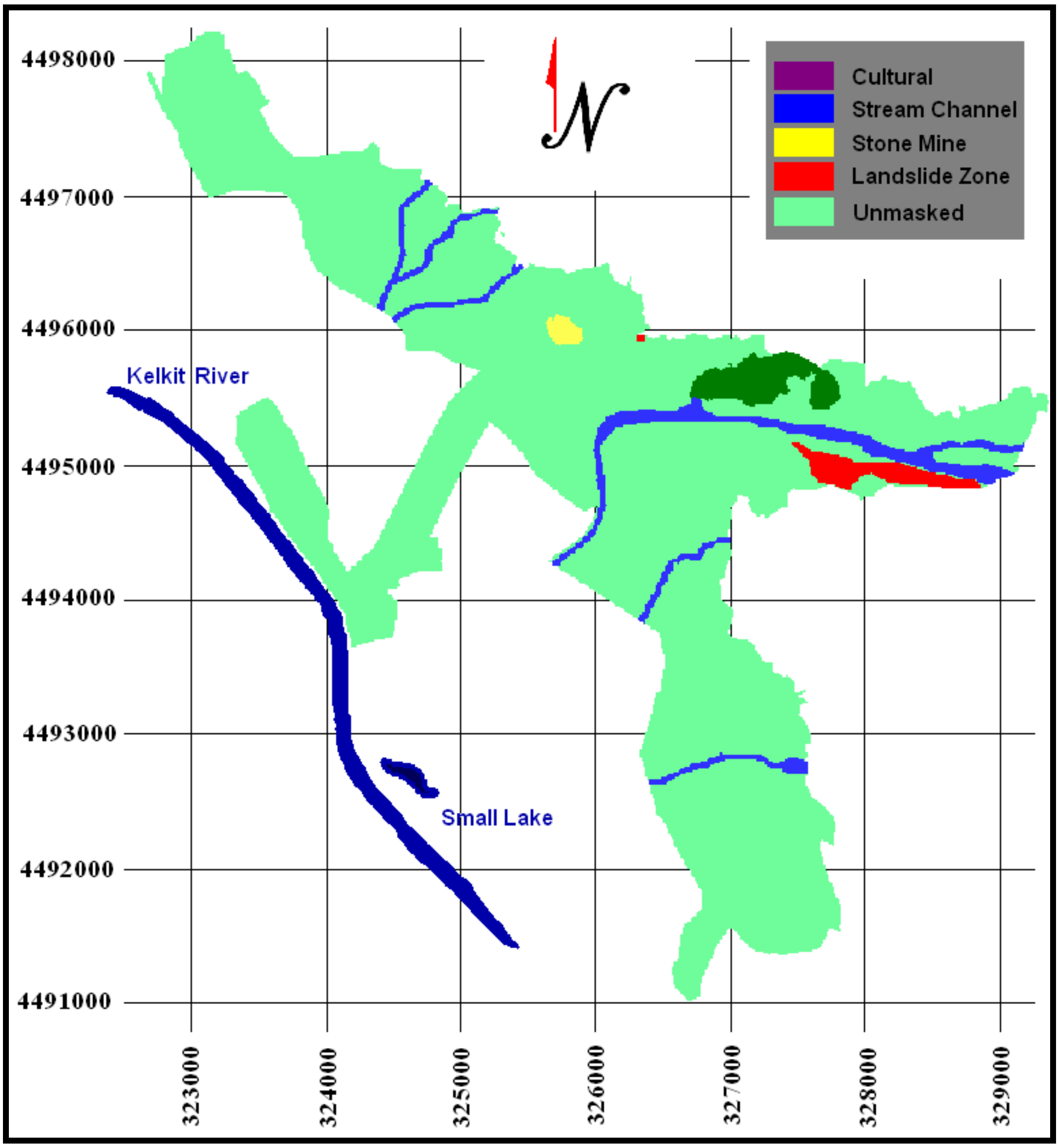

Figure 4.12. Niksar map of masked zones.

Totally, 7.94% of the study area is closed for the settlement. The microzonation is carried out among the rest. This portion does not contain the fault buffer areas, which are drawn with respect to the proximity to possible ground rupturing.

CHAPTER 5

APPLICATION OF THE MICROZONATION

In this chapter, the study area is evaluated for settlement suitability with all factors by means of both Simple Additive Weighing and Analytical Hierarchical Process. They are derived and classified with respect to both their internal particularities and cases observed. All of them are distributed among the study area as digital elevation models exhibiting classifications determining convenience for settlement. In this chapter all of them are processed again and unified as the resultant microzonation map.

All parameters are factors determining the properties of the ground, which are directly related with the urbanization quality and the safety. As it is expected, their effects are different on the result. In addition to these, some places are not included in the analysis because they are fault zones, cultural sites, previous landslide zones and stream channels. Whole is handled, in this chapter and two decision-making techniques are applied.

The suitability for the urban settlement is then categorized with respect to the classification of the General Directorate of Disaster Affairs and Topal et al. (2003) which are suitability standards for urban settlement that:

<u>Suitable areas</u>: This category represents areas, where normal residential developments can be planned without further precautions.

Provisional areas: This category represents probable problems of shallow groundwater table, soil expansion and partial settlement, which can be eliminated by means of proper precautions.

Areas requiring detailed geotechnical investigation: This category indicates high deformations due to the liquefaction, the ground amplification, considerable soil expansion or certain partial settlement problems. If an area exists with these conditions, a comprehensive geotechnical investigation contributed with drillings and testing will be obligatory in scale of parcels.

Unsuitable Areas: This category represents inconvenient areas for settlement. It directly refers to intense damage due to seismic activity or any other natural hazard. Areas of this category must be abstained and such zones must be allocated for recreational purposes.

5.1 Factors determining the suitability for urban settlement

Influences of seven factors constitute this microzonation. They are the liquefaction, the activity, the slope, the amplification, the lithology, the fault proximity and the aspect. Each of these covers five different classes affecting the convenience for settlement. Table 5.1 summarizes these and they are also explained next:

The Liquefaction: It is the expected ground deformation related with the liquefaction event under the dynamic conditions during the earthquake. This factor is derived from geotechnical data as in-situ SPT (Standard Penetration Test) and laboratory tests of samples obtained during drillings. Especially, LPI (Liquefaction Potential Index) results are decisive on this parameter.

The Activity: It is the activity with respect to the plasticity of the soil. Soil expansion and local excess ground amplification are expected. There is no evidence of high and very high expansion in the study area, but there is a small zone having medium plasticity and rest of the alluvium-covered part is low plastic. This factor is derived from geotechnical data as laboratory testing of the borehole samples.

Table 5.1. Factors determining suitability for urbanization of Niksar

Parameter	**Description**	**Data Type**	**Target**
Liquefaction	Surface deformation due to the liquefaction	Geotechnical	Stregth loss of the ground during an earthquake
Activity	Activty of soil due to plastic characterisitcs	Geotechnical	Expansion and local excess amplifications
Slope	Slope of the surface	Geographical	Slope instability problems
Amplification	Ground amplification of seismic waves	Geophysical	Ground accelerations on buildings
Lithology	Type of the ground material	Geological	Seperating competent nature of various materials
Aspect	Facing direction of the surface	Geographical	Most of landslide problems occurs in north facing slopes in the study area
Fault Proximity	Distance to the fault passing through the study area	Geographical / Geological	Sites that are far from the fault are considered to be safer
Excluded Zones	Definite zones excluded in microzonation map	Site information	Uncovered places due to some restrictions

The Slope: It is the estimation of possible slope failures with respect to the idea that steep inclinations give rise to landslides easier than gentle ones. This factor is derived from geographical data as cartographic maps of the study area. Furthermore steep slopes also create difficulties for urban planning.

The Amplification: It is the expected ground amplification and comparative condition between different locations. High ground amplification values will produce greater ground acceleration, consequently, greater shear forces to engineering constructions on the ground surface (Theodorakopoulos, 2003). This factor is derived from geophysical data of microtremor measurements.

The Lithology: It is the subdivision of the ground with respect to the material observed on the ground surface. Competent and unweathered rocks are preferred. The classification is prepared based on the field investigation of the stratigraphy. This factor is derived from geological data given in the geological map of the study area.

The Fault Proximity: This parameter divides the study area with respect to the distance to the fault passing through the study area. Proximal sites are considered to be unsuitable.

The Aspect: It is the facing of the sloping ground. The north facing is the most unfavorable condition for the study area, because majority of the landslide area, mentioned in previous chapter, is totally north facing and the buildings on this category get little sunshine. This factor is produced from geographical data as cartographic maps of the study area.

In addition to these, some of the definite sections of the study area are excluded and automatically assigned to the category of ‘unsuitable areas’ with respect to factors that:

The Fault Buffer: It is the proximity to possible ground rupturing with respect to the information about the location of the fault line. If it is well defined, the buffer radius will be 15m or if it is slightly known after the logical evidences, the 35m are more reliable distance (Waltham, 1994). This factor is derived from both geological data in geological and cartographic maps of the study area.

The Masked Zones: It is the excluded area due to the existence of the cultural and historical or danger zones. This factor is derived from geographical data and field investigations.

5.1.1 Relationships of factors

The reciprocal relationships of the factors should be searched for a logical output. To perform this, all factors are considered again in both its own cases and with respect to the cases of other factors (Table 5.2).

Table 5.2. Reciprocal relationships between factors (prop: proportional, in prop: inversely proportional, independ: independent of the other)

Reciprocal Relation	**Liquefaction**	**Activity**	**Slope**	**Amplification**	**Lithology**	**Fault Proximity**	**Aspect**
Liquefaction							
Activity	in prop						
Slope	in prop	in prop					
Amplification	in prop	prop	independ				
Lithology	in prop	in prop	in prop	in prop			
Fault Proximity	independ	independ	independ	independ	independ		
Aspect	independ	independ	independ	independ	independ	independ	

The liquefaction is mainly the characteristic of the sandy soils (SW, SP, SM and SC). On the contrary, the activity is the characteristic of the plastic soils (MH, CH, OH). In such a situation, they cannot occur at the same location. They share only the ground type because both are found in alluvium material instead of rocky topography eastward in the study area (Craig, 2001; Mitchell and Soga, 2005; Derakshandi et al., 2007).

The ground amplification is affected from the soil plasticity. Nevertheless, it is a function of geophysical properties of the soil column, even including weak rocks, down to the bedrock (Heuze et al., 1997). If the thick alluvium is the case, the plasticity is considered, but there is no sufficient borehole data for the study area. Therefore, only microtremor measurement results are applied to the output ignoring any relationship with other factors.

The slope of the ground cannot be independent from the ground material. The alluvium, especially, alluvium of Niksar city, which is young and comes from different sources, is unconsolidated. It cannot be seen on steep slopes. Consequently, effects of the activity and the liquefaction are not observed in steep slopes in the study area.

The aspect of sloping ground surface is not dependent of any other factor. It is included in this thesis because very unstable material of the Ilicaktepe formation exhibits slope instability in the southern bank of the channel of Canakci Brook, where the aspect is almost north facing. This material and this part of the study area are separated. A similar situation is observable at the excluded area of the ancient landslide. The fault proximity parameter is not related to any other parameter, either. The distance to the fault is effective, solitarily.

5.1.2 Setting up the problem

The aim of the microzonation is to evaluate suitable areas in the municipality service border, which is the study area, for the urban settlement. It does not cover any architectural and constructional parameter other than cases of the ground. These are the sum of the properties coming from disciplines of the geology, the geotechnics, the geography and the geophysics.

If the suitability for the urbanization is considered as a mathematical function, parameters of the liquefaction, the activity, the amplification, the lithology, the fault proximity, the slope and the aspect will be variables of this function. Then, the worst cases of all these parameters will give the most unsuitable area at the point of the unit cell. In this thesis, it is required best cases of all factors.

Setting up the problem has begun from the start of this thesis. In Chapter 4, all parameters, except from the fault buffer and the masked zones, are classified in five groups, certainly. Consequently, the consistency is kept and the application of the microzonation becomes practical. Then, the suitability will be observed with highest safety for the urban settlement if the liquefaction induced ground damage is minimum, the activity of the soil is low, the ground peak ground acceleration on the bedrock is not amplified much, the slope is gentle or nearly flat, the fault is far, the surface does not face toward north and the ground is competent rock.

Except masked zone and fault buffer zone, there is not any other of factors giving rise to emerge definite conditions of ‘unsuitable areas’ category.

5.2 Decision making with SAW

The microzonation is the mathematical expression of the engineering judgment on the factors determining the suitability. Saaty (2004) mentions that the multicriteria decision making analysis (MCDA) is logical way to deal with different conditions of definite factor. A general model for the suitability is constituted and it is applied to all unit cells, which carries the value belonging to each factor.

The principle of the Simple Additive Weighing Method (SAW) depends on selecting the most important factor and a weight is assigned to it. Then, sequence of others is determined according to the importance and they are assigned weights with respect to the most important.

The second phase is the normalizing the weights. The total of weights of all factors is divided by 10, 100 or 1000. The result of this division is a constant for normalizing. Weights of parameters are divided by this constant.

The third phase is the standardizing ranks. Ranks are values assigned to groups of classified factor cases. This thesis for example uses 5 groups and each takes rank from 1 to 5. The standardization is the division of all rank values by the greatest rank, of 5. It will not differ, if the normalized weight is divided by 5, instead of the rank.

The fourth and the last phase is the constitution of the model. The suitability is the function of the factors. Each factor is a variable taking ranks as limited values and normalized weight is its coefficient. Whole process is summarized in the Table 5.3.

Table 5.3. Summary of SAW (Simple Additive Weighing) method

Factors	Weights	Normalizing Constant	Normalizing Weights	Normalized Weights	Ranks	Standardizing Ranks	Standardized Ranks
Liquefaction	LQ_W	$C_N = (LQ_W + AP_W + AC_W + GR_W + FP_W SL_W + AS_W) / 10$	LQ_W / C_N	LO_{WN}	1, 2, 3, 4, 5	rank / 5	0.2, 0.4, 0.6, 0.8, 1
Amplification	AP_W		AP_W / C_N	AP_{WN}			
Activity	AC_W		AC_W / C_N	AC_{WN}			
Lithology	LT_W		LT_W / C_N	LT_{WN}			
Fault Proximity	FP_W		FP_W / C_N	FP_{WN}			
Slope	SL_W		SL_W / C_N	SL_{WN}			
Aspect	AS_W		AS_W / C_N	AS_{WN}			

The output of the model should have five groups according to the explanation in Table 5.3 to keep consistency. The only exception is the masked or buffered zones.

5.2.1 Ranking and weighing the factors

Weights of factors are assigned according to both their influence on the result and local effects on the study area. The most important factor in this study is the liquefaction because it is directly related with the surface deformation during the earthquake. The second level of the importance belongs to the lithology. There are different lithologies among the study area and their properties are decisive for the safety of the buildings. The slope has the third degree in the case of the slope instability or landslide possibility under dynamic conditions as increasing slope amount.

The other parameters are considered to have minor importance. The Amplification and the activity share the fourth degree. Such an area, which is very close to the active main faults of the North Anatolian Fault Zone, does not exhibit drastic changes in the ground acceleration. Therefore, the ground amplification differentiates at only some definite localities. The activity, at the same time, does not show very high levels so it is not risky. The last parameter, the aspect, is explained in previous section and has the least importance. The weighing and standardizing is tabulated in Table 5.4.

Table 5.4. Weighing, ranking and normalizing factors for SAW

Parameter	Weight	Normal. Weight	Rank \ Standardized Rank				
			1 \ 0.2	***2 \ 0.4***	***3 \ 0.6***	***4 \ 0.8***	***5 \ 1.0***
Liquefaction	5	0.25	Very High Def.	High Deformation	Medium Def.	Low Deformation	Rocky
Activity	2	0.10	***! Not Exist !***	***! Not Exist !***	Medium Exp..	Low Expansion	Rocky
Lithology	4	0.20	Alluvium	Fragmented Basalt and Tuff	***! Not Exist !***	Siltstone, Claystone	Limestone, Sandstone
Amplification	2	0.10	3.5 - 4.3	3.5 - 3.0	2.5 - 3.0	2.0 - 2.5	1.5 - 2.0
Fault Proximity	2	0.10	< 1000m	1000-2000m	2000-3000m	3000-4000m	> 4000m
Slope	4	0.20	> 30^{o}	20 - 30^{o}	10 - 20^{o}	5 - 10^{o}	0 - 5^{o}
Aspect	1	0.05	North	N.west-N.east	WNW-ENE	West-East	SW-South-SE
			345-360^{o}, 0-15^{o}	315-345^{o}, 15-45^{o}	285-315^{o}, 45-75^{o}	225-285^{o}, 75-135^{o}	135-225^{o}
TOTAL	20	1.00	*(Very Bad)*	*(Bad)*	*(Moderate)*	*(Good)*	*(Very Good)*

The total of weights is 100 so there is no need to an extra normalization. Nevertheless, it is preferred to divide the weights instead of ranks. It will give the same output. The result range starts from 0 and end at 100. The general model is given in the Equation 5.1:

$$\begin{aligned} Suitability = \quad & 0.25 \times LQ_{RS} + 0.1 \times AC_{RS} + 0.2 \times GL_{RS} + 0.1 \times AP_{RS} \\ & + 0.2 \times SL_{RS} + 0.1 \times FP + 0.05 \times AS_{RS} \end{aligned} \tag{5.1}$$

where *LQ*, *AC*, *GL*, *AP*, *SL*, *FP* and *AS* are symbols of factors. The suffix *RS* refers to standardized ranks of this factor. This model is not enough to produce the microzonation because excluded zones are absent in the model of Equation 5.1. Then Equation 5.2 gives the output:

$$Suiatabilty = Suitabilty_{FORMULA-4.1} \times FaultBuffer \times MaskedZones \tag{5.2}$$

In DEM’s of the fault buffer and masked zones, unit cells, which are inside of the buffer or masked zones, take the value of 0. Values of others are constantly 1. Actually, Formula 5.1 cannot produce a suitability value smaller than 0.20, mathematically. The Formula 5.2 can add 0 values to mask the excluded areas.

5.2.2 Output of SAW

After applying Formula 1 on totally 116382 unit cells (pixels) by means of layer analysis, microzonation values are obtained. Figure 5.1 shows the output of the statistical model throughout the study area and frequencies of microzonation values are plotted in Figure 5.2.

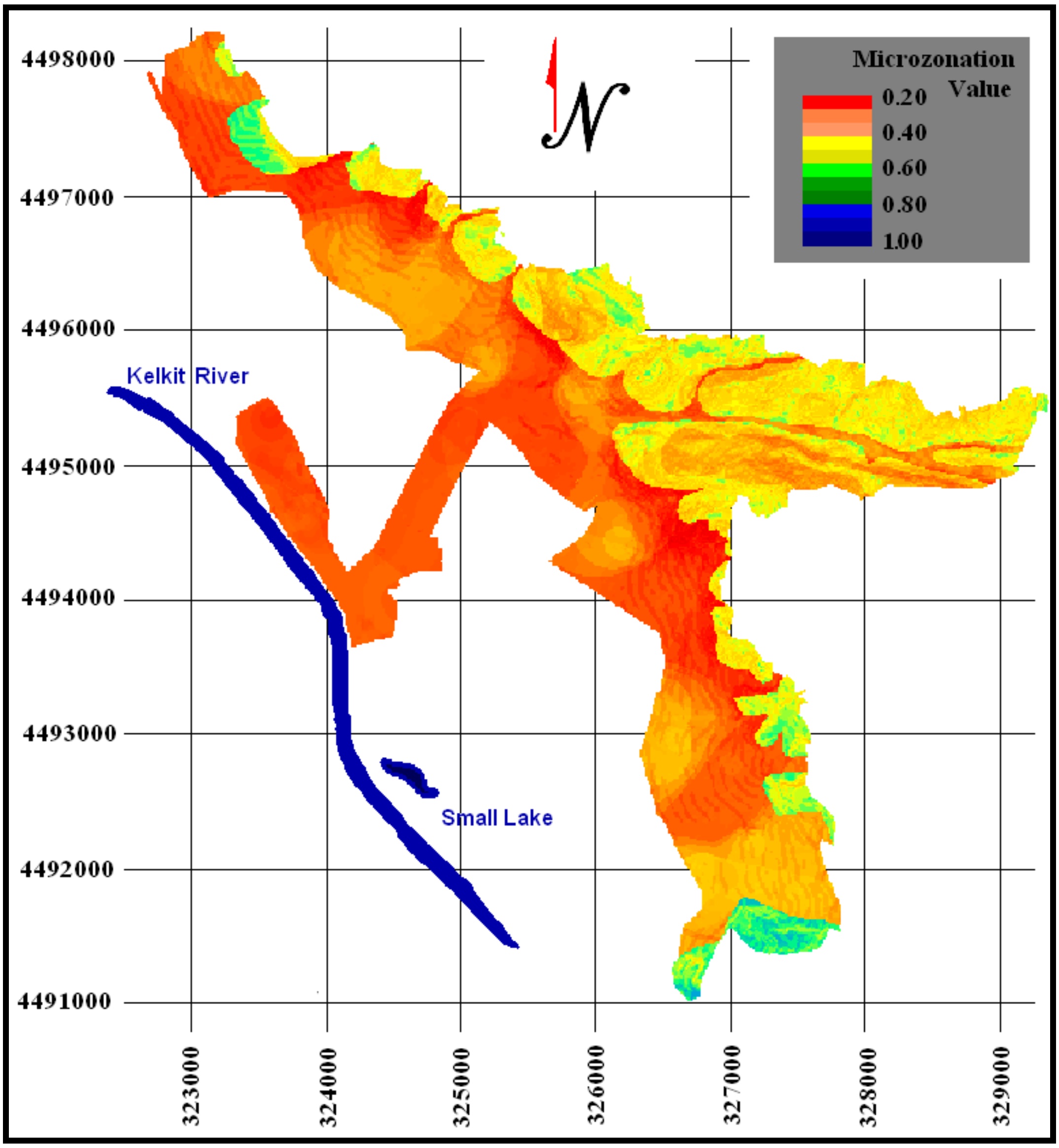

Figure 5.1. SAW microzonation map of Niksar without classification.

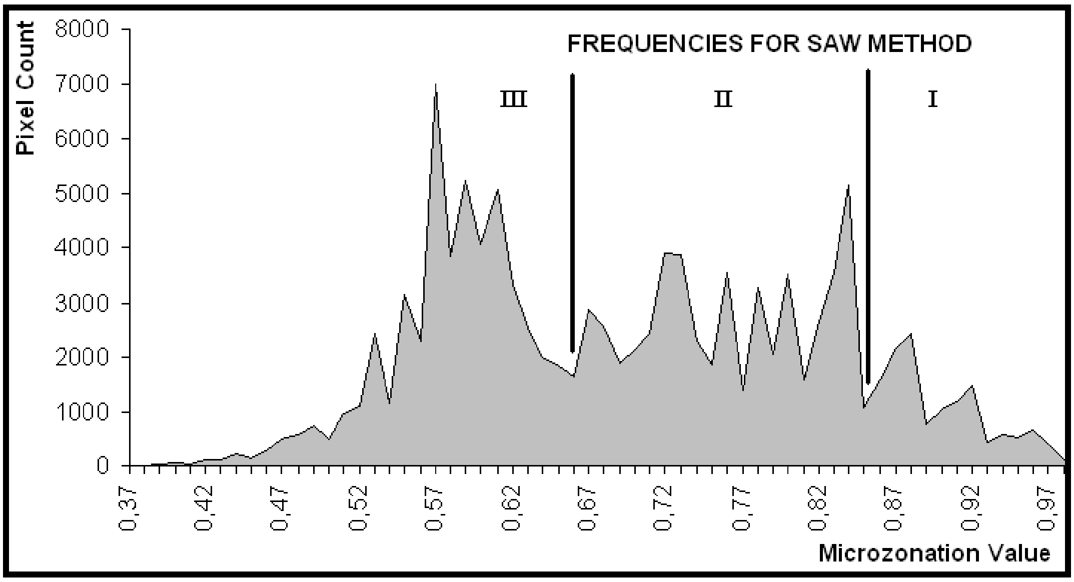

Figure 5.2 Frequencies of microzonation values without classification and histogram showing the classification for the microzonation using SAW method.

5.2.3. Microzonation of the study area with SAW

The microzonation map, which is obtained after applying the statistical model expressed in Formula 1, is not sufficient to exhibit convenience for the urban settlement in well-defined zones. To eliminate this shortcoming, these raw microzonation values are classified into distinct zones representing their safety situation.

Bottom most row of the Table 5.4 indicate the meaning of each ranking from 1 to 5. According to this naming, suitability situations of “Very Bad”, “Bad”, “Moderate”, “Good” and “Very Good” are placed in value intervals of 0-0.20, 0.21-0.40, 0.41-0.60, 0.61-0.80 and 0.81-1.00, respectively. Nevertheless, some of the factors must be 0.2 to be in “Bad” situation, while others take 0.4 ranking. Then, it is not applicable to use ranking intervals to classify the safety situation, properly. Therefore, limits for classification ranges are changed. In addition to these, the graphic in Figure 5.2 shows accumulation of close microzonation values around peak points. Then, new categories of the convenience for urban settlement, with excluded zones of masked and buffer, are tabulated in Table 5.5. The classified microzonation map of Niksar with SAW method is given in Figure 5.3 and details are tabulated in Table 5.6.

Table 5.5. Ranges of suitability classification for SAW without excluded zones

Range	**Name as Areas of**	**Pixel Count**	**Share**
0.30-0.67	Detailed Geotechnical Investigation	70528	60.60%
0.68-0.84	Provisional	39891	34.28%
0.85-0.98	Suitable	5963	05.12%
	Total:	*116382*	*100%*

Table 5.6. Classification of microzonation with SAW

Microzonation Class	Suitable Areas	Provisional Areas	Areas Requiring Detailed Geotechnical Investigations	Unsuitable Areas	
Class Value	I	II	III	IV	***Total***
Pixel Count	5828	35701	60107	14746	*116382*
Share	05.01%	30.68%	51.64%	12.67%	*100%*

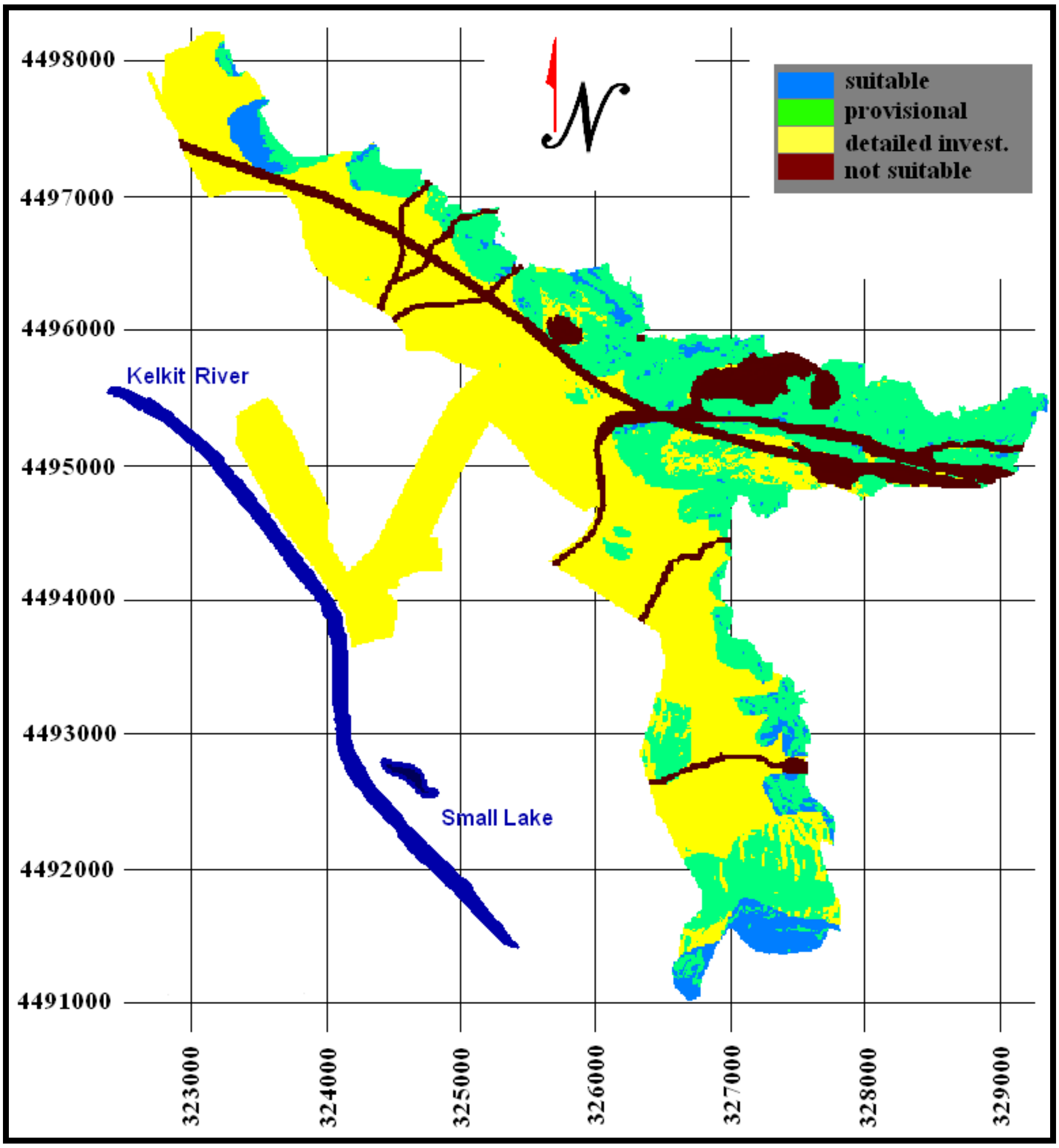

Figure 5.3. Classified microzonation map of Niksar with SAW method.

5.3. Decision making with AHP

The Analytical Hierarchy Process (AHP) is distinguished from the Simple Additive Weighing Method mainly with its three properties. Firstly, it has definite standard weights and ranks starting from 1 and ending at 9. Secondly, weights are normalized and/or ranks are standardized based on the reciprocal relationships.

Thirdly, controlling vectors check normalized weights and/or standardized ranks. If they are inefficient, normalization and/or standardization are iterated until efficiency is fulfilled (Saaty, 2004).

Parameters of the microzonation are factors for the decision making, here. Then, weight of the parameter is assigned a number with respect to intensity of the relationship (Table 5.7) with each of other factors, separately. The rank assignment has the similar operation except from that relative importance between different conditions of the factor considered in the decision-making.

Table 5.7. Comparison judgments from a fundamental scale of absolute numbers for assigning weight/rank (Saaty, 2004)

Weight / Rank	**Intensities**
1	Equal
3	Moderately Dominant
5	Strongly Dominant
7	Very Strongly Dominant
9	Extremely Dominant
2, 4, 6, 8	Intermediate Values
Reicprocals; 1/2, 1/3, 1/4, ..., 1/9	For Inverse Judgements

5.3.1. Ranking and weighing the factors

A pairwise comparison matrix of all seven factors is given in Table 5.8. In this table, rows belong to factors indicated at the starting column exhibiting names. Column of a factor shows the relation, which is required to be defined as intensity (Table 5.7). Sum of all intensities among a single row belonging to one factor gives the weight of this factor in the decision-making. After that, all these weights of factors are normalized.

Table 5.8. Pairwise comparison matrix of factors

AHP Category	*Lique.*	*Activity*	*Lithology*	*Amplifi.*	*F. Prox.*	*Slope*	*Aspect*
Liquefaction	1	5	2	5	3	2	9
Activity	1 / 5	1	1 / 3	1 / 2	1 / 2	1 / 3	3
Lithology	1 / 2	3	1	3	4	1 / 2	7
Amplification	1 / 5	2	1 / 3	1	1 / 3	1 / 5	5
Fault Distance	1 / 3	2	1 / 4	3	1	1 / 3	4
Slope	1 / 2	3	2	5	3	1	7
Aspect	1 / 9	1 / 3	1 / 7	1 / 5	1 / 4	1 / 7	1

Except from the lithology, all factors have certain five classes. The classification, which is applied to all factors, focuses on the suitability conditions for urban settlement and it is the same for the liquefaction, the amplification, the fault proximity, the slope and the aspect. Then, all of them have the same pairwise comparison matrices, which are equivalent of Table 5.9. Nevertheless, the lithology factor contains four conditions (Table 4.5) and the activity has three conditions (Table 4.12), then, both have different pairwise comparison matrices in Table 5.10 and Table 5.11, respectively.

Table 5.9. Pairwise comparison matrix of ranks for liquefaction, amplification, fault proximity, slope and aspect factors.

RANK	*Very Good*	*Good*	*Moderate*	*Bad*	*Very Bad*
Very Good	1	3	5	7	9
Good	1 / 3	1	3	5	7
Moderate	1 / 5	1 / 3	1	3	5
Bad	1 / 7	1 / 5	1 / 3	1	3
Very Bad	1 / 9	1 / 7	1 / 5	1 / 3	1

Table 5.10. Pairwise comparison matrix of ranks for lithology factor

RANK	***Very Good***	***Good***	***Bad***	***Very Bad***
Very Good	1	3	7	9
Good	1 / 3	1	3	7
Bad	1 / 7	1 / 3	1	3
Very Bad	1 / 9	1 / 7	1 / 3	1

Table 5.11. Pairwise comparison matrix of ranks for activity factor

RANK	***Very Good***	***Good***	***Moderate***
Very Good	1	3	5
Good	1 / 3	1	3
Moderate	1 / 5	1 / 3	1

The iteration phase starts with obtaining initial weights for factors or ranks for five different (it is four for the lithology factor and three for the activity factor) conditions of factors. A second pairwise comparison vector is prepared with respect to the existing weights. This process is repeated until the difference between the last normalized weight and the previous one approaching to zero.

AHP requires a controlling operation by means of Consistency Ratio (C_R). It must be smaller than 0.1 (Malczewski, 1999). C_R is the ratio (Equation 5.3):

$$C_r = C_I / R_I \qquad (5.3)$$

where C_I and R_I are the consistency index (Table 5.12) and random inconsistency index, respectively. The C_I is derived from Equation 5.4:

$$C_I = (\lambda - n) / (n - 1) \qquad (5.4)$$

where λ is consistency vector, which is the ratio of the weighed sum with respect to the most dominant criterion and weights of all factors (Figure 5.4).

Table 5.12. Random inconsistency indices (Saaty, 1980)

n	R_I	n	R_I	n	R_I
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

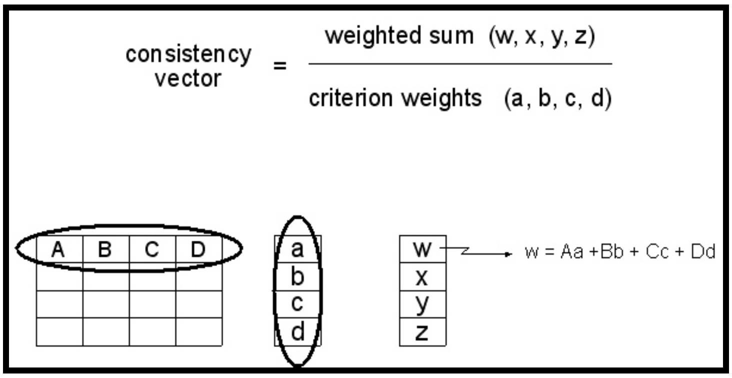

Figure 5.4. Calculation of consistency ratio (Kolat, 2004)

The result of the AHP weighing and ranking is tabulated in Table 5.13. The Lithology factor is in different condition as it is indicated before. Each factor has its own C_I and λ for its conditions and overall C_I and λ is 0.0894 and 7.71 respectively. In this thesis, all the C_I values are smaller than the required upper limit of 0.10 suggested by Malczewski (1999).

Table 5.13. Weighing Factors with AHP

Parameter	normal. weigh.	λ	Rank CR	rank class \ ranking				
				1 \ 0.0311	***3 \ 0.0815***	***5 \ 0.1663***	***7 \ 0.2849***	***9 \ 0.4362***
Liquefaction	0.2587	5.37	0.0824	Very High Def.	High Deformation	Medium Def.	Low Deformation	Rocky
Amplification	0.0901	5.37	0.0824	3.5 - 4.3	3.5 - 3.0	2.5 - 3.0	2.0 - 2.5	1.5 - 2.0
Fault Proximity	0.1090	5.37	0.0824	< 1000m	1000-2000m	2000-3000m	3000-4000m	> 4000m
Slope	0.2149	5.37	0.0824	> 30^o	20 - 30^o	10 - 20^o	5 - 10^o	0 - 5^o
Aspect	0.0230	5.37	0.0824	North 345-360^o, 0-15^o	N.west-N.east 315-345^o, 15-45^o	WNW-ENE 285-315^o, 45-75^o	West-East 225-285^o, 75-135^o	SW-South-SE 135-225^o
Lithology	0.2090	4.15	0.0571	***1 \ 0.0424***	***3 \ 0.1196***	***7 / 0.3031***	***9 \ 0.5349***	
				Alluvium	Fragmented Basalt and Tuff	Siltstone, Claystone	Limestone, Sandstone	
Activity	0.0975	3.05	0.0418	***5 \ 0.0909***	***7 \ 0.2568***	***9 \ 0.6523***		
				Medium Exp..	Low Expansion	Rocky		

5.3.2. Output of AHP

After using weights and ranks shown in Table 5.13 for the Equation 5.1, the mathematical model of the layer analysis is done using AHP (Equation 5.5). The unclassified result is exhibited in Figure 5.5. There are different unclassified microzonation values and their frequencies are plotted in Figure 5.6.

$$\begin{aligned} \textit{Suitability} = {} & 0.2768\times LQ_{RS} + 0.00982\times AC_{RS} + 0.1948\times GL_{RS} \\ & + 0.0724\times AP_{RS} + 0.2204\times SL_{RS} + 0.1119\times FP + 0.05\times AS_{RS} \end{aligned} \tag{5.5}$$

where *LQ*, *AC*, *GL*, *AP*, *SL*, *FP* and *AS* are symbols of factors. The suffix *RS* refers to standardized ranks of this factor. The equation lacks of excluded zones. Then, Equation 5.2 is also applied to obtain classified microzonation map with AHP method.

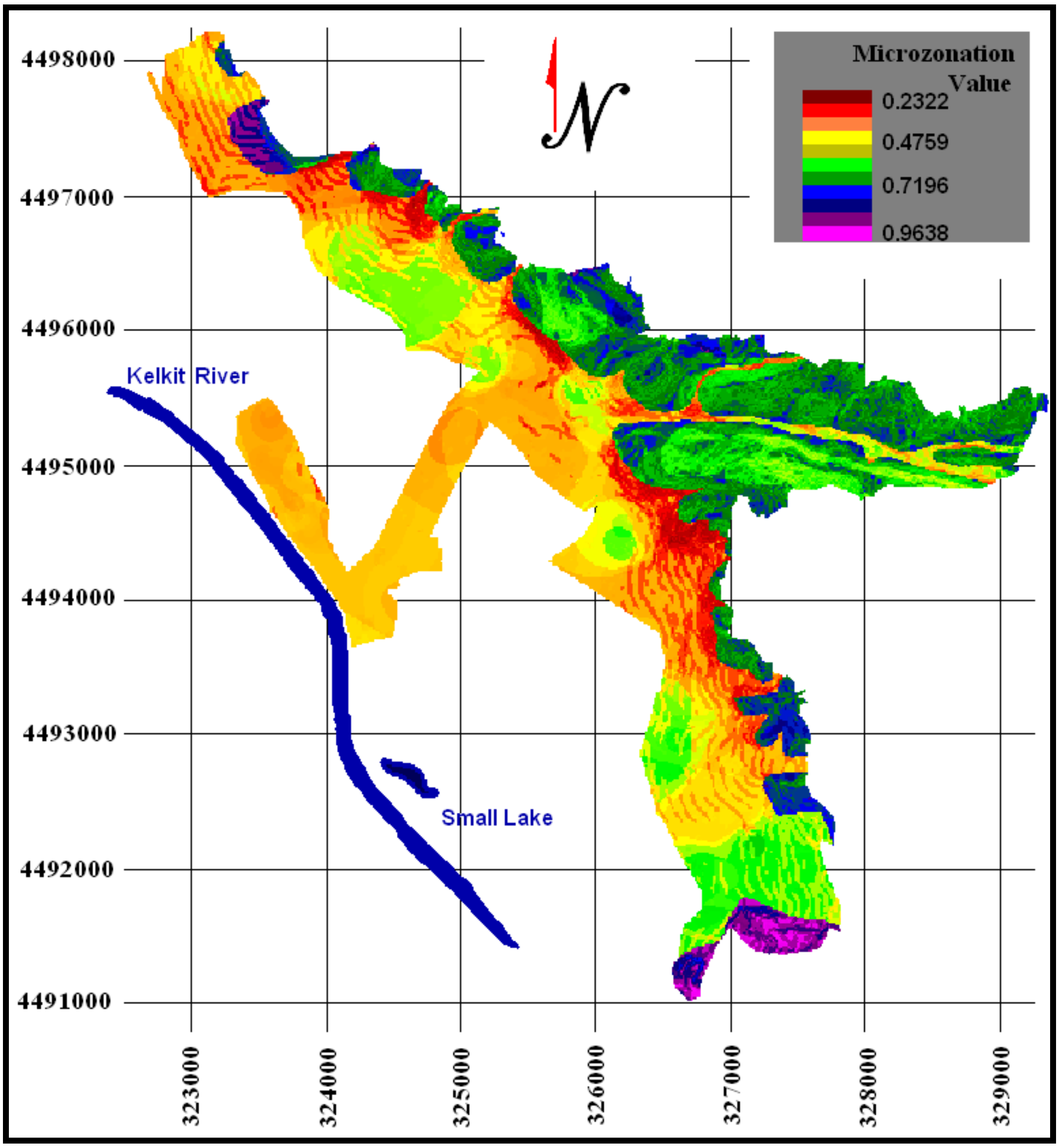

Figure 5.5. AHP microzonation map of Niksar without classification.

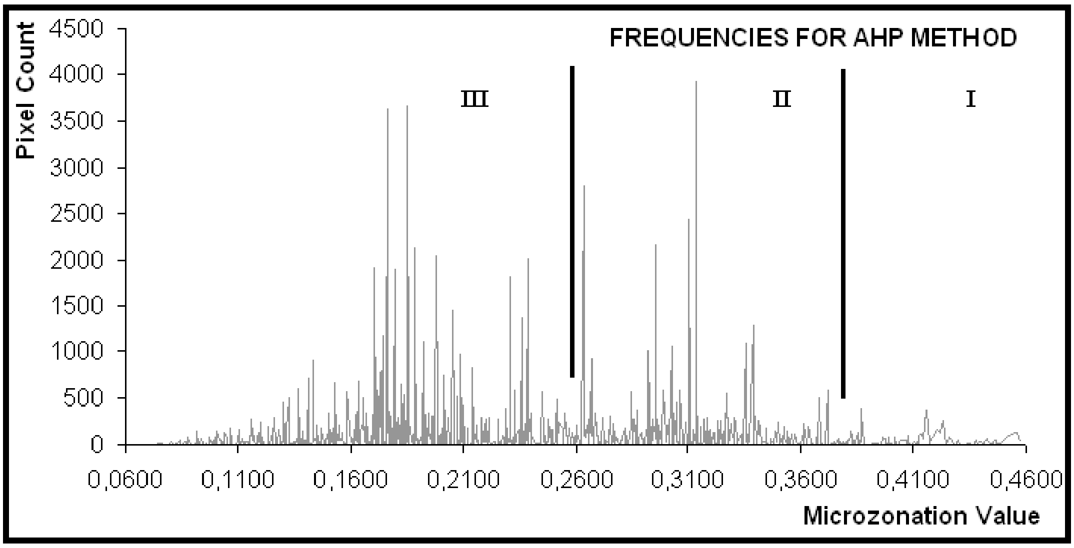

Figure 5.6 Frequencies of microzonation values without classification and histogram showing the classification for the microzonation using AHP method.

5.3.3. Microzonation of the study area with AHP

The division for the classified AHP microzonation is shown in Figure 5.6. Then, classified zones are determined and tabulated in Table 5.14. The resultant microzonation map with AHP is in Figure 5.7. The final proportions of suitability zones for the urban settlement are given in Table 5.15.

Table 5.14. Ranges of suitability classification without excluded zones

Range	Names as Areas of	Pixel Count	Share
0.06-0.26	Detailed Geothechnical Investigation	71468	61.41%
0.26-0.38	Provisional	40103	34.46%
0.38-0.46	Suitable	4811	04.13%
	Total:	*116382*	*100%*

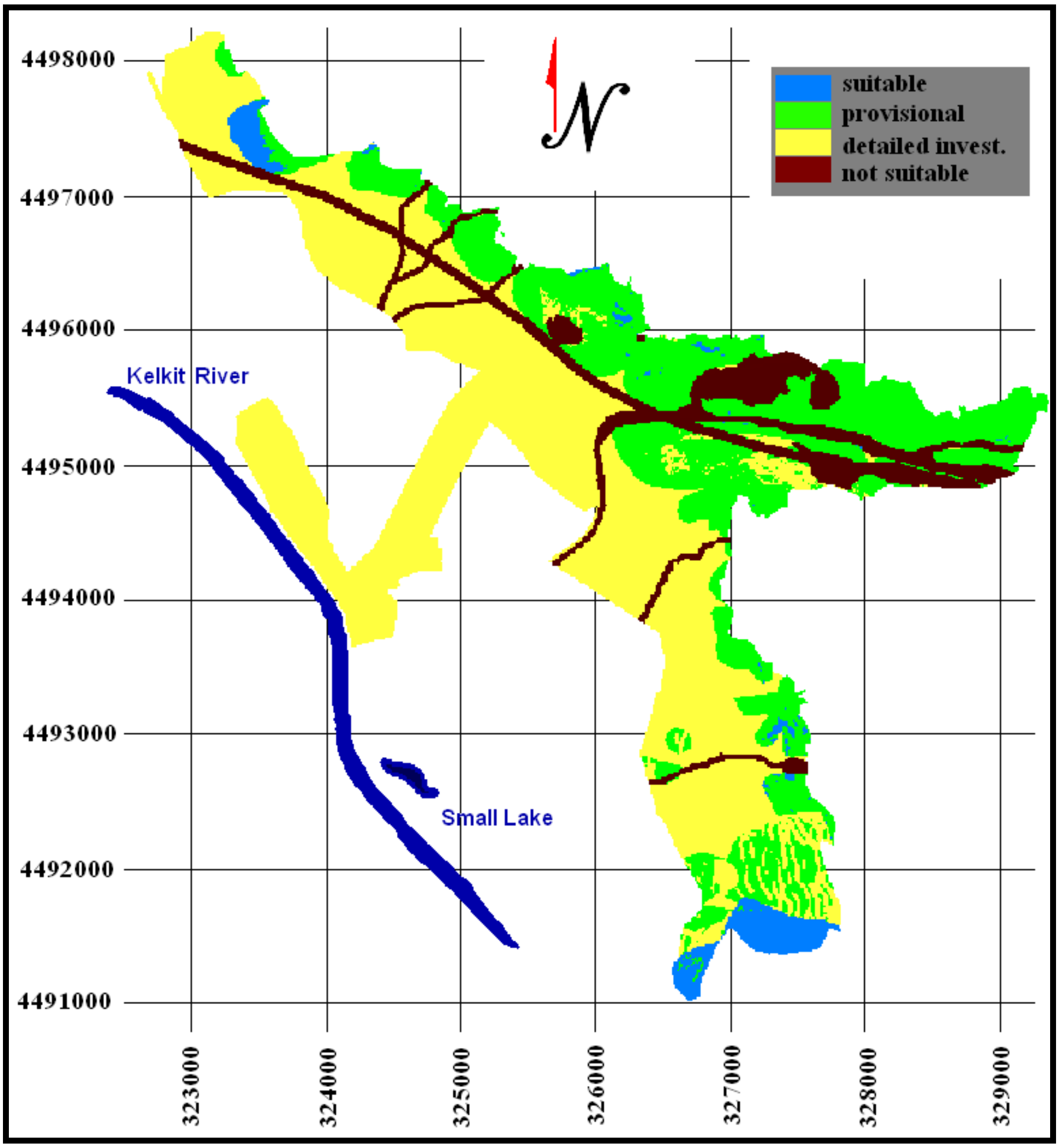

Figure 5.7. Classified microzonation map of Niksar with AHP method

Table 5.15. Classification of the microzonation with AHP

Microzonation Class	Suitable Areas	Provisional Areas	Areas Requiring Detailed Geotechnical Investigations	Unsuitable Areas	
Class Value	I	II	III	IV	***Total***
Pixel Count	4581	35185	61870	14746	*116382*
Share	03.94%	30.23%	53.16%	12.67%	*100%*

5.4. Comparison SAW and AHP results

Both of the methods produced almost consistent results. Totally, 94.20% of the study area reflects the same results with two methods. On the other hand, the deviation between two microzonation maps (Figure 5.1 and Figure 5.5) occurs only in marginal values between different suitability classes. Areas of the deviation are shown in Figure 5.8.

Both Figure 5.1 and Figure 5.5 has the same classification. The differentiation is tabulated in Table 5.16. This table contains class values of SAW at rows and AHP at columns. There is no occasion of the drastic changes between areas requiring detailed geotechnical investigations (3) to suitable areas (1).

The portion of the deviation is only 5.80%, meaning that both techniques output almost the same results. If it is necessary to select one of them, the microzonation with AHP method is recommended because it has self-control process to check consistency.

Table 5.16. Differentiation between two microzonation maps

		AHP		
		1	***2***	***3***
SAW	***1***	5963	-	-
	2	2657	30464	6770
	3	-	4744	65784

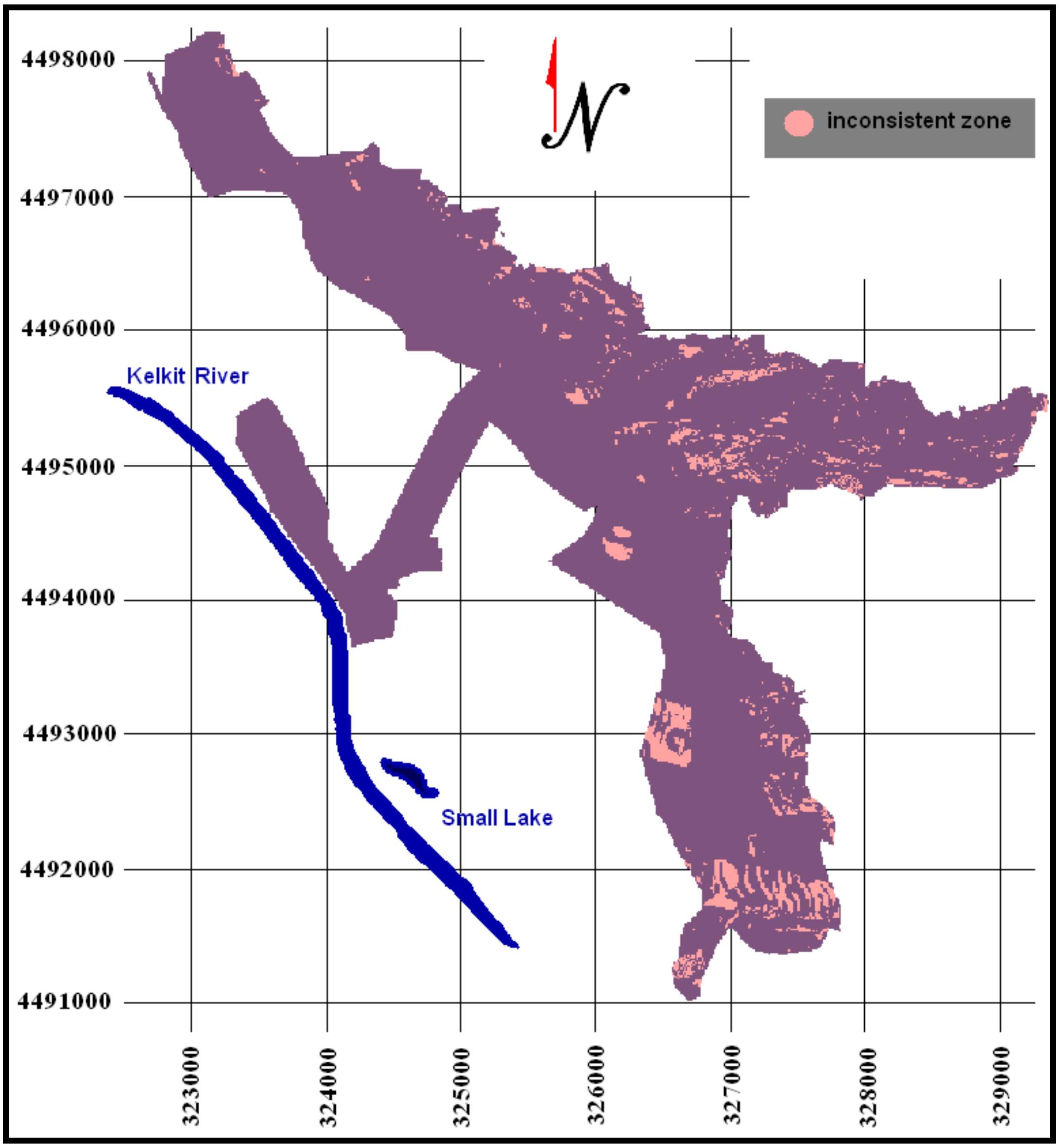

Figure 5.8. Comparison map of two decision-making methods

CHAPTER 6

DISCUSSION

The study area lies on the North Anatolian Fault zone where earthquakes having M_w of 7.0 to 7.2 are expected (Abraseys, 1970; Saroglu et al., 1992; Barka, 1996; Ozmen et al., 1997). In addition to this, a segment of NAFZ passes through the study area. Under this condition, the earthquake hazard is a problem for Niksar and the city planning must depend on the information about the ground.

The decisive property of the ground on the suitability of the settlement is the type of the ground material. This property is covered in factors of the activity, the liquefaction and the lithology. All three put a separation between the alluvium and rocky eastern part of the study area. Then, the eastern part at which all formations expose except from the Ilicaktepe formation is proposed as more favorable for the urbanization. This formation has poorly consolidated material giving rise to slope instability problem with increasing inclination of the ground surface.

Values of the factor of safety for the liquefaction are marginal ranging from 0.90 to 1.15, in some parts of the alluvium. Moreover, depths of some detected liquefiable layer are down to 8m or the groundwater table is at this depth in the vicinity of the city center. This situation might arise the idea that the liquefaction is not expected to cause noticeable damage on the ground surface using the method of Ishiara (1985). Nevertheless, the dominant soil type of the study area is SC, which is clayey sand with low plasticity. Therefore, liquefaction evaluation by LPI method gives better results when the distribution of the liquefaction related zones are considered. On the other hand, the non-liquefiable soil, which is defined after geotechnical investigation, cannot be considered as favorable as rocky ground observed at the east.

Depths of available boreholes are not enough to calculate actual ground amplification by using technical properties of the materials below the ground surface. If there were such data, the distribution of the ground amplification parameter would be derived. On the other hand, this data would supply the shear wave velocity values and the shear modulus degradation condition at the required depths.

To summarize all properties of the microzonation it can be said that the ground material supplies the main division between the alluvium and the rest. Then, slope, aspect and lithologies categorize the rocky ground, while the liquefaction and activity classify the soil. The fault proximity and the ground amplification are added to improve the result.

The category of ‘areas requiring detailed geotechnical investigation’ covers mainly areas having liquefaction susceptibility for the alluvium-covered part of the study area. The same category covers the ground material of fragmented basalt and tuff (material of Ilicaktepe formation.) on sloping ground (around 4494500N, 327000E). In steep slopes with this material, slope failures are observed and these zones of the study area are closed in the category of ‘unsuitable areas’.

In the decision-making phase of the thesis, all factors are ranked consistent with each other. All of factors are categorized into five cases as ‘very good’, ‘good’, ‘moderate’, ‘bad’ and ‘very bad’, initially. Nevertheless, the ground lithology and the activity are exceptional because the ground lithology does not have ‘moderate’ case and high or very high expansion of the soil is not observed in the study area for the factor of the activity. This situation is not a problem for SAW method because all cases are assigned rank values as 1, 2, 3, 4 and 5, for very bad to very good. And, they are normalized as 0.2, 0.4, 0.6, 0.8 to 1.0, respectively. Then, the activity does not have ranks of 1 and 2 while the ground lithology is lack of 3. Nevertheless, this is problem for AHP method. The activity and the ground lithology factors require their own comparison table while other five factors of the liquefaction, the ground amplification, the fault proximity, the slope and the aspect have similar comparison tables.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

In this thesis, the study area, which is the municipality service border of Niksar (Tokat), is investigated and a microzonation map is prepared for the purpose of urban settlement. This microzonation divides the study area into four categories with respect to factors of liquefaction, activity, lithology, ground amplification, fault proximity, slope and aspect. Moreover, some parts of the study area are closed previously due to cultural use, mining and some other dangers such as expected rupturing on the fault, landslide.

The liquefaction is a highly probable event for alluvium-covered parts of the study area. The medium expansion of the soil is expected southwest of the city center. The ground amplification is, commonly, in the range of 2.0 to 2.5. The slope instability is the problem for the study area around the southern bank of Canakci brook with high inclinations more than 30^o and in ground material of fragmented basalt and tuff (Ilicaktepe formation.), in north facing slopes, particularly.

The microzonation of the study area is produced by means of MCDA methods of SAW and AHP, separately. Both of them are used to obtain classified microzonation maps. Nevertheless, the map prepared with AHP method is preferable because it has the methodology to check its own consistency.

According to the suitability condition exhibited in the microzonation map, it is recommended that the rocky parts of the study area composed of siltstone, claystone are more convenient for urban settlement in the study area than alluvium if the slope instability problem does not exist. Moreover, sandstone and limestone are recommended, decisively. Then, this will be more reliable if new settlement areas are shifted to these zones.

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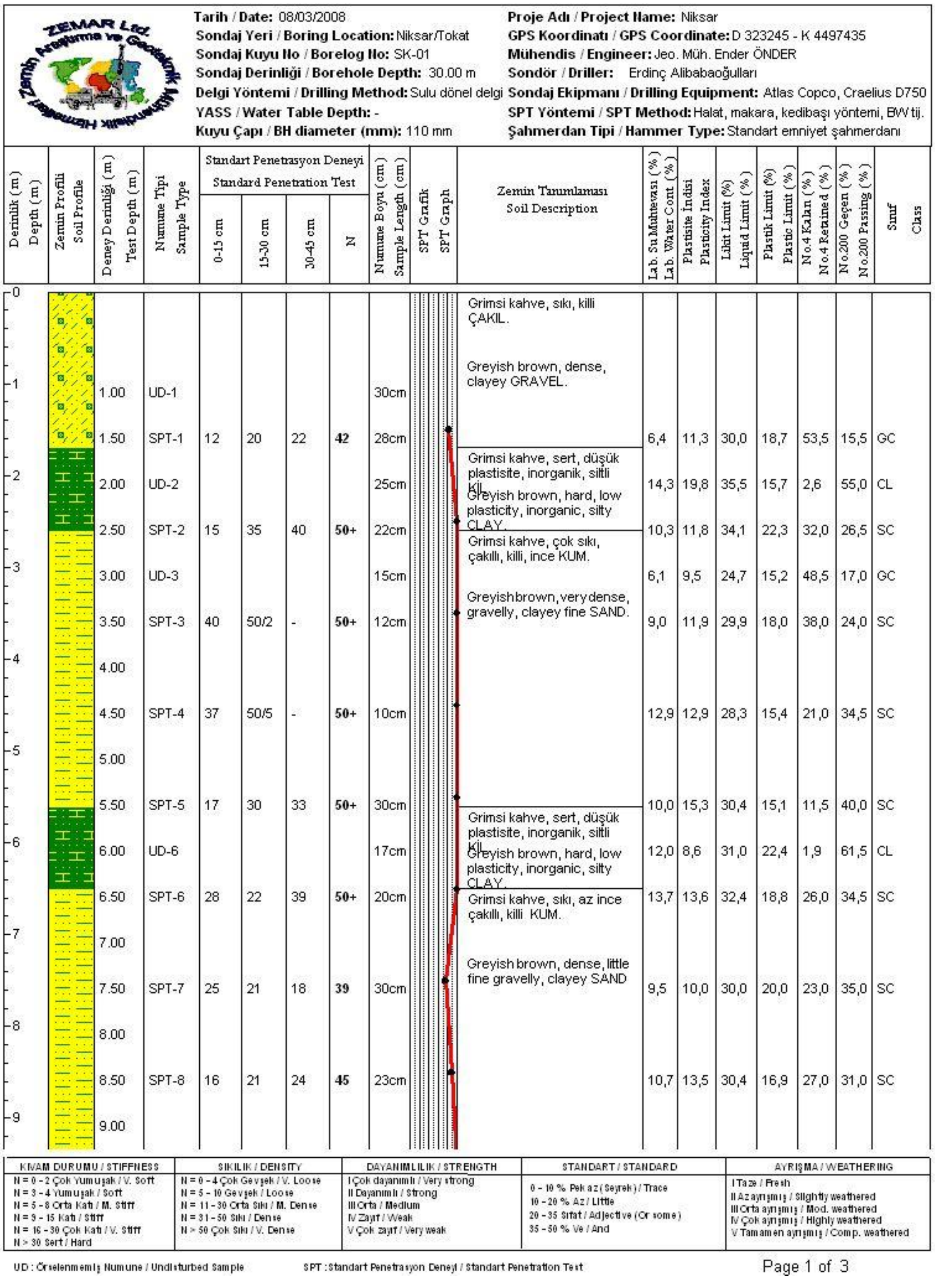
APPENDIX A



ZEMAR Ltd. Zemin Araştırma ve Geoteknik Mühendislik Hizmetleri

Tarih / Date: 08/03/2008
Sondaj Yeri / Boring Location: Niksar/Tokat
Sondaj Kuyu No / Borelog No: SK-01
Sondaj Derinliği / Borehole Depth: 30.00 m
Delgi Yöntemi / Drilling Method: Sulu dönel delgi
YASS / Water Table Depth: -
Kuyu Çapı / BH diameter (mm): 110 mm

Proje Adı / Project Name: Niksar
GPS Koordinatı / GPS Coordinate: D 323245 - K 4497435
Mühendis / Engineer: Jeo. Müh. Ender ÖNDER
Sondör / Driller: Erdinç Alibabaoğulları
Sondaj Ekipmanı / Drilling Equipment: Atlas Copco, Craelius D750
SPT Yöntemi / SPT Method: Halat, makara, kedibaşı yöntemi, BW tij.
Şahmerdan Tipi / Hammer Type: Standart emniyet şahmerdanı

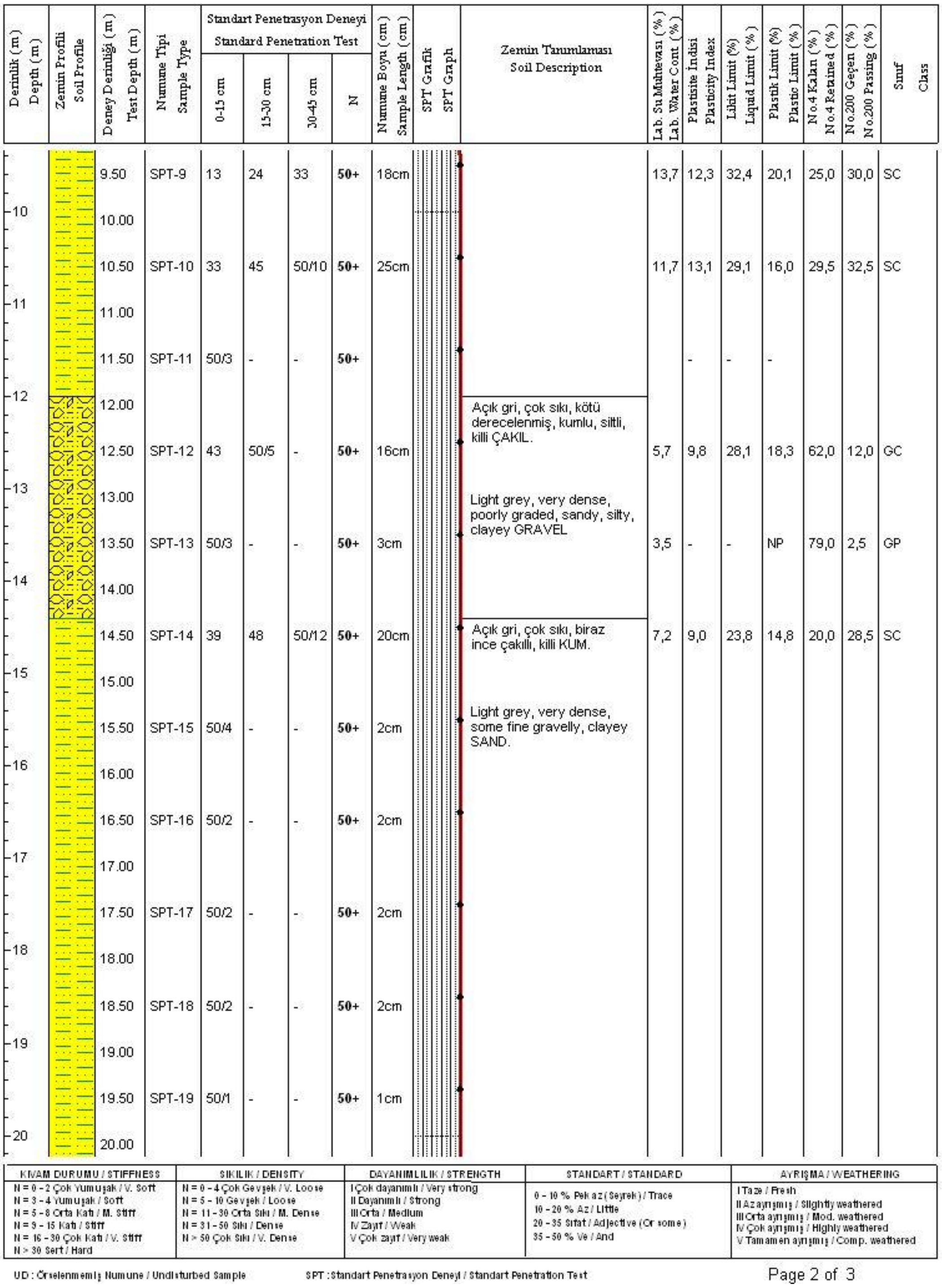
Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
1.00	UD-1					30cm	Grimsi kahve, sıkı, killi ÇAKIL. Greyish brown, dense, clayey GRAVEL.							
1.50	SPT-1	12	20	22	**42**	28cm		6,4	11,3	30,0	18,7	53,5	15,5	GC
2.00	UD-2					25cm	Grimsi kahve, sert, düşük plastisite, inorganik, siltli KİL. Greyish brown, hard, low plasticity, inorganic, silty CLAY.	14,3	19,8	35,5	15,7	2,6	55,0	CL
2.50	SPT-2	15	35	40	**50+**	22cm	Grimsi kahve, çok sıkı, çakıllı, killi, ince KUM. Greyishbrown, very dense, gravelly, clayey fine SAND.	10,3	11,8	34,1	22,3	32,0	26,5	SC
3.00	UD-3					15cm		6,1	9,5	24,7	15,2	48,5	17,0	GC
3.50	SPT-3	40	50/2	-	**50+**	12cm		9,0	11,9	29,9	18,0	38,0	24,0	SC
4.00														
4.50	SPT-4	37	50/5	-	**50+**	10cm		12,9	12,9	28,3	15,4	21,0	34,5	SC
5.00														
5.50	SPT-5	17	30	33	**50+**	30cm		10,0	15,3	30,4	15,1	11,5	40,0	SC
6.00	UD-6					17cm	Grimsi kahve, sert, düşük plastisite, inorganik, siltli KİL. Greyish brown, hard, low plasticity, inorganic, silty CLAY.	12,0	8,6	31,0	22,4	1,9	61,5	CL
6.50	SPT-6	28	22	39	**50+**	20cm	Grimsi kahve, sıkı, az ince çakıllı, killi KUM. Greyish brown, dense, little fine gravelly, clayey SAND	13,7	13,6	32,4	18,8	26,0	34,5	SC
7.00														
7.50	SPT-7	25	21	18	**39**	30cm		9,5	10,0	30,0	20,0	23,0	35,0	SC
8.00														
8.50	SPT-8	16	21	24	**45**	23cm		10,7	13,5	30,4	16,9	27,0	31,0	SC
9.00														

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

Page 1 of 3

Figure A.1. Borehole drilled for the thesis: D02 (1/3)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
		9.50	SPT-9	13	24	33	**50+**	18cm			13,7	12,3	32,4	20,1	25,0	30,0	SC
10		10.00															
		10.50	SPT-10	33	45	50/10	**50+**	25cm			11,7	13,1	29,1	16,0	29,5	32,5	SC
11		11.00															
		11.50	SPT-11	50/3	-	-	**50+**					-	-	-			
12		12.00								Açık gri, çok sıkı, kötü derecelenmiş, kumlu, siltli, killi ÇAKIL. Light grey, very dense, poorly graded, sandy, silty, clayey GRAVEL							
		12.50	SPT-12	43	50/5	-	**50+**	16cm			5,7	9,8	28,1	18,3	62,0	12,0	GC
13		13.00															
		13.50	SPT-13	50/3	-	-	**50+**	3cm			3,5	-	-	NP	79,0	2,5	GP
14		14.00															
		14.50	SPT-14	39	48	50/12	**50+**	20cm		Açık gri, çok sıkı, biraz ince çakıllı, killi KUM. Light grey, very dense, some fine gravelly, clayey SAND.	7,2	9,0	23,8	14,8	20,0	28,5	SC
15		15.00															
		15.50	SPT-15	50/4	-	-	**50+**	2cm									
16		16.00															
		16.50	SPT-16	50/2	-	-	**50+**	2cm									
17		17.00															
		17.50	SPT-17	50/2	-	-	**50+**	2cm									
18		18.00															
		18.50	SPT-18	50/2	-	-	**50+**	2cm									
19		19.00															
		19.50	SPT-19	50/1	-	-	**50+**	1cm									
20		20.00															

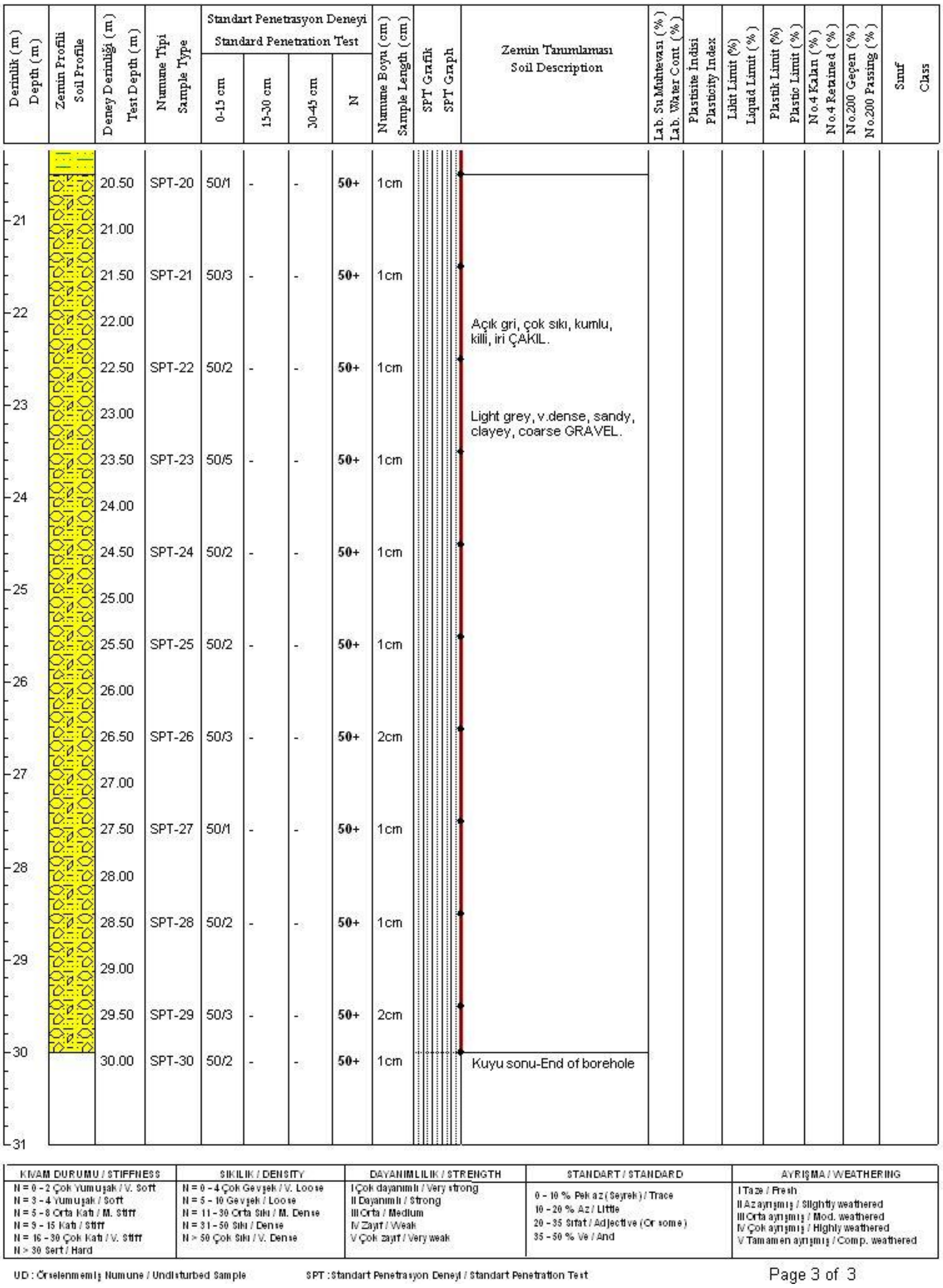
KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

Page 2 of 3

Figure A.2. Boreholes drilled for the thesis: D02 (2/3)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
		20.50	SPT-20	50/1	-	-	**50+**	1cm		Açık gri, çok sıkı, kumlu, killi, iri ÇAKIL. Light grey, v.dense, sandy, clayey, coarse GRAVEL.							
21		21.00															
		21.50	SPT-21	50/3	-	-	**50+**	1cm									
22		22.00															
		22.50	SPT-22	50/2	-	-	**50+**	1cm									
23		23.00															
		23.50	SPT-23	50/5	-	-	**50+**	1cm									
24		24.00															
		24.50	SPT-24	50/2	-	-	**50+**	1cm									
25		25.00															
		25.50	SPT-25	50/2	-	-	**50+**	1cm									
26		26.00															
		26.50	SPT-26	50/3	-	-	**50+**	2cm									
27		27.00															
		27.50	SPT-27	50/1	-	-	**50+**	1cm									
28		28.00															
		28.50	SPT-28	50/2	-	-	**50+**	1cm									
29		29.00															
		29.50	SPT-29	50/3	-	-	**50+**	2cm									
30		30.00	SPT-30	50/2	-	-	**50+**	1cm		Kuyu sonu-End of borehole							
31																	

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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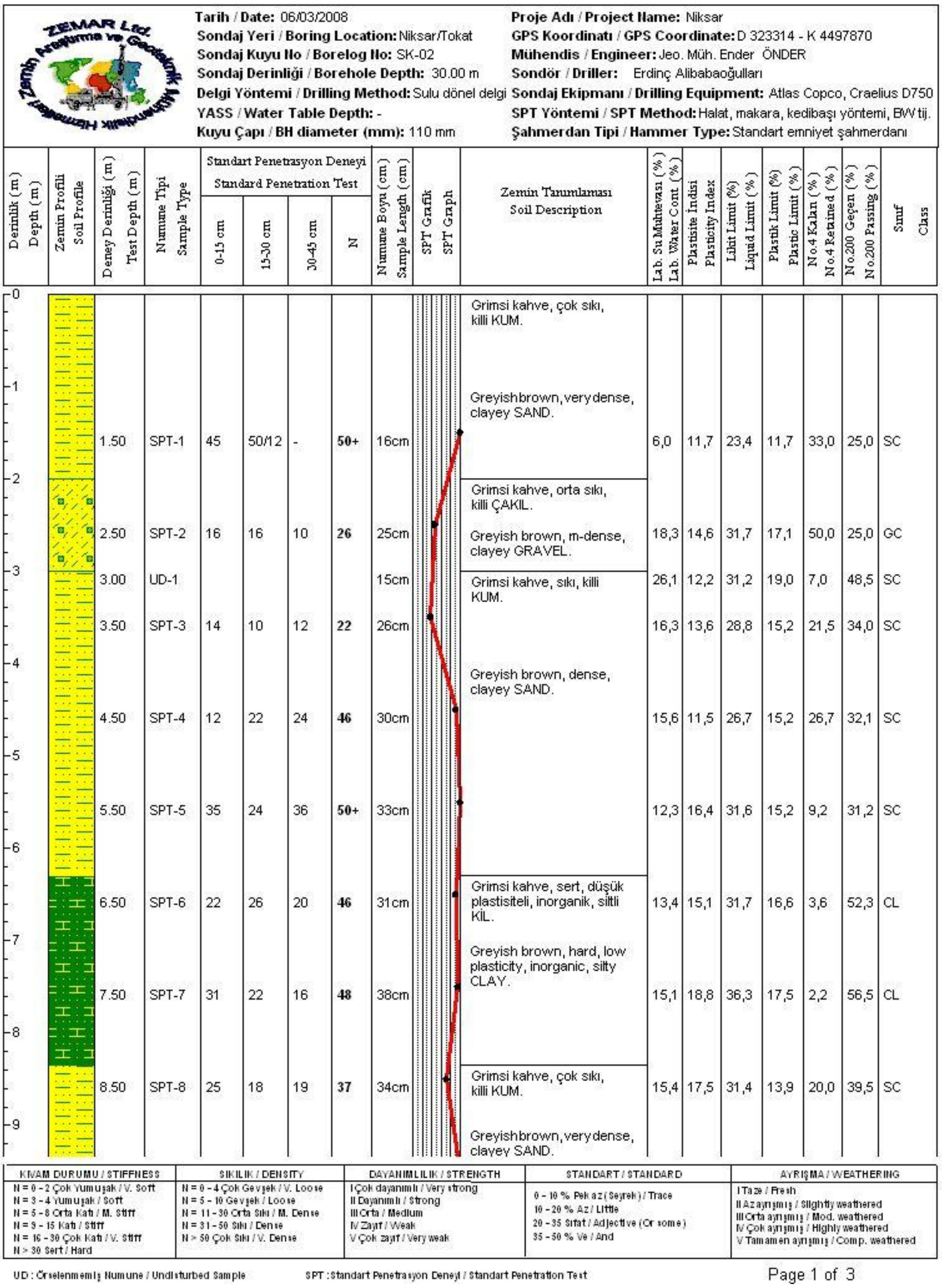
Figure A.3. Boreholes drilled for the thesis: D02 - 3/3



ZEMAR Ltd. Zemin Araştırma ve Geoteknik Mühendislik Hizmetleri

Tarih / Date: 06/03/2008
Sondaj Yeri / Boring Location: Niksar/Tokat
Sondaj Kuyu No / Borelog No: SK-02
Sondaj Derinliği / Borehole Depth: 30.00 m
Delgi Yöntemi / Drilling Method: Sulu dönel delgi
YASS / Water Table Depth: -
Kuyu Çapı / BH diameter (mm): 110 mm

Proje Adı / Project Name: Niksar
GPS Koordinatı / GPS Coordinate: D 323314 - K 4497870
Mühendis / Engineer: Jeo. Müh. Ender ÖNDER
Sondör / Driller: Erdinç Alibabaoğulları
Sondaj Ekipmanı / Drilling Equipment: Atlas Copco, Craelius D750
SPT Yöntemi / SPT Method: Halat, makara, kedibaşı yöntemi, BW tij.
Şahmerdan Tipi / Hammer Type: Standart emniyet şahmerdanı

Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
0	🟨									Grimsi kahve, çok sıkı, killi KUM. Greyish brown, very dense, clayey SAND.							
1	🟨	1.50	SPT-1	45	50/12	-	**50+**	16cm			6,0	11,7	23,4	11,7	33,0	25,0	SC
2	🟨	2.50	SPT-2	16	16	10	**26**	25cm		Grimsi kahve, orta sıkı, killi ÇAKIL. Greyish brown, m-dense, clayey GRAVEL.	18,3	14,6	31,7	17,1	50,0	25,0	GC
3	🟨	3.00	UD-1					15cm		Grimsi kahve, sıkı, killi KUM. Greyish brown, dense, clayey SAND.	26,1	12,2	31,2	19,0	7,0	48,5	SC
	🟨	3.50	SPT-3	14	10	12	**22**	26cm			16,3	13,6	28,8	15,2	21,5	34,0	SC
4	🟨	4.50	SPT-4	12	22	24	**46**	30cm			15,6	11,5	26,7	15,2	26,7	32,1	SC
5	🟨	5.50	SPT-5	35	24	36	**50+**	33cm			12,3	16,4	31,6	15,2	9,2	31,2	SC
6	🟩	6.50	SPT-6	22	26	20	**46**	31cm		Grimsi kahve, sert, düşük plastisiteli, inorganik, siltli KİL. Greyish brown, hard, low plasticity, inorganic, silty CLAY.	13,4	15,1	31,7	16,6	3,6	52,3	CL
7	🟩	7.50	SPT-7	31	22	16	**48**	38cm			15,1	18,8	36,3	17,5	2,2	56,5	CL
8	🟨	8.50	SPT-8	25	18	19	**37**	34cm		Grimsi kahve, çok sıkı, killi KUM. Greyish brown, very dense, clayey SAND.	15,4	17,5	31,4	13,9	20,0	39,5	SC
9	🟨																

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft	N = 0 - 4 Çok Gevşek / V. Loose	I Çok dayanımlı / Very strong	0 - 10 % Pek az (Seyrek) / Trace	I Taze / Fresh
N = 3 - 4 Yumuşak / Soft	N = 5 - 10 Gevşek / Loose	II Dayanımlı / Strong	10 - 20 % Az / Little	II Az ayrışmış / Slightly weathered
N = 5 - 8 Orta Katı / M. Stiff	N = 11 - 30 Orta Sıkı / M. Dense	III Orta / Medium	20 - 35 Sıfat / Adjective (Or some)	III Orta ayrışmış / Mod. weathered
N = 9 - 15 Katı / Stiff	N = 31 - 50 Sıkı / Dense	IV Zayıf / Weak	35 - 50 % Ve / And	IV Çok ayrışmış / Highly weathered
N = 16 - 30 Çok Katı / V. Stiff	N > 50 Çok Sıkı / V. Dense	V Çok zayıf / Very weak		V Tamamen ayrışmış / Comp. weathered
N > 30 Sert / Hard				

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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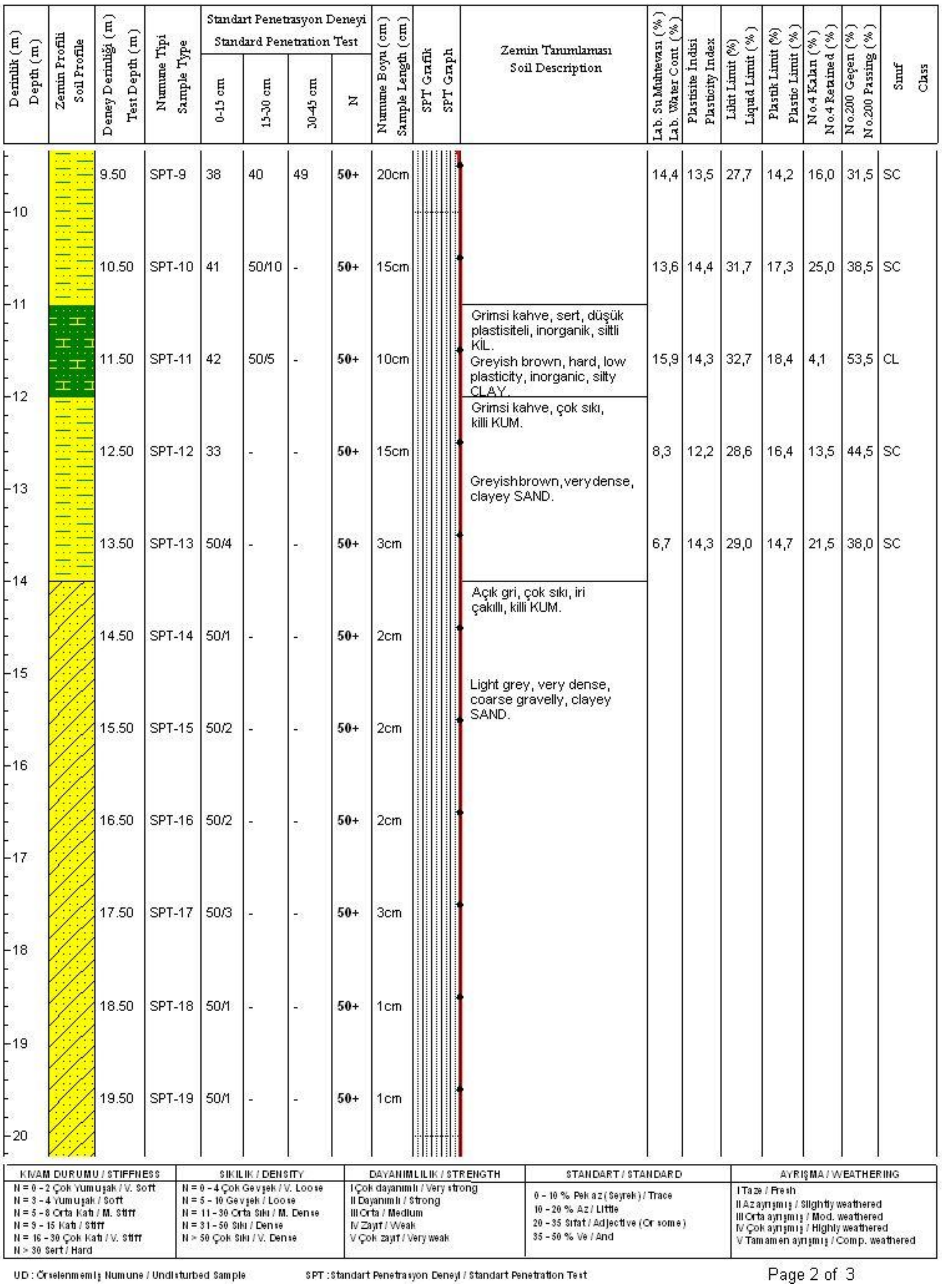
Figure A.4. Boreholes drilled for the thesis: D01 (1/3)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
		9.50	SPT-9	38	40	49	**50+**	20cm			14,4	13,5	27,7	14,2	16,0	31,5	SC
		10.50	SPT-10	41	50/10	-	**50+**	15cm			13,6	14,4	31,7	17,3	25,0	38,5	SC
		11.50	SPT-11	42	50/5	-	**50+**	10cm		Grimsi kahve, sert, düşük plastisiteli, inorganik, siltli KİL. Greyish brown, hard, low plasticity, inorganic, silty CLAY.	15,9	14,3	32,7	18,4	4,1	53,5	CL
		12.50	SPT-12	33	-	-	**50+**	15cm		Grimsi kahve, çok sıkı, killi KUM. Greyishbrown, verydense, clayey SAND.	8,3	12,2	28,6	16,4	13,5	44,5	SC
		13.50	SPT-13	50/4	-	-	**50+**	3cm			6,7	14,3	29,0	14,7	21,5	38,0	SC
		14.50	SPT-14	50/1	-	-	**50+**	2cm		Açık gri, çok sıkı, iri çakıllı, killi KUM. Light grey, very dense, coarse gravelly, clayey SAND.							
		15.50	SPT-15	50/2	-	-	**50+**	2cm									
		16.50	SPT-16	50/2	-	-	**50+**	2cm									
		17.50	SPT-17	50/3	-	-	**50+**	3cm									
		18.50	SPT-18	50/1	-	-	**50+**	1cm									
		19.50	SPT-19	50/1	-	-	**50+**	1cm									

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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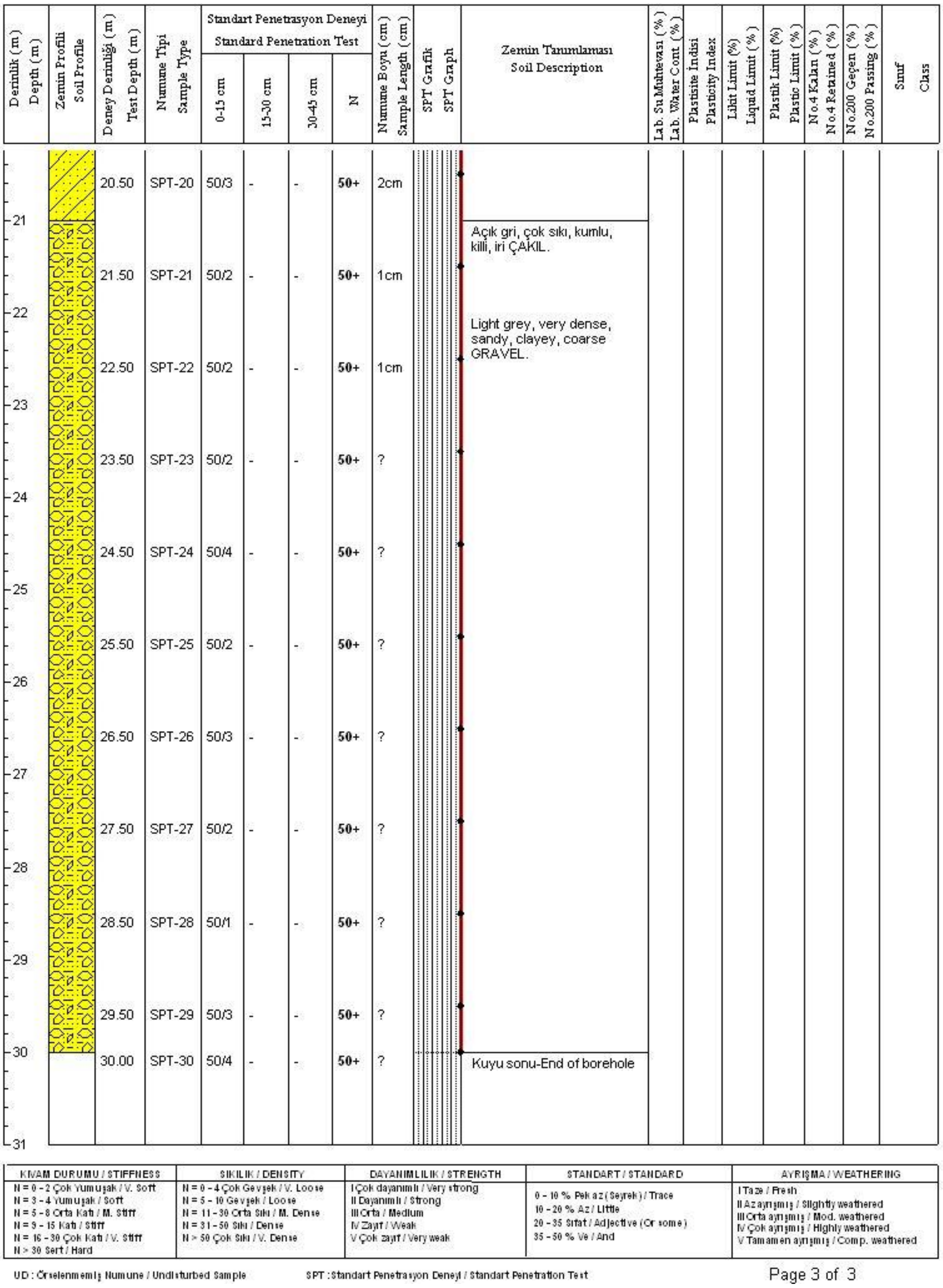
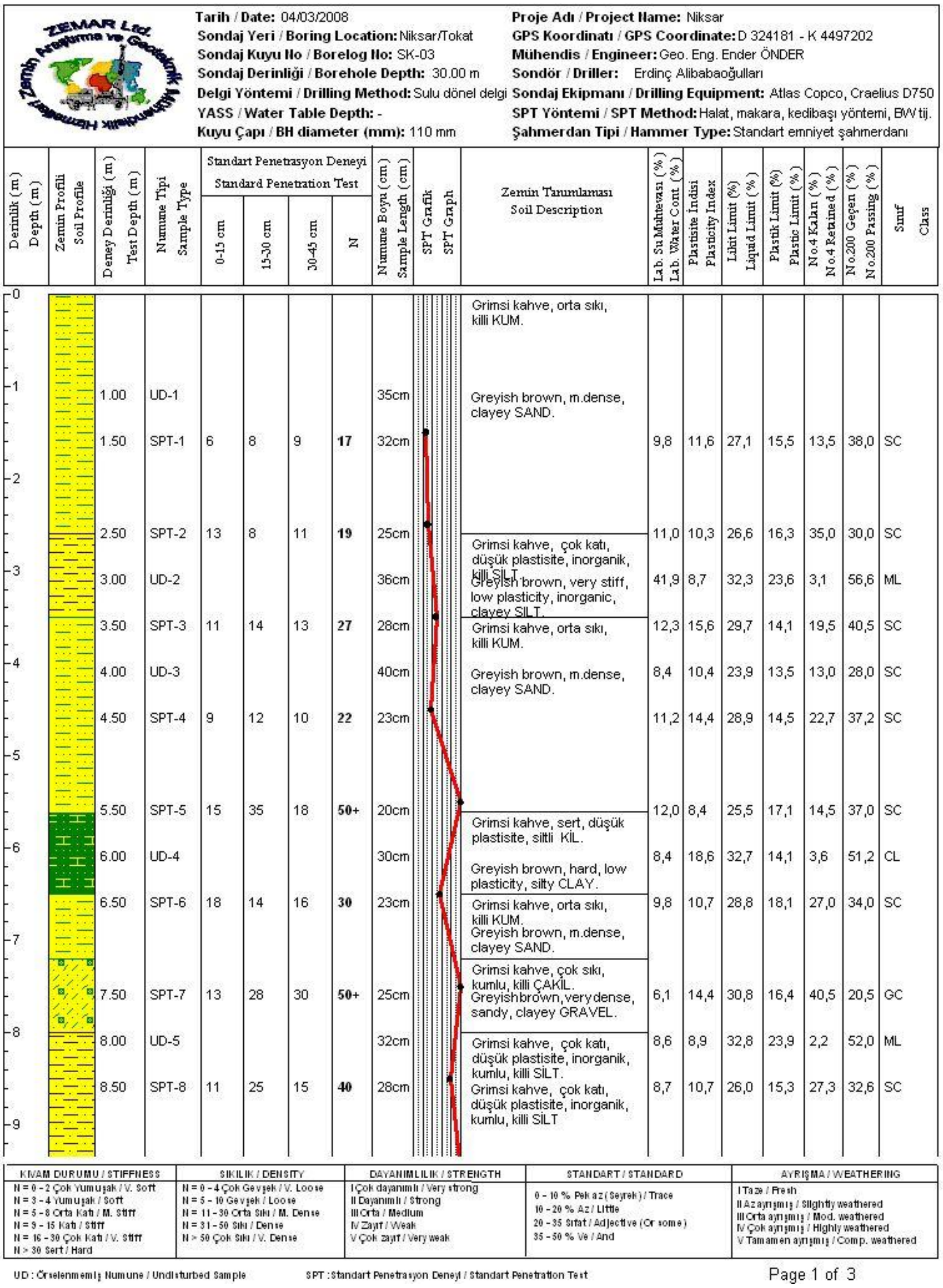
Figure A.5. Boreholes drilled for the thesis: D01 (2/3)





Tarih / Date: 04/03/2008
Sondaj Yeri / Boring Location: Niksar/Tokat
Sondaj Kuyu No / Borelog No: SK-03
Sondaj Derinliği / Borehole Depth: 30.00 m
Delgi Yöntemi / Drilling Method: Sulu dönel delgi
YASS / Water Table Depth: -
Kuyu Çapı / BH diameter (mm): 110 mm

Proje Adı / Project Name: Niksar
GPS Koordinatı / GPS Coordinate: D 324181 - K 4497202
Mühendis / Engineer: Geo. Eng. Ender ÖNDER
Sondör / Driller: Erdinç Alibabaoğulları
Sondaj Ekipmanı / Drilling Equipment: Atlas Copco, Craelius D750
SPT Yöntemi / SPT Method: Halat, makara, kedibaşı yöntemi, BW tij.
Şahmerdan Tipi / Hammer Type: Standart emniyet şahmerdanı

Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
0										Grimsi kahve, orta sıkı, killi KUM. Greyish brown, m.dense, clayey SAND.							
1		1.00	UD-1					35cm									
		1.50	SPT-1	6	8	9	**17**	32cm			9,8	11,6	27,1	15,5	13,5	38,0	SC
2		2.50	SPT-2	13	8	11	**19**	25cm			11,0	10,3	26,6	16,3	35,0	30,0	SC
3		3.00	UD-2					36cm		Grimsi kahve, çok katı, düşük plastisite, inorganik, killi SİLT. Greyish brown, very stiff, low plasticity, inorganic, clayey SILT.	41,9	8,7	32,3	23,6	3,1	56,6	ML
		3.50	SPT-3	11	14	13	**27**	28cm		Grimsi kahve, orta sıkı, killi KUM. Greyish brown, m.dense, clayey SAND.	12,3	15,6	29,7	14,1	19,5	40,5	SC
4		4.00	UD-3					40cm			8,4	10,4	23,9	13,5	13,0	28,0	SC
		4.50	SPT-4	9	12	10	**22**	23cm			11,2	14,4	28,9	14,5	22,7	37,2	SC
5		5.50	SPT-5	15	35	18	**50+**	20cm			12,0	8,4	25,5	17,1	14,5	37,0	SC
6		6.00	UD-4					30cm		Grimsi kahve, sert, düşük plastisite, siltli KİL. Greyish brown, hard, low plasticity, silty CLAY.	8,4	18,6	32,7	14,1	3,6	51,2	CL
		6.50	SPT-6	18	14	16	**30**	23cm		Grimsi kahve, orta sıkı, killi KUM. Greyish brown, m.dense, clayey SAND.	9,8	10,7	28,8	18,1	27,0	34,0	SC
7		7.50	SPT-7	13	28	30	**50+**	25cm		Grimsi kahve, çok sıkı, kumlu, killi ÇAKİL. Greyishbrown, very dense, sandy, clayey GRAVEL.	6,1	14,4	30,8	16,4	40,5	20,5	GC
8		8.00	UD-5					32cm		Grimsi kahve, çok katı, düşük plastisite, inorganik, kumlu, killi SİLT.	8,6	8,9	32,8	23,9	2,2	52,0	ML
		8.50	SPT-8	11	25	15	**40**	28cm		Grimsi kahve, çok katı, düşük plastisite, inorganik, kumlu, killi SİLT	8,7	10,7	26,0	15,3	27,3	32,6	SC
9																	

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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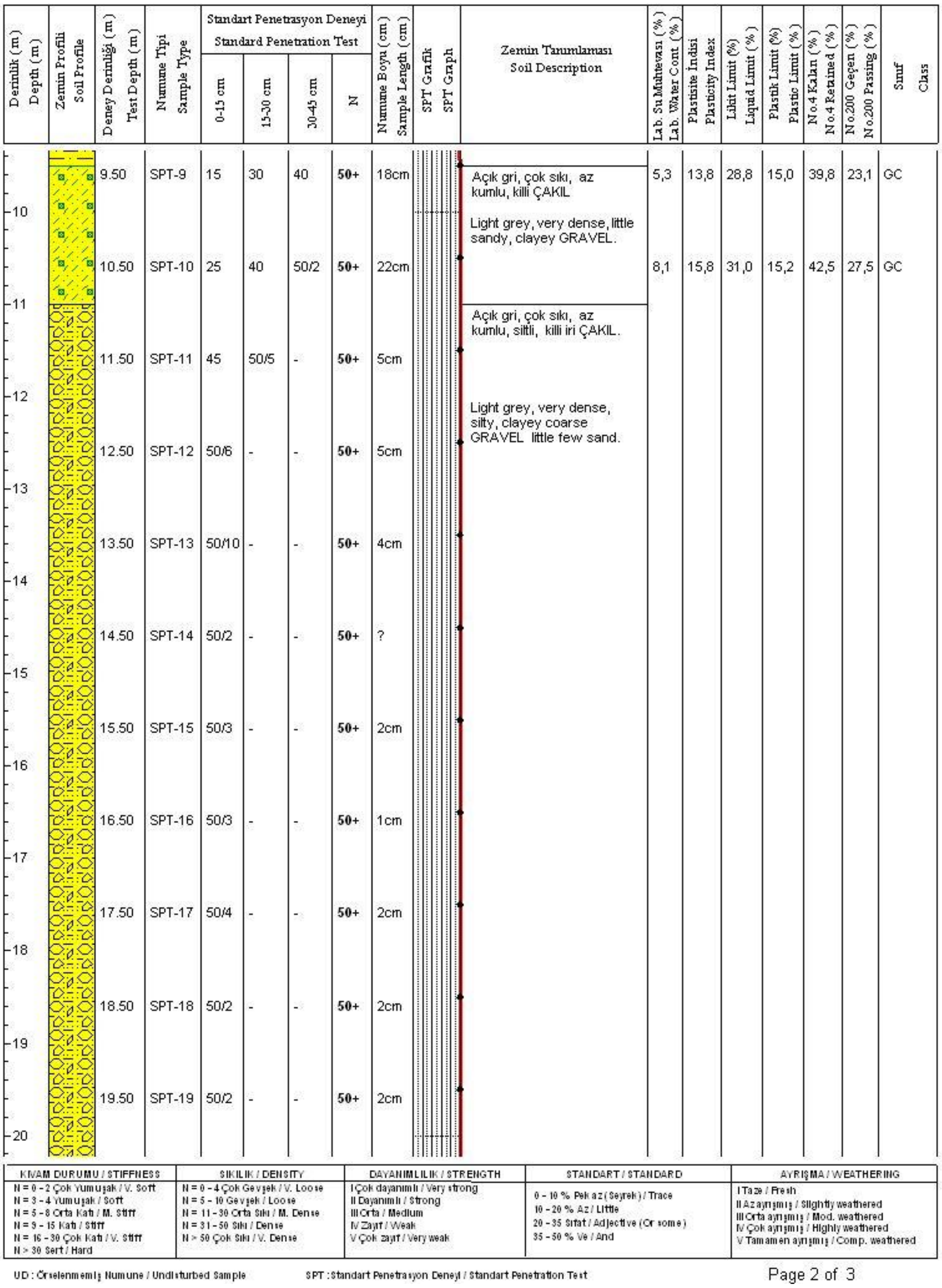
Figure A.7. Boreholes drilled for the thesis: D03 (1/3)

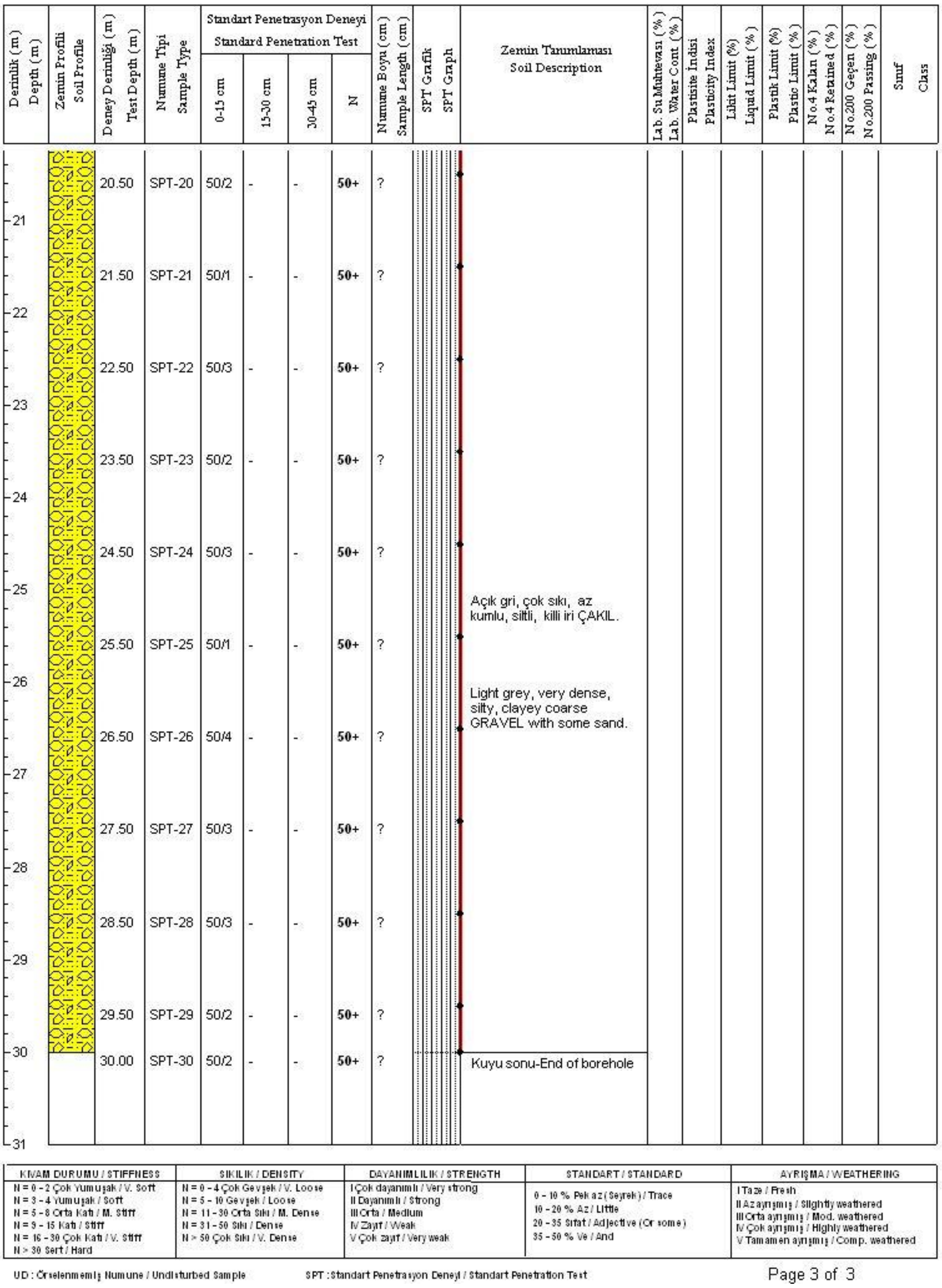


Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
		9.50	SPT-9	15	30	40	**50+**	18cm		Açık gri, çok sıkı, az kumlu, killi ÇAKIL Light grey, very dense, little sandy, clayey GRAVEL.	5,3	13,8	28,8	15,0	39,8	23,1	GC
		10.50	SPT-10	25	40	50/2	**50+**	22cm			8,1	15,8	31,0	15,2	42,5	27,5	GC
		11.50	SPT-11	45	50/5	-	**50+**	5cm		Açık gri, çok sıkı, az kumlu, siltli, killi iri ÇAKIL. Light grey, very dense, silty, clayey coarse GRAVEL little few sand.							
		12.50	SPT-12	50/6	-	-	**50+**	5cm									
		13.50	SPT-13	50/10	-	-	**50+**	4cm									
		14.50	SPT-14	50/2	-	-	**50+**	?									
		15.50	SPT-15	50/3	-	-	**50+**	2cm									
		16.50	SPT-16	50/3	-	-	**50+**	1cm									
		17.50	SPT-17	50/4	-	-	**50+**	2cm									
		18.50	SPT-18	50/2	-	-	**50+**	2cm									
		19.50	SPT-19	50/2	-	-	**50+**	2cm									

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample SPT : Standart Penetrasyon Deneyi / Standart Penetration Test Page 2 of 3

Figure A.8. Boreholes drilled for the thesis: D03 (2/3)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
		20.50	SPT-20	50/2	-	-	50+	?		Açık gri, çok sıkı, az kumlu, siltli, killi iri ÇAKIL. Light grey, very dense, silty, clayey coarse GRAVEL with some sand.							
		21.50	SPT-21	50/1	-	-	50+	?									
		22.50	SPT-22	50/3	-	-	50+	?									
		23.50	SPT-23	50/2	-	-	50+	?									
		24.50	SPT-24	50/3	-	-	50+	?									
		25.50	SPT-25	50/1	-	-	50+	?									
		26.50	SPT-26	50/4	-	-	50+	?									
		27.50	SPT-27	50/3	-	-	50+	?									
		28.50	SPT-28	50/3	-	-	50+	?									
		29.50	SPT-29	50/2	-	-	50+	?									
		30.00	SPT-30	50/2	-	-	50+	?		Kuyu sonu-End of borehole							

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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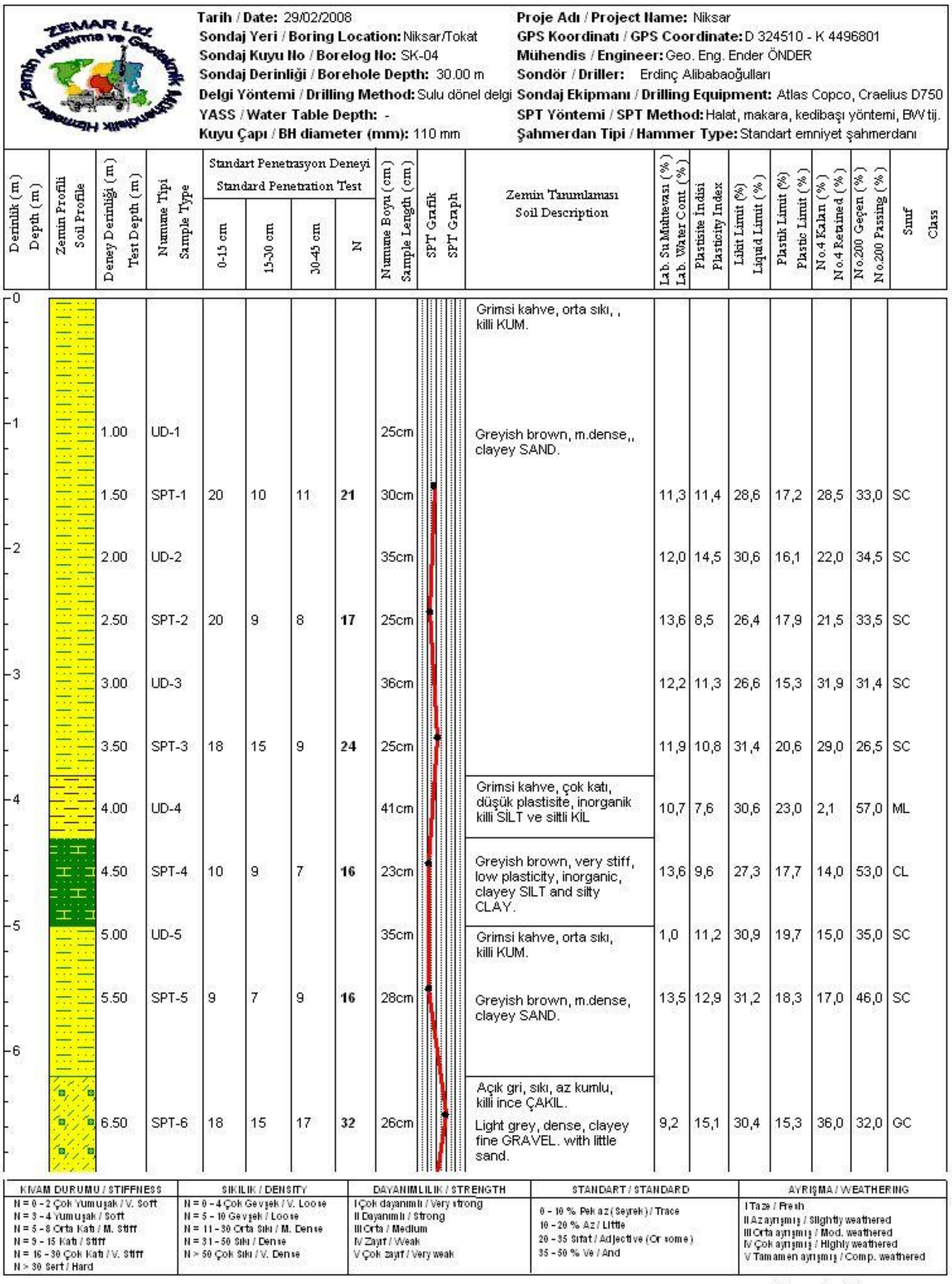
Figure A.9. Boreholes drilled for the thesis: D03 (3/3)



Tarih / Date: 29/02/2008
Sondaj Yeri / Boring Location: Niksar/Tokat
Sondaj Kuyu No / Borelog No: SK-04
Sondaj Derinliği / Borehole Depth: 30.00 m
Delgi Yöntemi / Drilling Method: Sulu dönel delgi
YASS / Water Table Depth: -
Kuyu Çapı / BH diameter (mm): 110 mm

Proje Adı / Project Name: Niksar
GPS Koordinatı / GPS Coordinate: D 324510 - K 4496801
Mühendis / Engineer: Geo. Eng. Ender ÖNDER
Sondör / Driller: Erdinç Alibabaoğulları
Sondaj Ekipmanı / Drilling Equipment: Atlas Copco, Craelius D750
SPT Yöntemi / SPT Method: Halat, makara, kedibaşı yöntemi, BW tij.
Şahmerdan Tipi / Hammer Type: Standart emniyet şahmerdanı

Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
0										Grimsi kahve, orta sıkı, , killi KUM.							
1		1.00	UD-1					25cm		Greyish brown, m.dense,, clayey SAND.							
		1.50	SPT-1	20	10	11	**21**	30cm			11,3	11,4	28,6	17,2	28,5	33,0	SC
2		2.00	UD-2					35cm			12,0	14,5	30,6	16,1	22,0	34,5	SC
		2.50	SPT-2	20	9	8	**17**	25cm			13,6	8,5	26,4	17,9	21,5	33,5	SC
3		3.00	UD-3					36cm			12,2	11,3	26,6	15,3	31,9	31,4	SC
		3.50	SPT-3	18	15	9	**24**	25cm			11,9	10,8	31,4	20,6	29,0	26,5	SC
4		4.00	UD-4					41cm		Grimsi kahve, çok katı, düşük plastisite, inorganik killi SİLT ve siltli KİL	10,7	7,6	30,6	23,0	2,1	57,0	ML
		4.50	SPT-4	10	9	7	**16**	23cm		Greyish brown, very stiff, low plasticity, inorganic, clayey SILT and silty CLAY.	13,6	9,6	27,3	17,7	14,0	53,0	CL
5		5.00	UD-5					35cm		Grimsi kahve, orta sıkı, killi KUM.	1,0	11,2	30,9	19,7	15,0	35,0	SC
		5.50	SPT-5	9	7	9	**16**	28cm		Greyish brown, m.dense, clayey SAND.	13,5	12,9	31,2	18,3	17,0	46,0	SC
6																	
		6.50	SPT-6	18	15	17	**32**	26cm		Açık gri, sıkı, az kumlu, killi ince ÇAKIL. Light grey, dense, clayey fine GRAVEL. with little sand.	9,2	15,1	30,4	15,3	36,0	32,0	GC

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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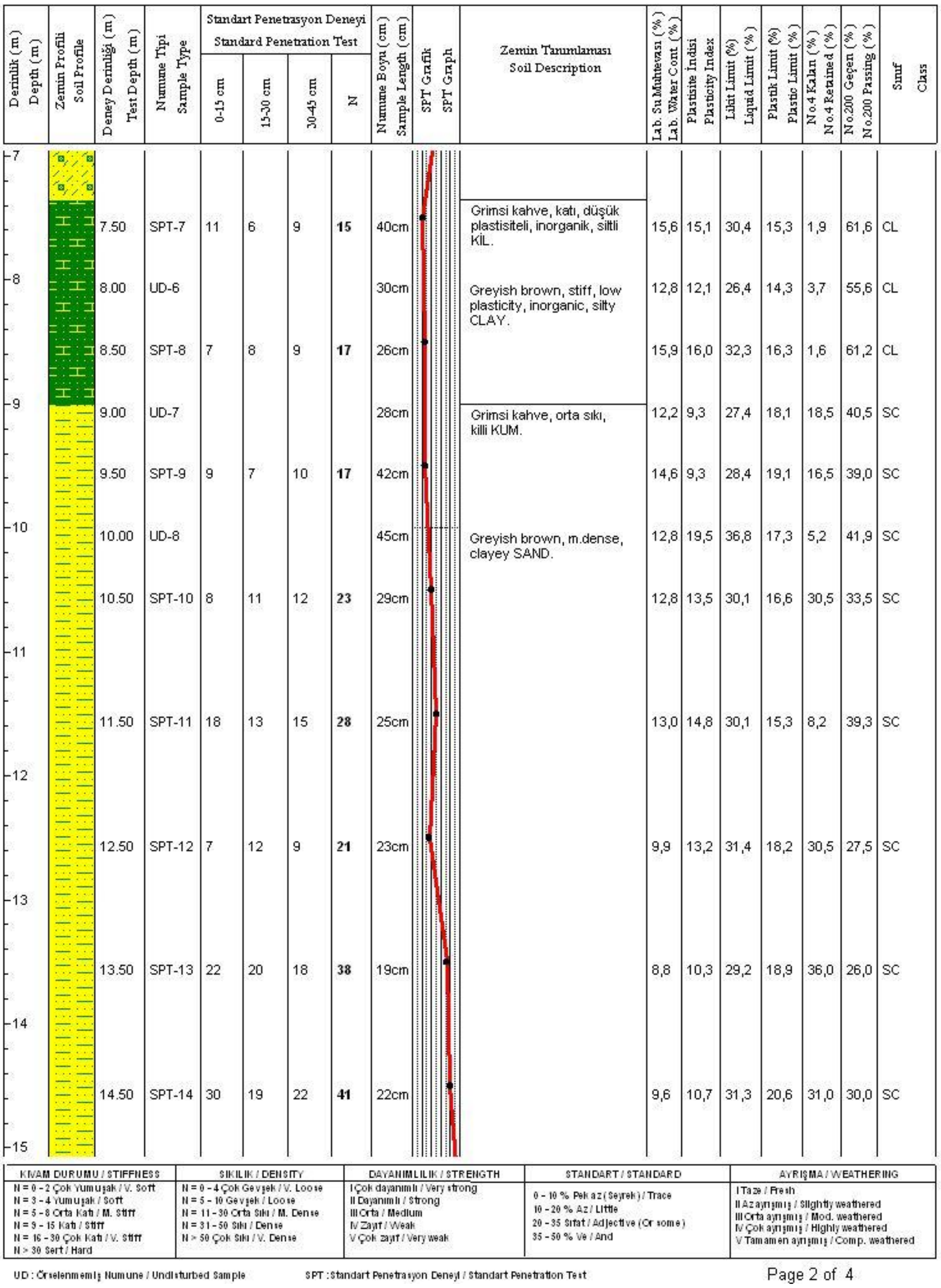
Figure A.10. Boreholes drilled for the thesis: D04 (1/4)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
-7																	
		7.50	SPT-7	11	6	9	**15**	40cm		Grimsi kahve, katı, düşük plastisiteli, inorganik, siltli KİL.	15,6	15,1	30,4	15,3	1,9	61,6	CL
-8		8.00	UD-6					30cm		Greyish brown, stiff, low plasticity, inorganic, silty CLAY.	12,8	12,1	26,4	14,3	3,7	55,6	CL
		8.50	SPT-8	7	8	9	**17**	26cm			15,9	16,0	32,3	16,3	1,6	61,2	CL
-9		9.00	UD-7					28cm		Grimsi kahve, orta sıkı, killi KUM.	12,2	9,3	27,4	18,1	18,5	40,5	SC
		9.50	SPT-9	9	7	10	**17**	42cm			14,6	9,3	28,4	19,1	16,5	39,0	SC
-10		10.00	UD-8					45cm		Greyish brown, m.dense, clayey SAND.	12,8	19,5	36,8	17,3	5,2	41,9	SC
		10.50	SPT-10	8	11	12	**23**	29cm			12,8	13,5	30,1	16,6	30,5	33,5	SC
-11																	
		11.50	SPT-11	18	13	15	**28**	25cm			13,0	14,8	30,1	15,3	8,2	39,3	SC
-12																	
		12.50	SPT-12	7	12	9	**21**	23cm			9,9	13,2	31,4	18,2	30,5	27,5	SC
-13																	
		13.50	SPT-13	22	20	18	**38**	19cm			8,8	10,3	29,2	18,9	36,0	26,0	SC
-14																	
		14.50	SPT-14	30	19	22	**41**	22cm			9,6	10,7	31,3	20,6	31,0	30,0	SC
-15																	

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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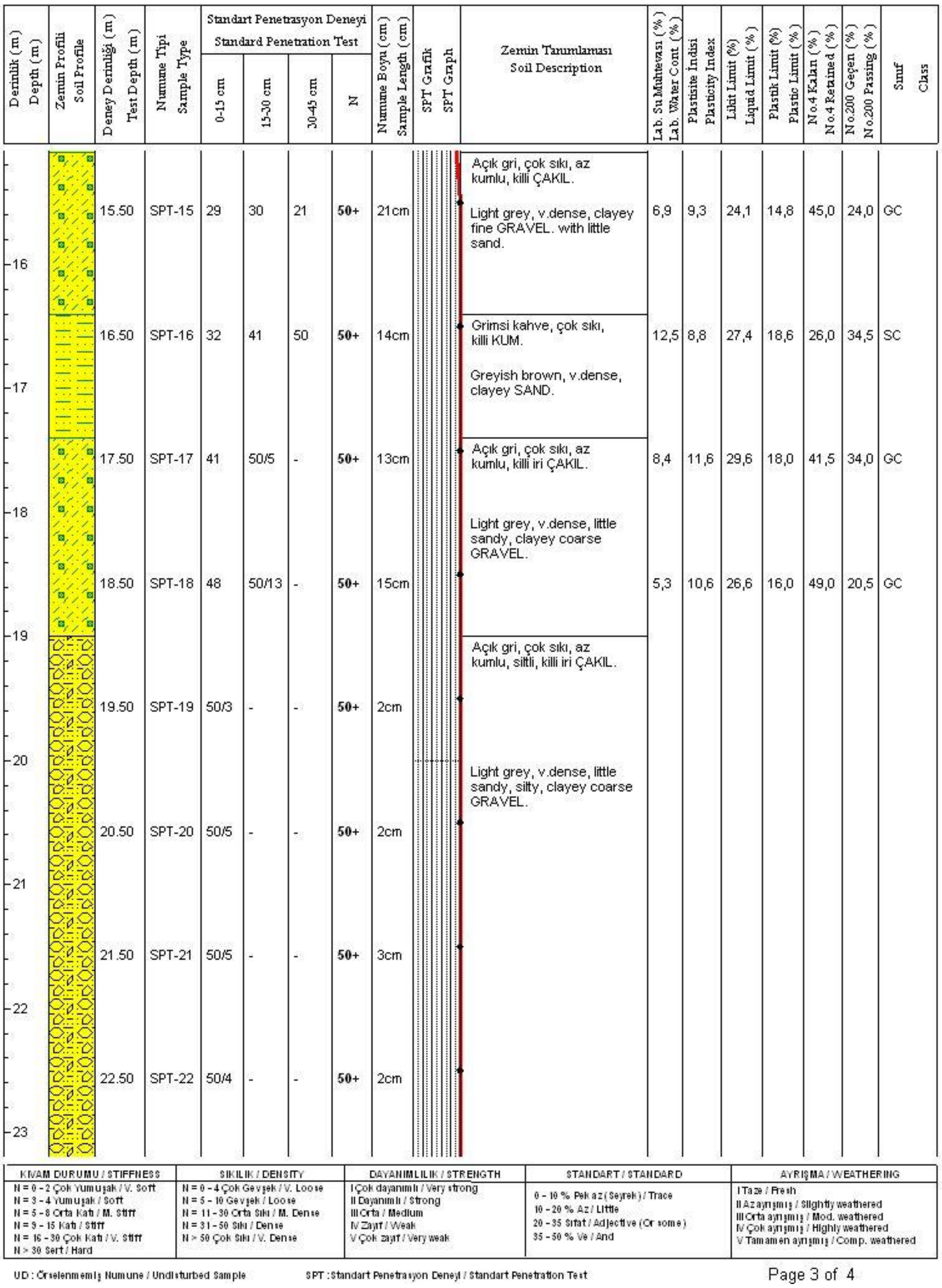
Figure A.11. Boreholes drilled for the thesis: D04 (2/4)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
		15.50	SPT-15	29	30	21	**50+**	21cm		Açık gri, çok sıkı, az kumlu, killi ÇAKIL. Light grey, v.dense, clayey fine GRAVEL. with little sand.	6,9	9,3	24,1	14,8	45,0	24,0	GC
16																	
		16.50	SPT-16	32	41	50	**50+**	14cm		Grimsi kahve, çok sıkı, killi KUM. Greyish brown, v.dense, clayey SAND.	12,5	8,8	27,4	18,6	26,0	34,5	SC
17																	
		17.50	SPT-17	41	50/5	-	**50+**	13cm		Açık gri, çok sıkı, az kumlu, killi iri ÇAKIL. Light grey, v.dense, little sandy, clayey coarse GRAVEL.	8,4	11,6	29,6	18,0	41,5	34,0	GC
18																	
		18.50	SPT-18	48	50/13	-	**50+**	15cm			5,3	10,6	26,6	16,0	49,0	20,5	GC
19										Açık gri, çok sıkı, az kumlu, siltli, killi iri ÇAKIL. Light grey, v.dense, little sandy, silty, clayey coarse GRAVEL.							
		19.50	SPT-19	50/3	-	-	**50+**	2cm									
20																	
		20.50	SPT-20	50/5	-	-	**50+**	2cm									
21																	
		21.50	SPT-21	50/5	-	-	**50+**	3cm									
22																	
		22.50	SPT-22	50/4	-	-	**50+**	2cm									
23																	

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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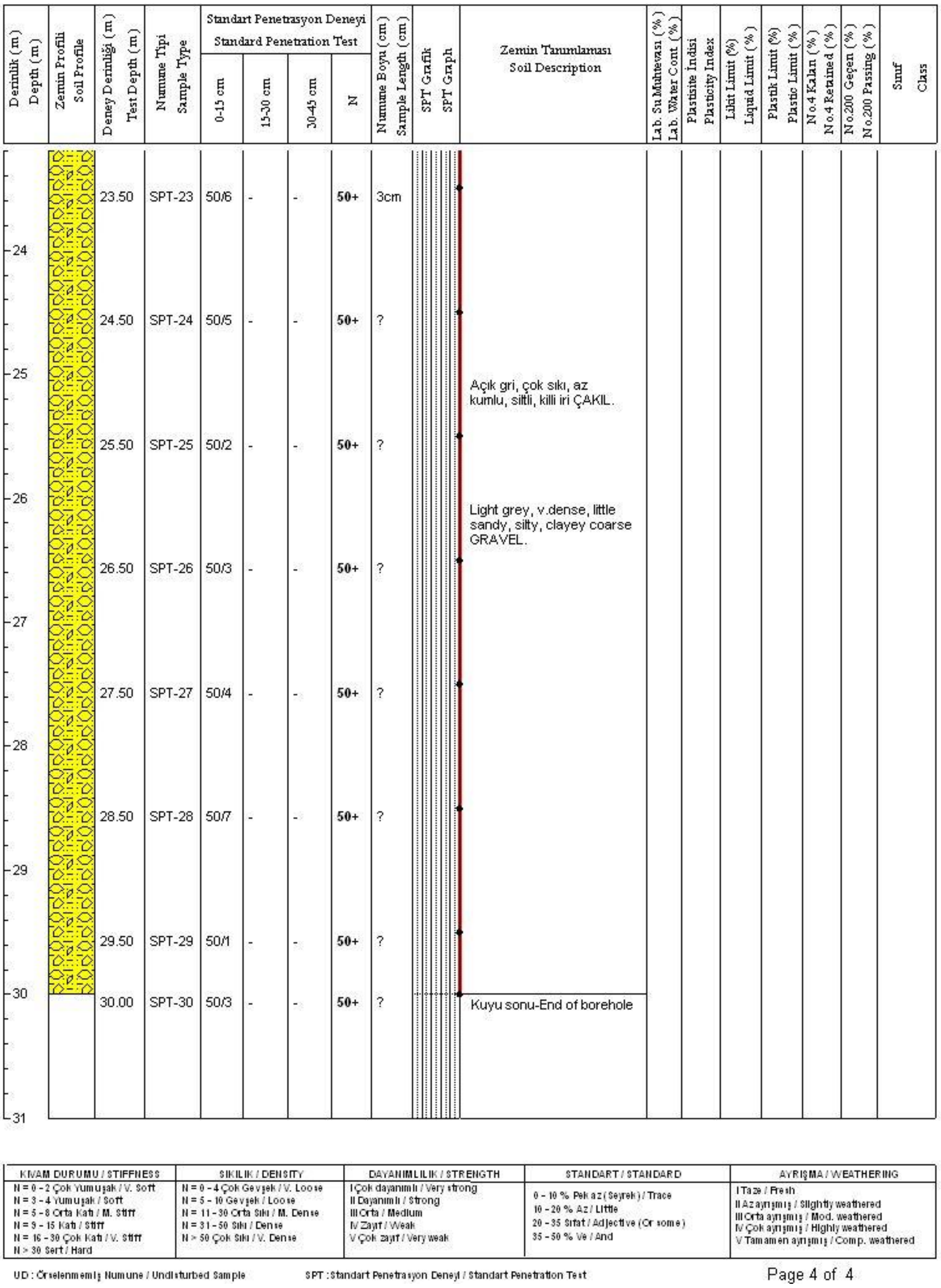
Figure A.12. Boreholes drilled for the thesis: D04 (3/4)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
		23.50	SPT-23	50/6	-	-	**50+**	3cm		Açık gri, çok sıkı, az kumlu, siltli, killi iri ÇAKIL. Light grey, v.dense, little sandy, silty, clayey coarse GRAVEL.							
		24.50	SPT-24	50/5	-	-	**50+**	?									
		25.50	SPT-25	50/2	-	-	**50+**	?									
		26.50	SPT-26	50/3	-	-	**50+**	?									
		27.50	SPT-27	50/4	-	-	**50+**	?									
		28.50	SPT-28	50/7	-	-	**50+**	?									
		29.50	SPT-29	50/1	-	-	**50+**	?									
		30.00	SPT-30	50/3	-	-	**50+**	?		Kuyu sonu-End of borehole							

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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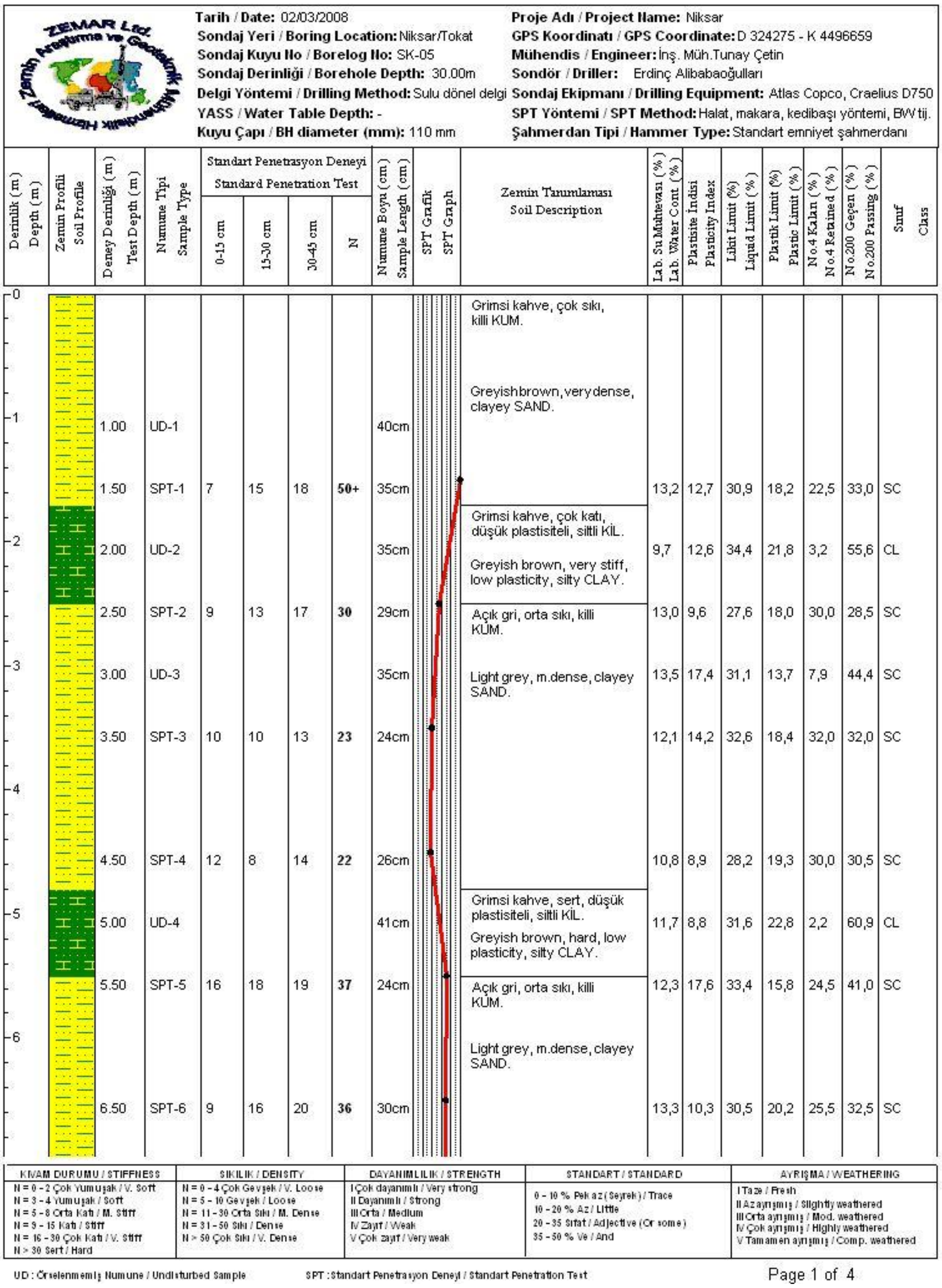
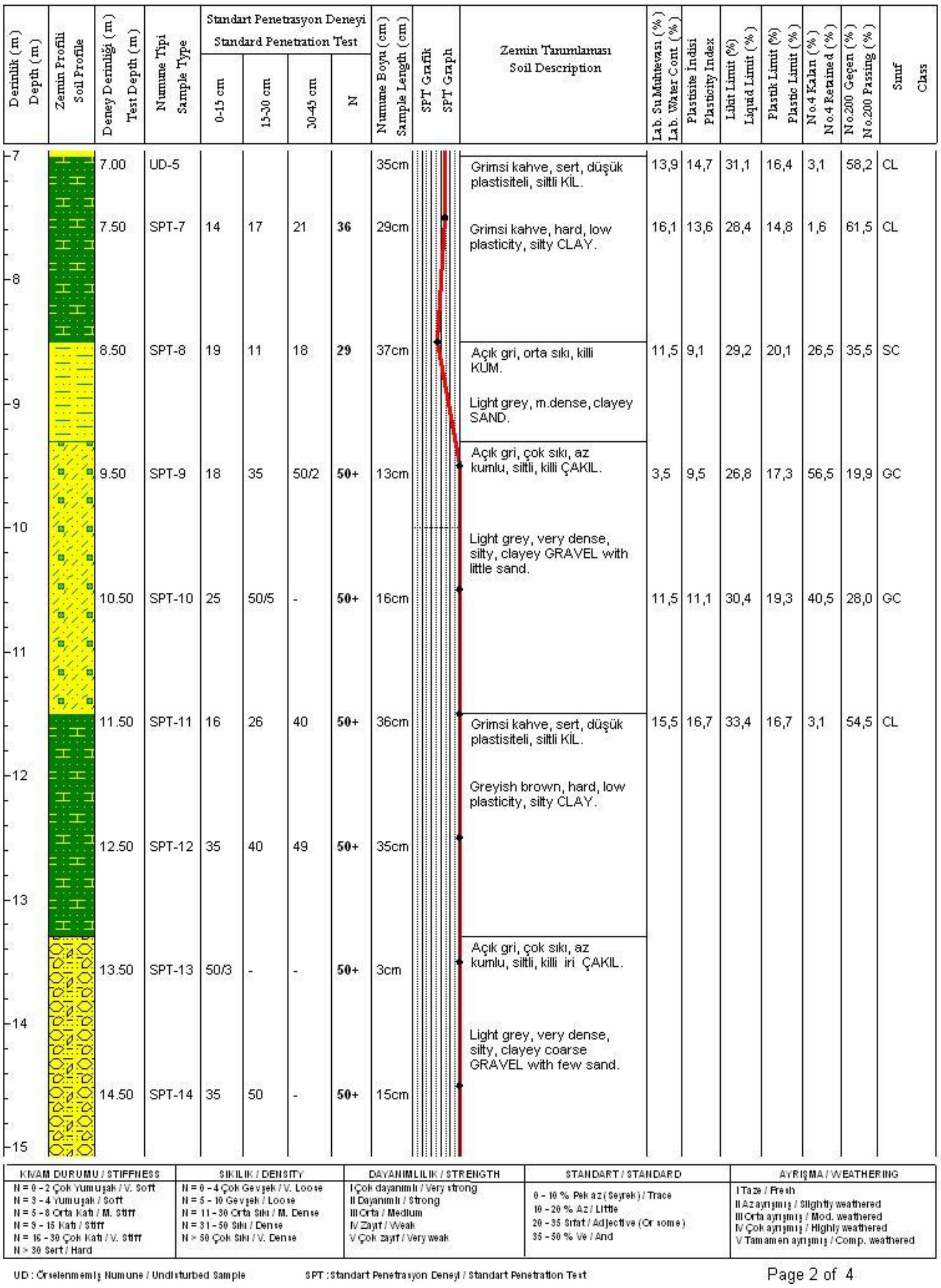
Figure A.13. Boreholes drilled for the thesis: D04 (4/4)





Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
7		7.00	UD-5					35cm		Grimsi kahve, sert, düşük plastisiteli, siltli KİL. Grimsi kahve, hard, low plasticity, silty CLAY.	13,9	14,7	31,1	16,4	3,1	58,2	CL
		7.50	SPT-7	14	17	21	**36**	29cm			16,1	13,6	28,4	14,8	1,6	61,5	CL
8		8.50	SPT-8	19	11	18	**29**	37cm		Açık gri, orta sıkı, killi KUM. Light grey, m.dense, clayey SAND.	11,5	9,1	29,2	20,1	26,5	35,5	SC
9		9.50	SPT-9	18	35	50/2	**50+**	13cm		Açık gri, çok sıkı, az kumlu, siltli, killi ÇAKIL. Light grey, very dense, silty, clayey GRAVEL with little sand.	3,5	9,5	26,8	17,3	56,5	19,9	GC
10		10.50	SPT-10	25	50/5	-	**50+**	16cm			11,5	11,1	30,4	19,3	40,5	28,0	GC
11		11.50	SPT-11	16	26	40	**50+**	36cm		Grimsi kahve, sert, düşük plastisiteli, siltli KİL. Greyish brown, hard, low plasticity, silty CLAY.	15,5	16,7	33,4	16,7	3,1	54,5	CL
12		12.50	SPT-12	35	40	49	**50+**	35cm									
13		13.50	SPT-13	50/3	-	-	**50+**	3cm		Açık gri, çok sıkı, az kumlu, siltli, killi iri ÇAKIL. Light grey, very dense, silty, clayey coarse GRAVEL with few sand.							
14		14.50	SPT-14	35	50	-	**50+**	15cm									
15																	

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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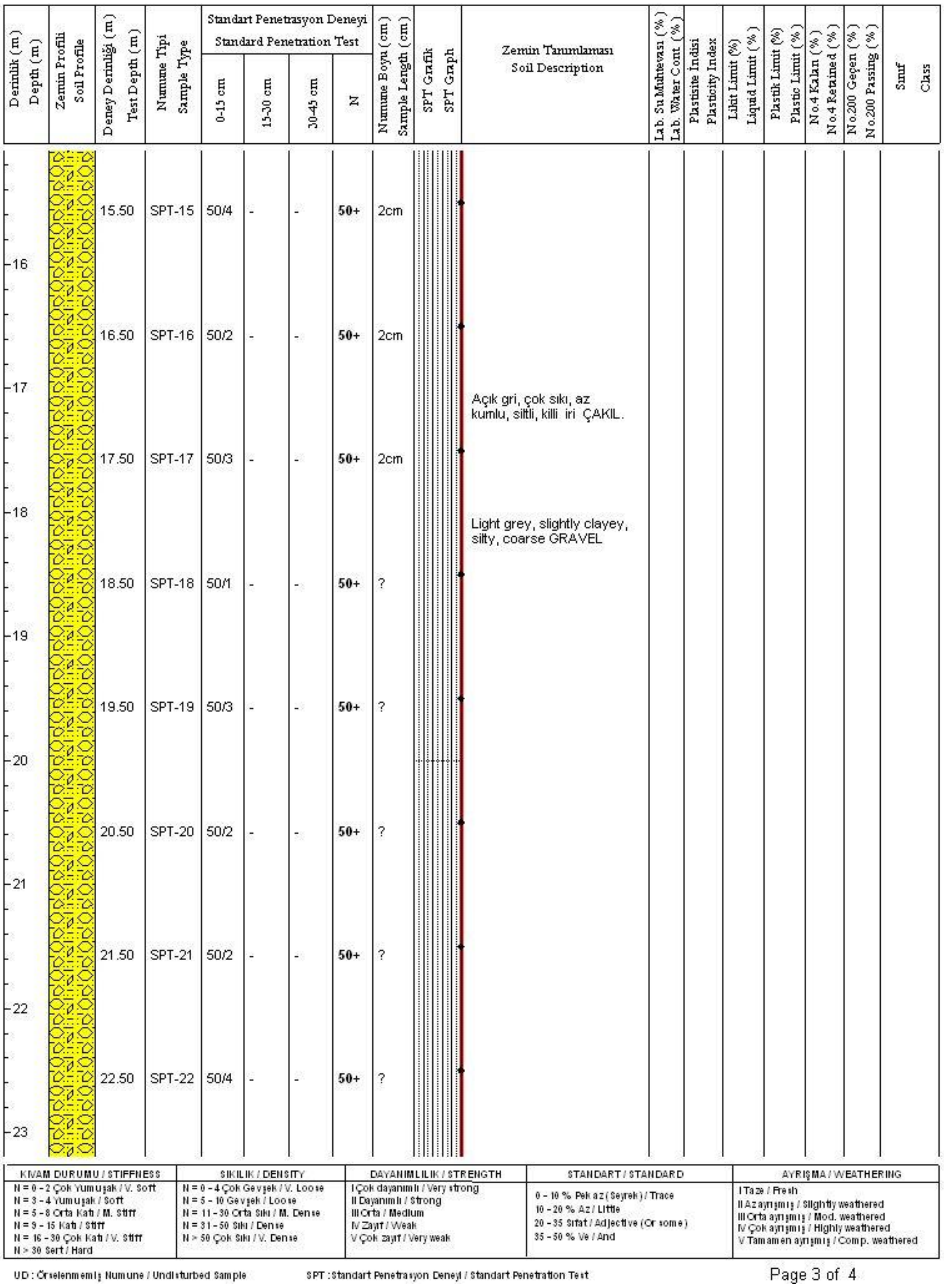
Figure A.15. Boreholes drilled for the thesis: D05 (2/4)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
		15.50	SPT-15	50/4	-	-	**50+**	2cm		Açık gri, çok sıkı, az kumlu, siltli, killi iri ÇAKIL. Light grey, slightly clayey, silty, coarse GRAVEL							
16																	
		16.50	SPT-16	50/2	-	-	**50+**	2cm									
17																	
		17.50	SPT-17	50/3	-	-	**50+**	2cm									
18																	
		18.50	SPT-18	50/1	-	-	**50+**	?									
19																	
		19.50	SPT-19	50/3	-	-	**50+**	?									
20																	
		20.50	SPT-20	50/2	-	-	**50+**	?									
21																	
		21.50	SPT-21	50/2	-	-	**50+**	?									
22																	
		22.50	SPT-22	50/4	-	-	**50+**	?									
23																	

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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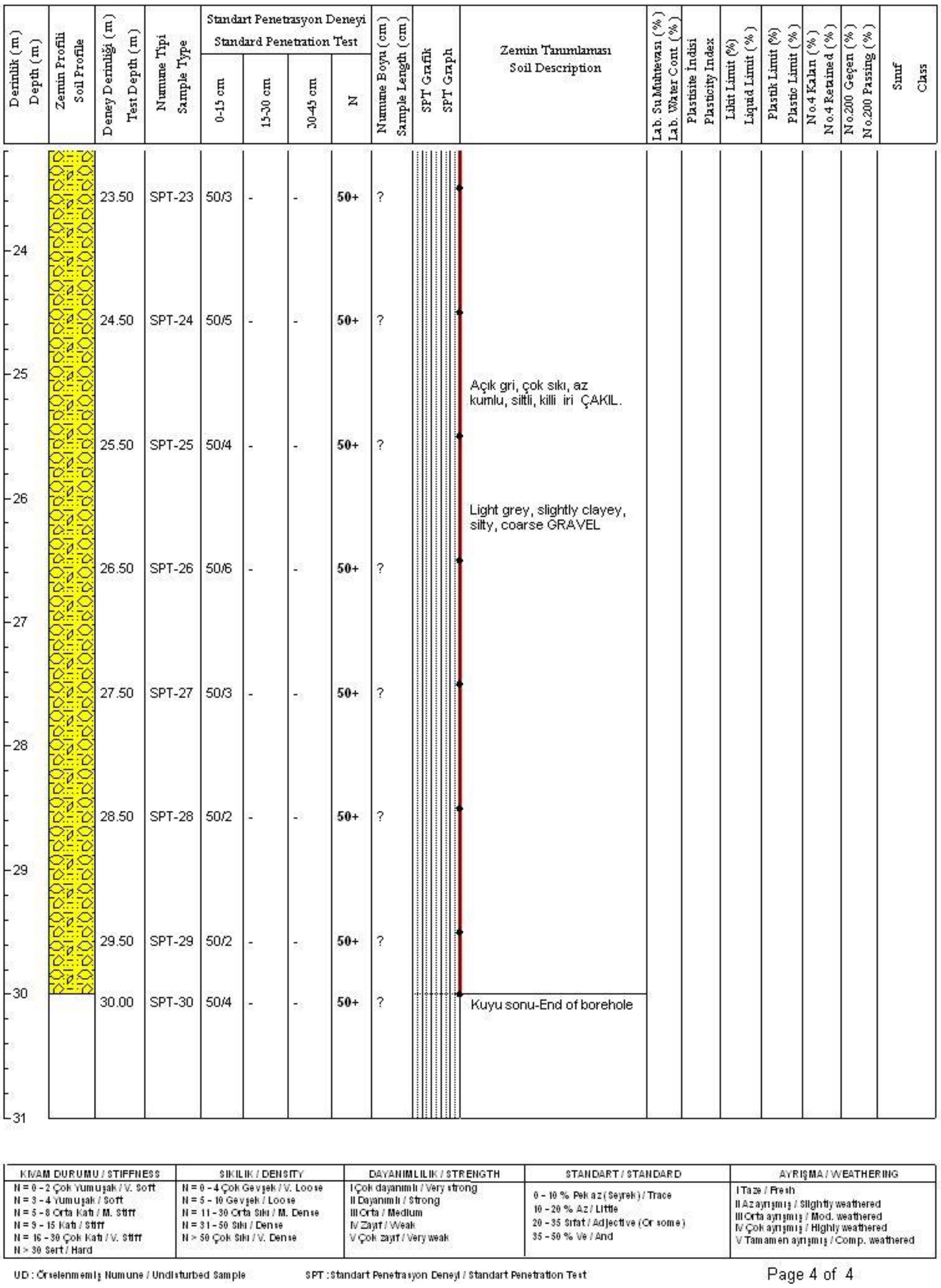
Figure A.16. Boreholes drilled for the thesis: D05 (3/4)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi / Standard Penetration Test: 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
		23.50	SPT-23	50/3	-	-	50+	?		Açık gri, çok sıkı, az kumlu, siltli, killi iri ÇAKIL. Light grey, slightly clayey, silty, coarse GRAVEL							
24																	
		24.50	SPT-24	50/5	-	-	50+	?									
25																	
		25.50	SPT-25	50/4	-	-	50+	?									
26																	
		26.50	SPT-26	50/6	-	-	50+	?									
27																	
		27.50	SPT-27	50/3	-	-	50+	?									
28																	
		28.50	SPT-28	50/2	-	-	50+	?									
29																	
		29.50	SPT-29	50/2	-	-	50+	?									
30		30.00	SPT-30	50/4	-	-	50+	?		Kuyu sonu-End of borehole							
31																	

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft	N = 0 - 4 Çok Gevşek / V. Loose	I Çok dayanımlı / Very strong	0 - 10 % Pek az (Seyrek) / Trace	I Taze / Fresh
N = 3 - 4 Yumuşak / Soft	N = 5 - 10 Gevşek / Loose	II Dayanımlı / Strong	10 - 20 % Az / Little	II Az ayrışmış / Slightly weathered
N = 5 - 8 Orta Katı / M. Stiff	N = 11 - 30 Orta Sıkı / M. Dense	III Orta / Medium	20 - 35 Sıfat / Adjective (Or some)	III Orta ayrışmış / Mod. weathered
N = 9 - 15 Katı / Stiff	N = 31 - 50 Sıkı / Dense	IV Zayıf / Weak	35 - 50 % Ve / And	IV Çok ayrışmış / Highly weathered
N = 16 - 30 Çok Katı / V. Stiff	N > 50 Çok Sıkı / V. Dense	V Çok zayıf / Very weak		V Tamamen ayrışmış / Comp. weathered
N > 30 Sert / Hard				

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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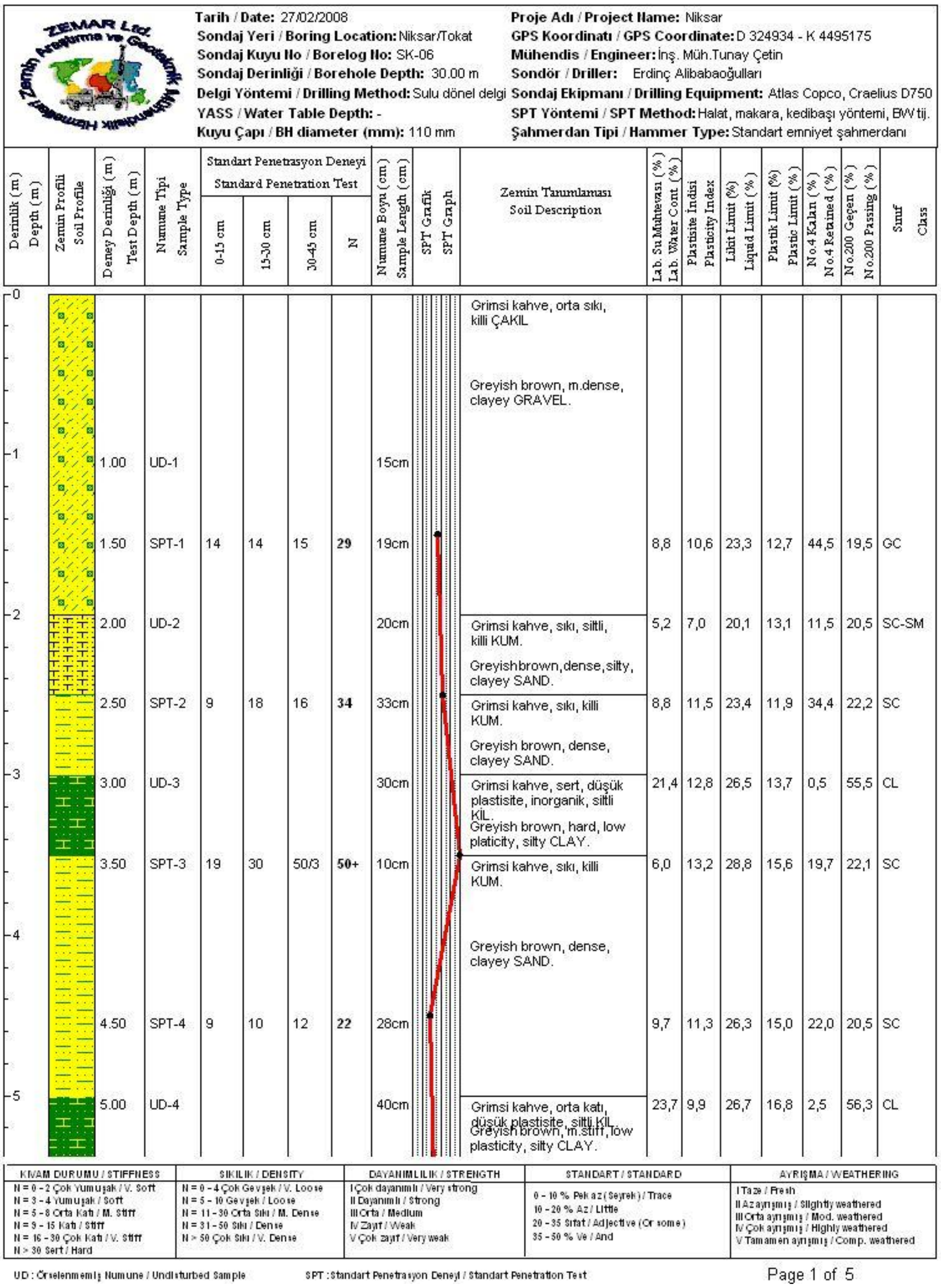
Figure A.17. Boreholes drilled for the thesis: D05 (4/4)



ZEMAR Ltd. Zemin Araştırma ve Geoteknik Mühendislik Hizmetleri

Tarih / Date: 27/02/2008
Sondaj Yeri / Boring Location: Niksar/Tokat
Sondaj Kuyu No / Borelog No: SK-06
Sondaj Derinliği / Borehole Depth: 30.00 m
Delgi Yöntemi / Drilling Method: Sulu dönel delgi
YASS / Water Table Depth: -
Kuyu Çapı / BH diameter (mm): 110 mm

Proje Adı / Project Name: Niksar
GPS Koordinatı / GPS Coordinate: D 324934 - K 4495175
Mühendis / Engineer: İnş. Müh.Tunay Çetin
Sondör / Driller: Erdinç Alibabaoğulları
Sondaj Ekipmanı / Drilling Equipment: Atlas Copco, Craelius D750
SPT Yöntemi / SPT Method: Halat, makara, kedibaşı yöntemi, BW tij.
Şahmerdan Tipi / Hammer Type: Standart emniyet şahmerdanı

Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
0										Grimsi kahve, orta sıkı, killi ÇAKIL Greyish brown, m.dense, clayey GRAVEL.							
1		1.00	UD-1					15cm									
		1.50	SPT-1	14	14	15	**29**	19cm			8,8	10,6	23,3	12,7	44,5	19,5	GC
2		2.00	UD-2					20cm		Grimsi kahve, sıkı, siltli, killi KUM. Greyishbrown,dense,silty, clayey SAND.	5,2	7,0	20,1	13,1	11,5	20,5	SC-SM
		2.50	SPT-2	9	18	16	**34**	33cm		Grimsi kahve, sıkı, killi KUM. Greyish brown, dense, clayey SAND.	8,8	11,5	23,4	11,9	34,4	22,2	SC
3		3.00	UD-3					30cm		Grimsi kahve, sert, düşük plastisite, inorganik, siltli KİL. Greyish brown, hard, low platicity, silty CLAY.	21,4	12,8	26,5	13,7	0,5	55,5	CL
		3.50	SPT-3	19	30	50/3	**50+**	10cm		Grimsi kahve, sıkı, killi KUM. Greyish brown, dense, clayey SAND.	6,0	13,2	28,8	15,6	19,7	22,1	SC
4																	
		4.50	SPT-4	9	10	12	**22**	28cm			9,7	11,3	26,3	15,0	22,0	20,5	SC
5		5.00	UD-4					40cm		Grimsi kahve, orta katı, düşük plastisite, siltli KİL. Greyish brown, m.stiff, low plasticity, silty CLAY.	23,7	9,9	26,7	16,8	2,5	56,3	CL

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft	N = 0 - 4 Çok Gevşek / V. Loose	I Çok dayanımlı / Very strong	0 - 10 % Pek az (Seyrek) / Trace	I Taze / Fresh
N = 3 - 4 Yumuşak / Soft	N = 5 - 10 Gevşek / Loose	II Dayanımlı / Strong	10 - 20 % Az / Little	II Az ayrışmış / Slightly weathered
N = 5 - 8 Orta Katı / M. Stiff	N = 11 - 30 Orta Sıkı / M. Dense	III Orta / Medium	20 - 35 Sıfat / Adjective (Or some)	III Orta ayrışmış / Mod. weathered
N = 9 - 15 Katı / Stiff	N = 31 - 50 Sıkı / Dense	IV Zayıf / Weak	35 - 50 % Ve / And	IV Çok ayrışmış / Highly weathered
N = 16 - 30 Çok Katı / V. Stiff	N > 50 Çok Sıkı / V. Dense	V Çok zayıf / Very weak		V Tamamen ayrışmış / Comp. weathered
N > 30 Sert / Hard				

UD : Örselenmemiş Numune / Undisturbed Sample
SPT : Standart Penetrasyon Deneyi / Standart Penetration Test
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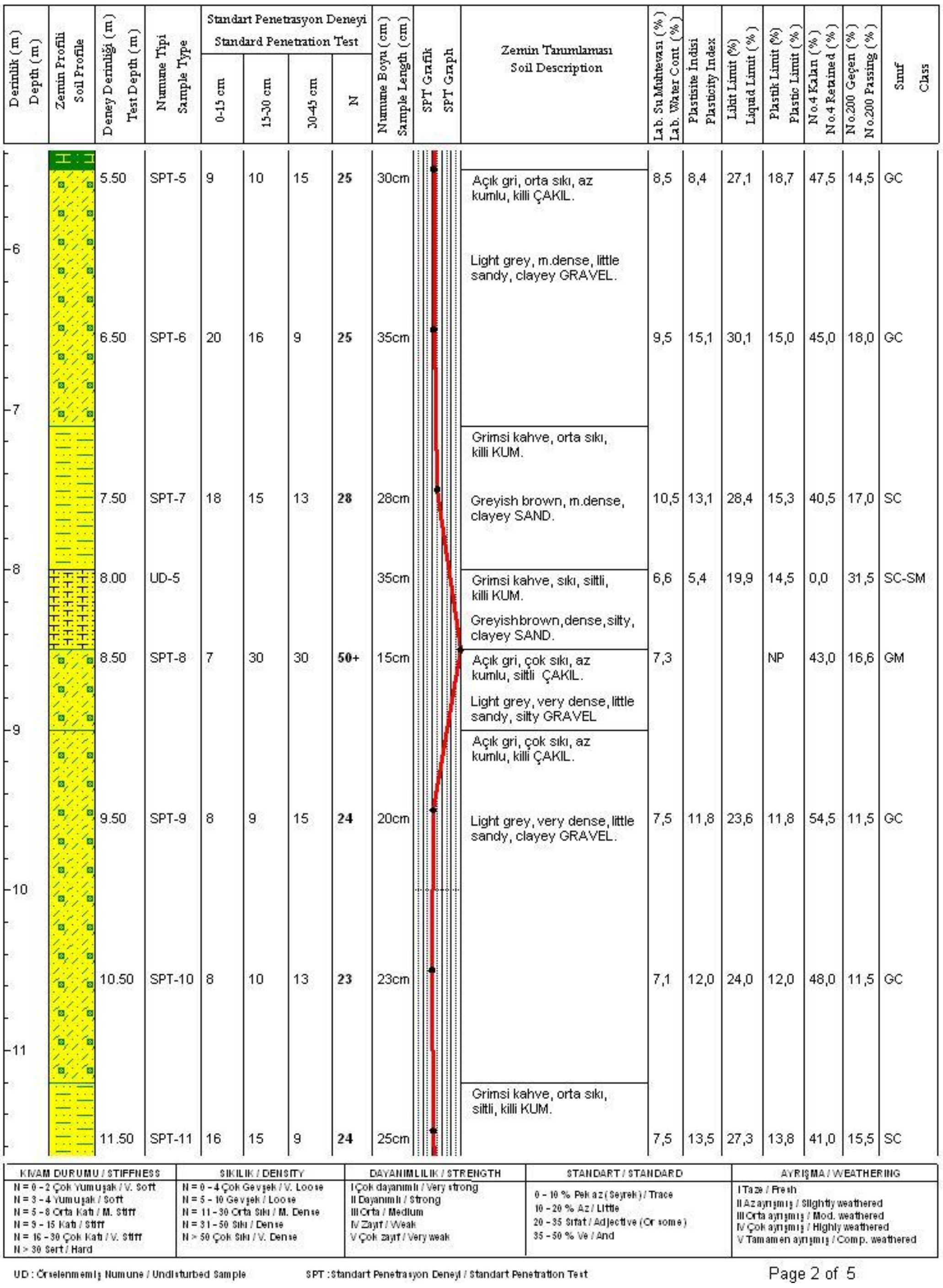
Figure A.18. Boreholes drilled for the thesis: D21 (1/5)

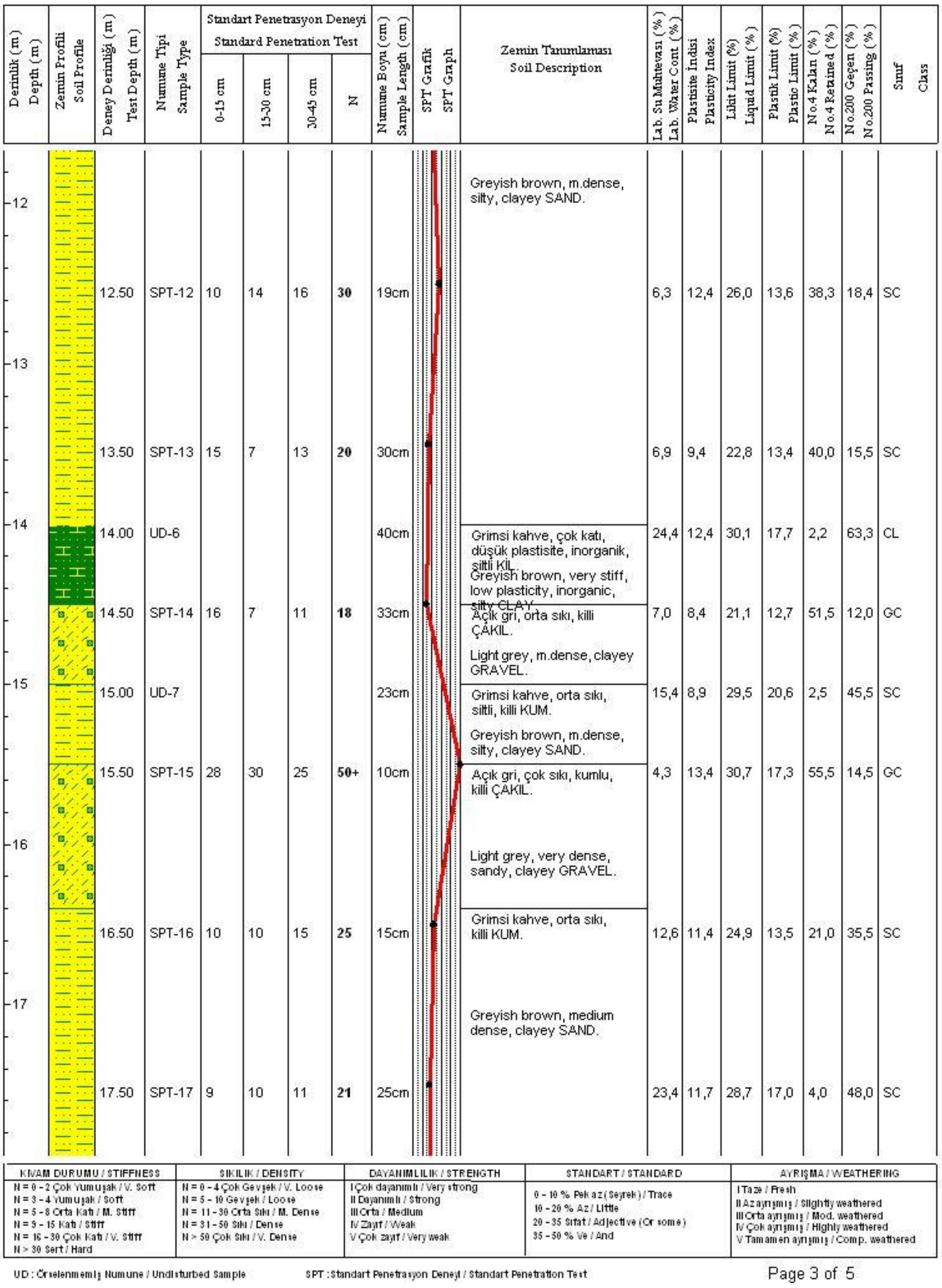


Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
5.50	SPT-5	9	10	15	**25**	30cm	Açık gri, orta sıkı, az kumlu, killi ÇAKIL. Light grey, m.dense, little sandy, clayey GRAVEL.	8,5	8,4	27,1	18,7	47,5	14,5	GC
6.50	SPT-6	20	16	9	**25**	35cm		9,5	15,1	30,1	15,0	45,0	18,0	GC
7.50	SPT-7	18	15	13	**28**	28cm	Grimsi kahve, orta sıkı, killi KUM. Greyish brown, m.dense, clayey SAND.	10,5	13,1	28,4	15,3	40,5	17,0	SC
8.00	UD-5					35cm	Grimsi kahve, sıkı, siltli, killi KUM. Greyishbrown,dense,silty, clayey SAND.	6,6	5,4	19,9	14,5	0,0	31,5	SC-SM
8.50	SPT-8	7	30	30	**50+**	15cm	Açık gri, çok sıkı, az kumlu, siltli ÇAKIL. Light grey, very dense, little sandy, silty GRAVEL	7,3			NP	43,0	16,6	GM
9.50	SPT-9	8	9	15	**24**	20cm	Açık gri, çok sıkı, az kumlu, killi ÇAKIL. Light grey, very dense, little sandy, clayey GRAVEL.	7,5	11,8	23,6	11,8	54,5	11,5	GC
10.50	SPT-10	8	10	13	**23**	23cm		7,1	12,0	24,0	12,0	48,0	11,5	GC
11.50	SPT-11	16	15	9	**24**	25cm	Grimsi kahve, orta sıkı, siltli, killi KUM.	7,5	13,5	27,3	13,8	41,0	15,5	SC

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample   SPT : Standart Penetrasyon Deneyi / Standart Penetration Test   Page 2 of 5

Figure A.19. Boreholes drilled for the thesis: D21 (2/5)



Derinlik (m) Depth (m)	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi / Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
-12								Greyish brown, m.dense, silty, clayey SAND.							
	12.50	SPT-12	10	14	16	**30**	19cm		6,3	12,4	26,0	13,6	38,3	18,4	SC
-13															
	13.50	SPT-13	15	7	13	**20**	30cm		6,9	9,4	22,8	13,4	40,0	15,5	SC
-14	14.00	UD-6					40cm	Grimsi kahve, çok katı, düşük plastisite, inorganik, siltli KİL. Greyish brown, very stiff, low plasticity, inorganic, silty CLAY.	24,4	12,4	30,1	17,7	2,2	63,3	CL
	14.50	SPT-14	16	7	11	**18**	33cm	Açık gri, orta sıkı, killi ÇAKIL. Light grey, m.dense, clayey GRAVEL.	7,0	8,4	21,1	12,7	51,5	12,0	GC
-15	15.00	UD-7					23cm	Grimsi kahve, orta sıkı, siltli, killi KUM. Greyish brown, m.dense, silty, clayey SAND.	15,4	8,9	29,5	20,6	2,5	45,5	SC
	15.50	SPT-15	28	30	25	**50+**	10cm	Açık gri, çok sıkı, kumlu, killi ÇAKIL. Light grey, very dense, sandy, clayey GRAVEL.	4,3	13,4	30,7	17,3	55,5	14,5	GC
-16															
	16.50	SPT-16	10	10	15	**25**	15cm	Grimsi kahve, orta sıkı, killi KUM. Greyish brown, medium dense, clayey SAND.	12,6	11,4	24,9	13,5	21,0	35,5	SC
-17															
	17.50	SPT-17	9	10	11	**21**	25cm		23,4	11,7	28,7	17,0	4,0	48,0	SC

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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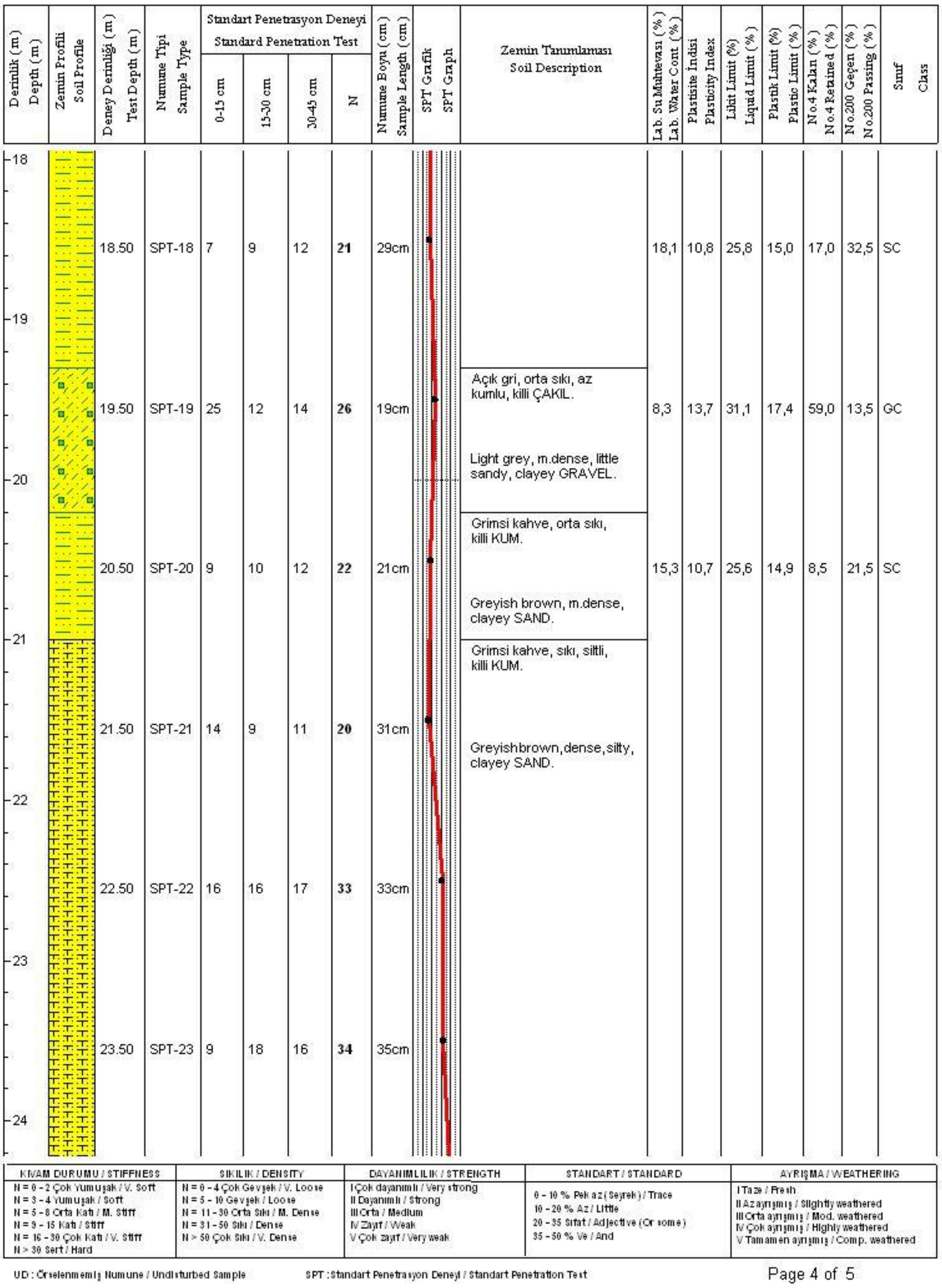
Figure A.20. Boreholes drilled for the thesis: D21 (3/5)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
		18.50	SPT-18	7	9	12	**21**	29cm			18,1	10,8	25,8	15,0	17,0	32,5	SC
		19.50	SPT-19	25	12	14	**26**	19cm		Açık gri, orta sıkı, az kumlu, killi ÇAKIL. Light grey, m.dense, little sandy, clayey GRAVEL.	8,3	13,7	31,1	17,4	59,0	13,5	GC
		20.50	SPT-20	9	10	12	**22**	21cm		Grimsi kahve, orta sıkı, killi KUM. Greyish brown, m.dense, clayey SAND.	15,3	10,7	25,6	14,9	8,5	21,5	SC
		21.50	SPT-21	14	9	11	**20**	31cm		Grimsi kahve, sıkı, siltli, killi KUM. Greyishbrown, dense, silty, clayey SAND.							
		22.50	SPT-22	16	16	17	**33**	33cm									
		23.50	SPT-23	9	18	16	**34**	35cm									

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

UD : Örselenmemiş Numune / Undisturbed Sample   SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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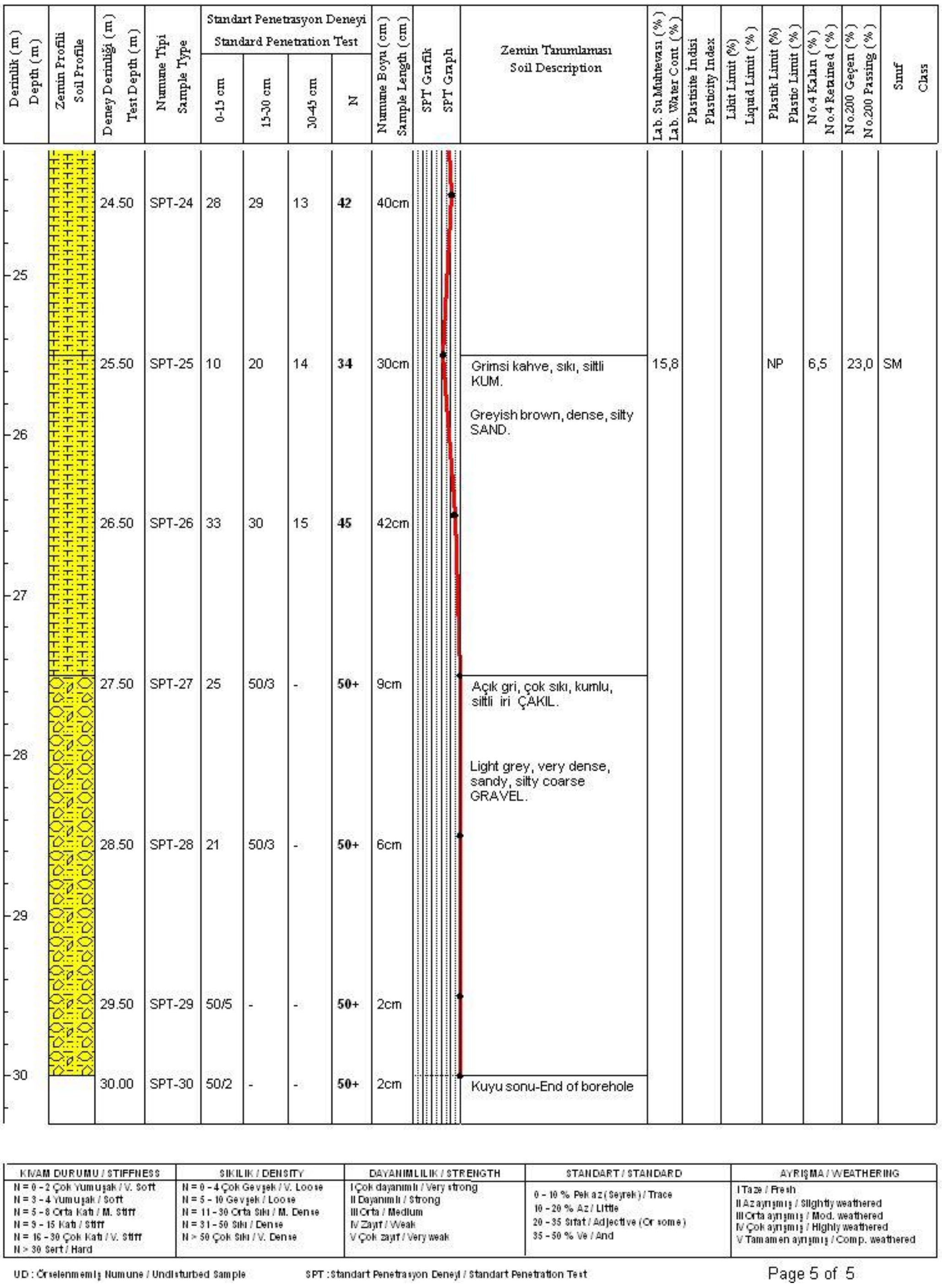
Figure A.21. Boreholes drilled for the thesis: D21 (4/5)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
		24.50	SPT-24	28	29	13	**42**	40cm									
		25.50	SPT-25	10	20	14	**34**	30cm		Grimsi kahve, sıkı, siltli KUM. Greyish brown, dense, silty SAND.	15,8			NP	6,5	23,0	SM
		26.50	SPT-26	33	30	15	**45**	42cm									
		27.50	SPT-27	25	50/3	-	**50+**	9cm		Açık gri, çok sıkı, kumlu, siltli iri ÇAKIL. Light grey, very dense, sandy, silty coarse GRAVEL.							
		28.50	SPT-28	21	50/3	-	**50+**	6cm									
		29.50	SPT-29	50/5	-	-	**50+**	2cm									
		30.00	SPT-30	50/2	-	-	**50+**	2cm		Kuyu sonu-End of borehole							

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft	N = 0 - 4 Çok Gevşek / V. Loose	I Çok dayanımlı / Very strong	0 - 10 % Pek az (Seyrek) / Trace	I Taze / Fresh
N = 3 - 4 Yumuşak / Soft	N = 5 - 10 Gevşek / Loose	II Dayanımlı / Strong	10 - 20 % Az / Little	II Az ayrışmış / Slightly weathered
N = 5 - 8 Orta Katı / M. Stiff	N = 11 - 30 Orta Sıkı / M. Dense	III Orta / Medium	20 - 35 Sıfat / Adjective (Or some)	III Orta ayrışmış / Mod. weathered
N = 9 - 15 Katı / Stiff	N = 31 - 50 Sıkı / Dense	IV Zayıf / Weak	35 - 50 % Ve / And	IV Çok ayrışmış / Highly weathered
N = 16 - 30 Çok Katı / V. Stiff	N > 50 Çok Sıkı / V. Dense	V Çok zayıf / Very weak		V Tamamen ayrışmış / Comp. weathered
N > 30 Sert / Hard				

UD : Örselenmemiş Numune / Undisturbed Sample

SPT : Standart Penetrasyon Deneyi / Standart Penetration Test

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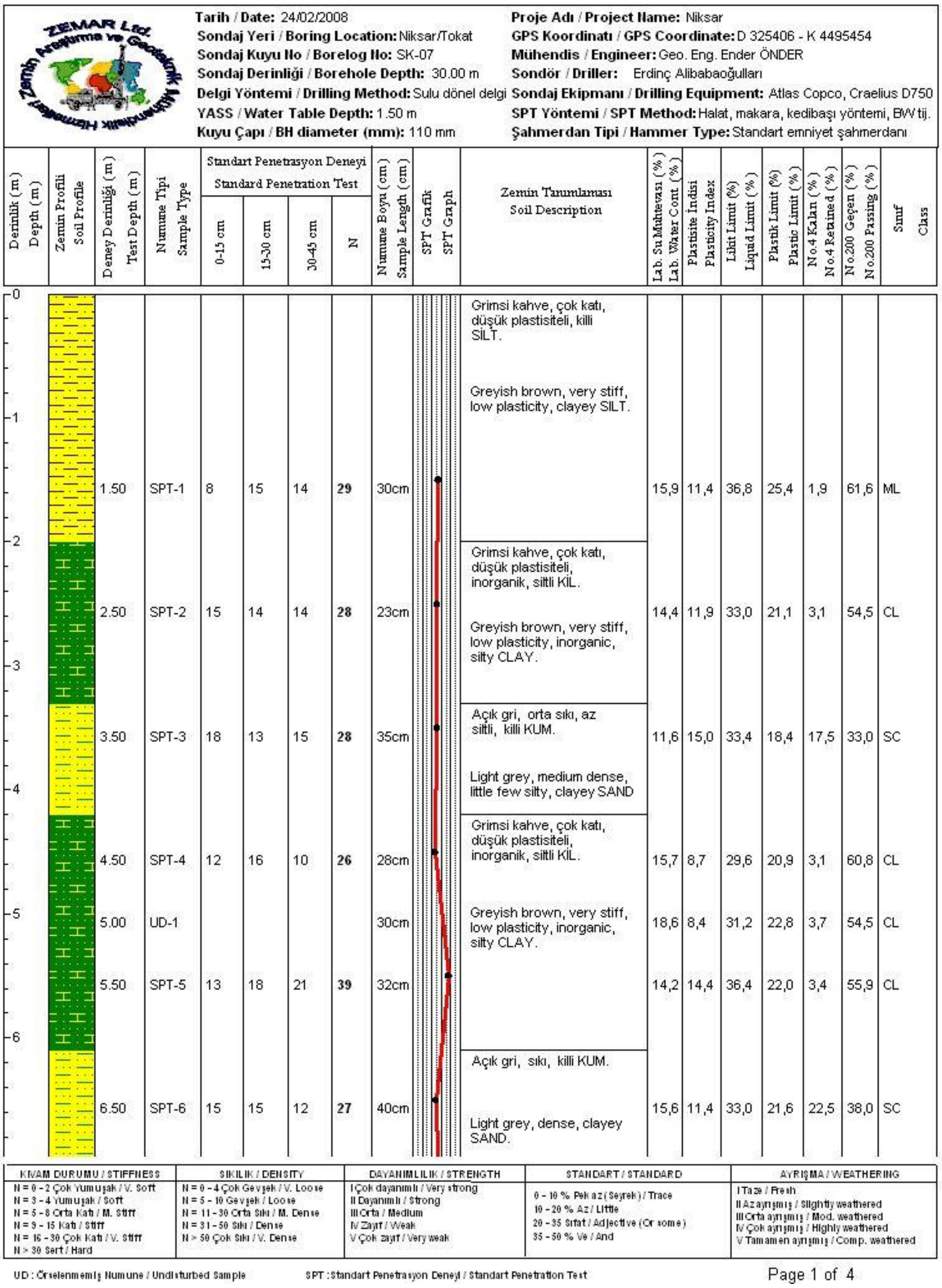
Figure A.22. Boreholes drilled for the thesis: D21 (5/5)



ZEMAR Ltd. Zemin Araştırma ve Geoteknik Mühendislik Hizmetleri

Tarih / Date: 24/02/2008
Sondaj Yeri / Boring Location: Niksar/Tokat
Sondaj Kuyu No / Borelog No: SK-07
Sondaj Derinliği / Borehole Depth: 30.00 m
Delgi Yöntemi / Drilling Method: Sulu dönel delgi
YASS / Water Table Depth: 1.50 m
Kuyu Çapı / BH diameter (mm): 110 mm

Proje Adı / Project Name: Niksar
GPS Koordinatı / GPS Coordinate: D 325406 - K 4495454
Mühendis / Engineer: Geo. Eng. Ender ÖNDER
Sondör / Driller: Erdinç Alibabaoğulları
Sondaj Ekipmanı / Drilling Equipment: Atlas Copco, Craelius D750
SPT Yöntemi / SPT Method: Halat, makara, kedibaşı yöntemi, BW tij.
Şahmerdan Tipi / Hammer Type: Standart emniyet şahmerdanı

Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
		1.50	SPT-1	8	15	14	**29**	30cm		Grimsi kahve, çok katı, düşük plastisiteli, killi SİLT. Greyish brown, very stiff, low plasticity, clayey SILT.	15,9	11,4	36,8	25,4	1,9	61,6	ML
		2.50	SPT-2	15	14	14	**28**	23cm		Grimsi kahve, çok katı, düşük plastisiteli, inorganik, siltli KİL. Greyish brown, very stiff, low plasticity, inorganic, silty CLAY.	14,4	11,9	33,0	21,1	3,1	54,5	CL
		3.50	SPT-3	18	13	15	**28**	35cm		Açık gri, orta sıkı, az siltli, killi KUM. Light grey, medium dense, little few silty, clayey SAND	11,6	15,0	33,4	18,4	17,5	33,0	SC
		4.50	SPT-4	12	16	10	**26**	28cm		Grimsi kahve, çok katı, düşük plastisiteli, inorganik, siltli KİL. Greyish brown, very stiff, low plasticity, inorganic, silty CLAY.	15,7	8,7	29,6	20,9	3,1	60,8	CL
		5.00	UD-1					30cm			18,6	8,4	31,2	22,8	3,7	54,5	CL
		5.50	SPT-5	13	18	21	**39**	32cm			14,2	14,4	36,4	22,0	3,4	55,9	CL
		6.50	SPT-6	15	15	12	**27**	40cm		Açık gri, sıkı, killi KUM. Light grey, dense, clayey SAND.	15,6	11,4	33,0	21,6	22,5	38,0	SC

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

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SPT : Standart Penetrasyon Deneyi / Standart Penetration Test
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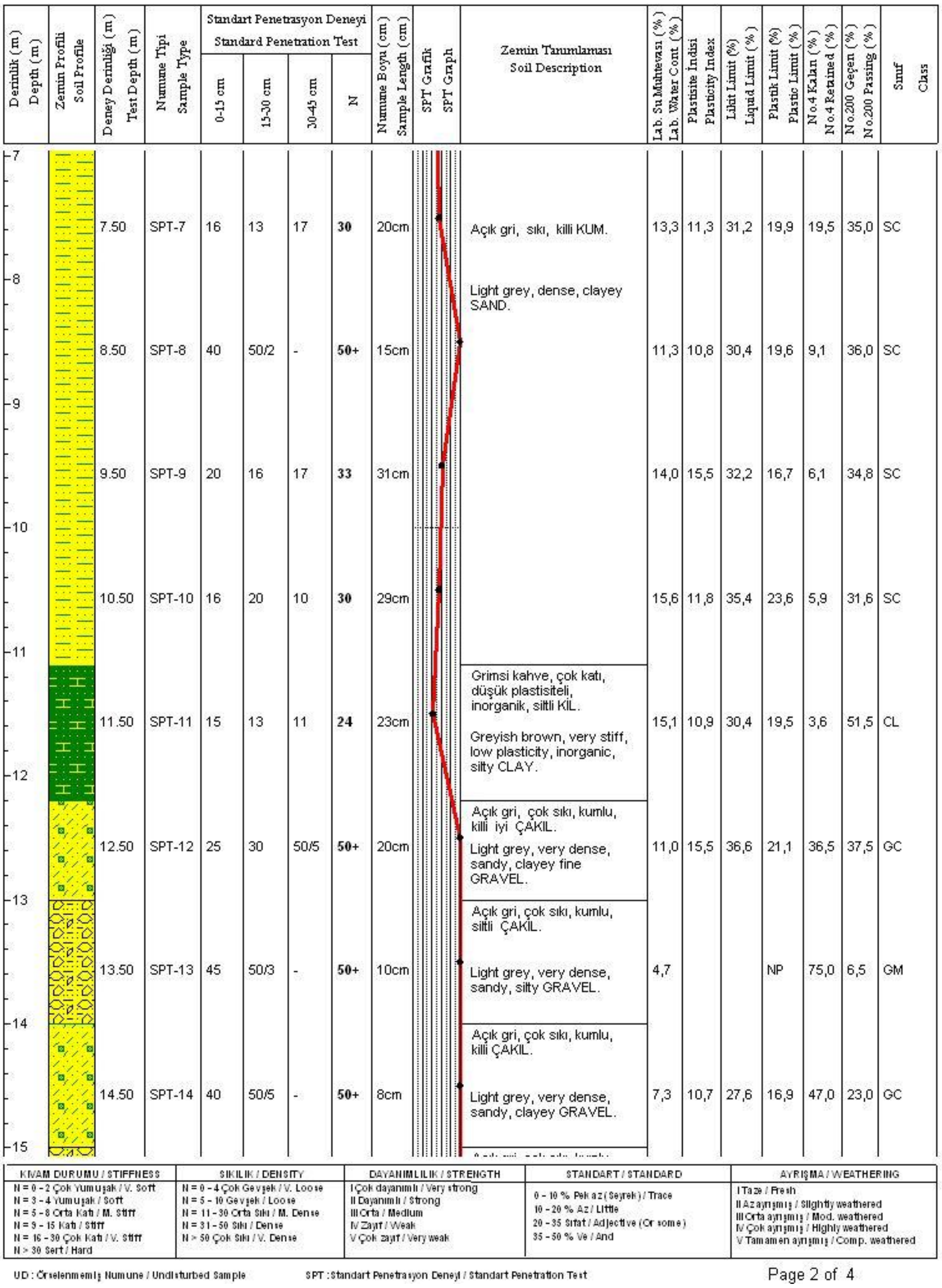
Figure A.23. Boreholes drilled for the thesis: D18 (1/4)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test 0-15 cm	15-30 cm	30-45 cm	N	Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
		7.50	SPT-7	16	13	17	**30**	20cm		Açık gri, sıkı, killi KUM. Light grey, dense, clayey SAND.	13,3	11,3	31,2	19,9	19,5	35,0	SC
		8.50	SPT-8	40	50/2	-	**50+**	15cm			11,3	10,8	30,4	19,6	9,1	36,0	SC
		9.50	SPT-9	20	16	17	**33**	31cm			14,0	15,5	32,2	16,7	6,1	34,8	SC
		10.50	SPT-10	16	20	10	**30**	29cm			15,6	11,8	35,4	23,6	5,9	31,6	SC
		11.50	SPT-11	15	13	11	**24**	23cm		Grimsi kahve, çok katı, düşük plastisiteli, inorganik, siltli KİL. Greyish brown, very stiff, low plasticity, inorganic, silty CLAY.	15,1	10,9	30,4	19,5	3,6	51,5	CL
		12.50	SPT-12	25	30	50/5	**50+**	20cm		Açık gri, çok sıkı, kumlu, killi iyi ÇAKIL. Light grey, very dense, sandy, clayey fine GRAVEL.	11,0	15,5	36,6	21,1	36,5	37,5	GC
		13.50	SPT-13	45	50/3	-	**50+**	10cm		Açık gri, çok sıkı, kumlu, siltli ÇAKIL. Light grey, very dense, sandy, silty GRAVEL.	4,7			NP	75,0	6,5	GM
		14.50	SPT-14	40	50/5	-	**50+**	8cm		Açık gri, çok sıkı, kumlu, killi ÇAKIL. Light grey, very dense, sandy, clayey GRAVEL.	7,3	10,7	27,6	16,9	47,0	23,0	GC

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

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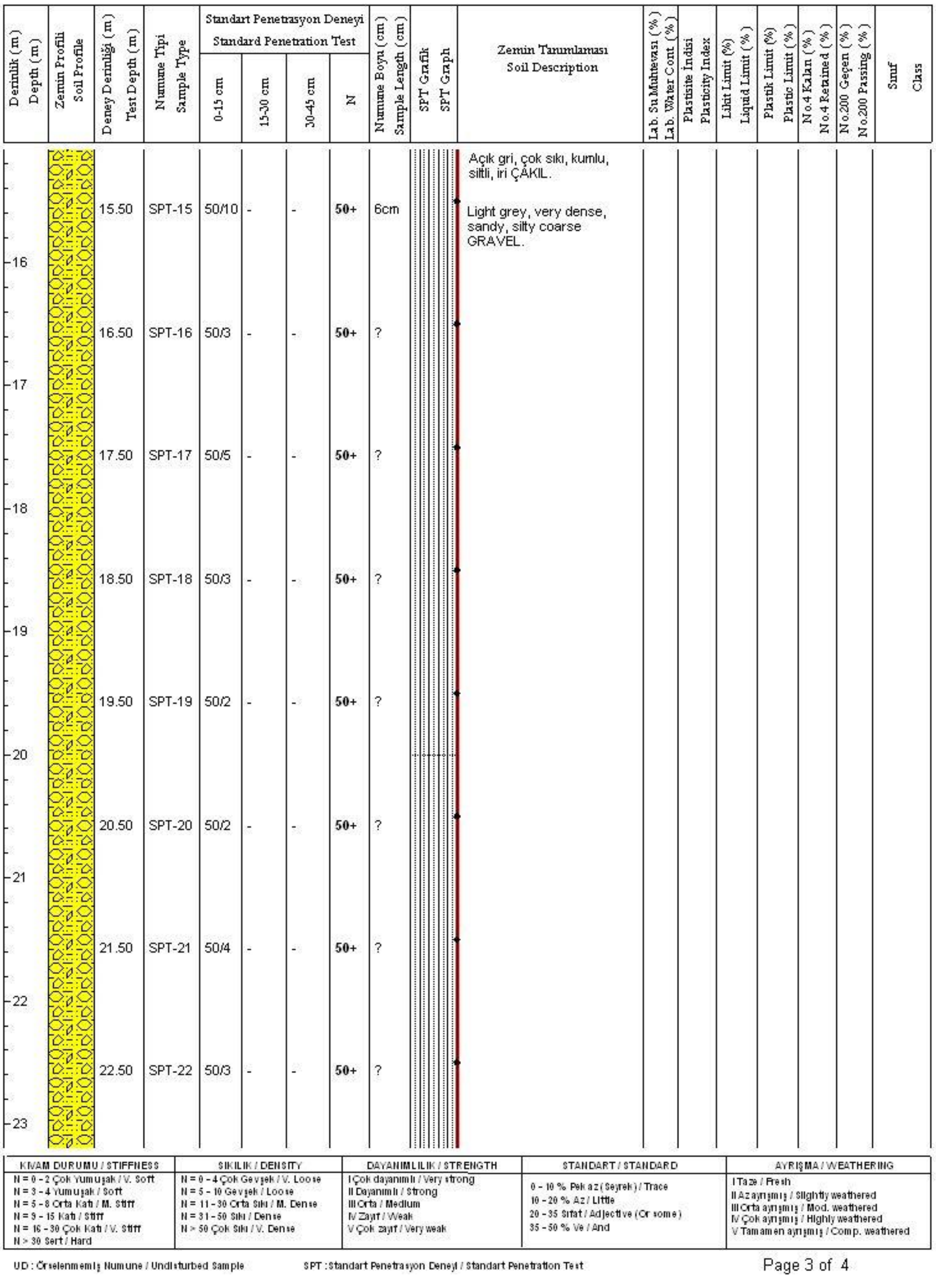
Figure A.24. Boreholes drilled for the thesis: D18 (2/4)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
		15.50	SPT-15	50/10	-	-	**50+**	6cm		Açık gri, çok sıkı, kumlu, siltli, iri ÇAKIL. Light grey, very dense, sandy, silty coarse GRAVEL.							
		16.50	SPT-16	50/3	-	-	**50+**	?									
		17.50	SPT-17	50/5	-	-	**50+**	?									
		18.50	SPT-18	50/3	-	-	**50+**	?									
		19.50	SPT-19	50/2	-	-	**50+**	?									
		20.50	SPT-20	50/2	-	-	**50+**	?									
		21.50	SPT-21	50/4	-	-	**50+**	?									
		22.50	SPT-22	50/3	-	-	**50+**	?									

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

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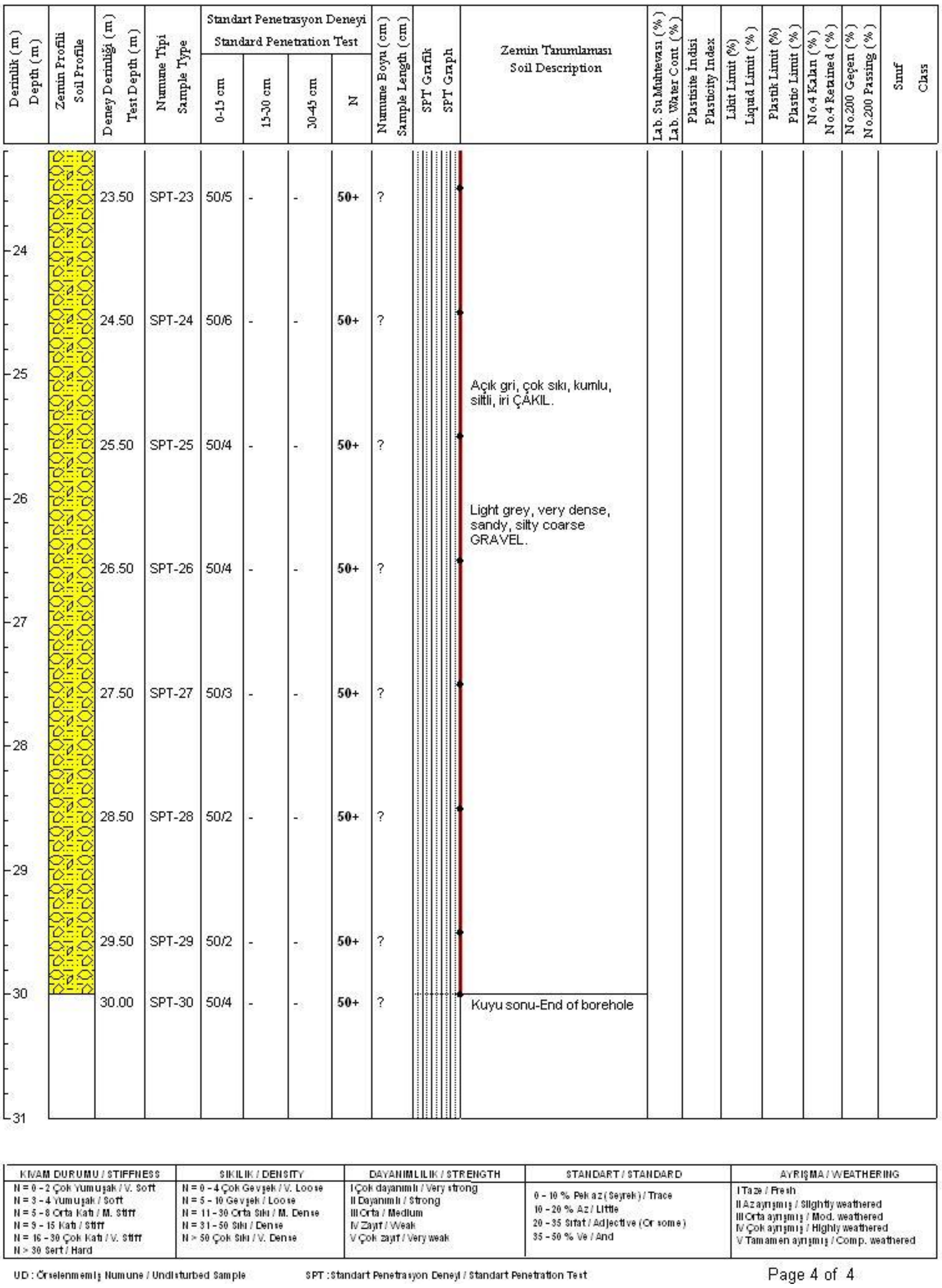
Figure A.25. Boreholes drilled for the thesis: D18 (3/4)



Derinlik (m) Depth (m)	Zemin Profili Soil Profile	Deney Derinliği (m) Test Depth (m)	Numune Tipi Sample Type	Standart Penetrasyon Deneyi Standard Penetration Test				Numune Boyu (cm) Sample Length (cm)	SPT Grafik SPT Graph	Zemin Tanımlaması Soil Description	Lab. Su Muhtevası (%) Lab. Water Cont. (%)	Plastisite İndisi Plasticity Index	Likit Limit (%) Liquid Limit (%)	Plastik Limit (%) Plastic Limit (%)	No.4 Kalan (%) No.4 Retained (%)	No.200 Geçen (%) No.200 Passing (%)	Sınıf Class
				0-15 cm	15-30 cm	30-45 cm	N										
		23.50	SPT-23	50/5	-	-	**50+**	?		Açık gri, çok sıkı, kumlu, siltli, iri ÇAKIL. Light grey, very dense, sandy, silty coarse GRAVEL.							
24																	
		24.50	SPT-24	50/6	-	-	**50+**	?									
25																	
		25.50	SPT-25	50/4	-	-	**50+**	?									
26																	
		26.50	SPT-26	50/4	-	-	**50+**	?									
27																	
		27.50	SPT-27	50/3	-	-	**50+**	?									
28																	
		28.50	SPT-28	50/2	-	-	**50+**	?									
29																	
		29.50	SPT-29	50/2	-	-	**50+**	?									
30		30.00	SPT-30	50/4	-	-	**50+**	?		Kuyu sonu-End of borehole							
31																	

KIVAM DURUMU / STIFFNESS	SIKILIK / DENSITY	DAYANIMLILIK / STRENGTH	STANDART / STANDARD	AYRIŞMA / WEATHERING
N = 0 - 2 Çok Yumuşak / V. Soft N = 3 - 4 Yumuşak / Soft N = 5 - 8 Orta Katı / M. Stiff N = 9 - 15 Katı / Stiff N = 16 - 30 Çok Katı / V. Stiff N > 30 Sert / Hard	N = 0 - 4 Çok Gevşek / V. Loose N = 5 - 10 Gevşek / Loose N = 11 - 30 Orta Sıkı / M. Dense N = 31 - 50 Sıkı / Dense N > 50 Çok Sıkı / V. Dense	I Çok dayanımlı / Very strong II Dayanımlı / Strong III Orta / Medium IV Zayıf / Weak V Çok zayıf / Very weak	0 - 10 % Pek az (Seyrek) / Trace 10 - 20 % Az / Little 20 - 35 Sıfat / Adjective (Or some) 35 - 50 % Ve / And	I Taze / Fresh II Az ayrışmış / Slightly weathered III Orta ayrışmış / Mod. weathered IV Çok ayrışmış / Highly weathered V Tamamen ayrışmış / Comp. weathered

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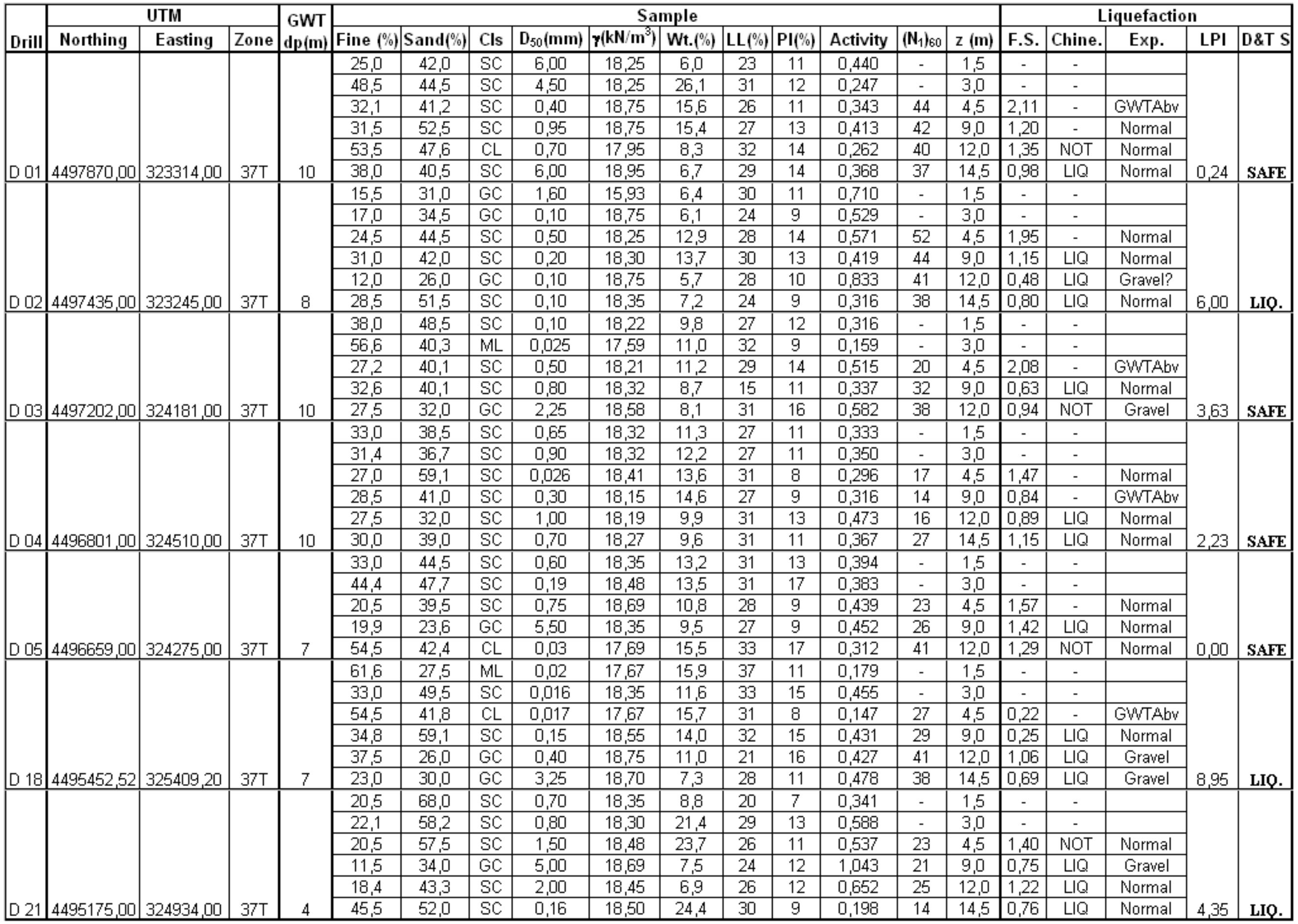
Figure A.26. Boreholes drilled for the thesis: D18 (4/4)

APPENDIX B

Table B.1. Borehole database for 7 boreholes drilled for this thesis



	UTM			GWT	Sample											Liquefaction				
Drill	Northing	Easting	Zone	dp(m)	Fine (%)	Sand(%)	Cls	D_{50}(mm)	γ(kN/m^3)	Wt.(%)	LL(%)	PI(%)	Activity	$(N_1)_{60}$	z (m)	F.S.	Chine.	Exp.	LPI	D&T S
D 01	4497870,00	323314,00	37T	10	25,0	42,0	SC	6,00	18,25	6,0	23	11	0,440	-	1,5	-	-		0,24	**SAFE**
					48,5	44,5	SC	4,50	18,25	26,1	31	12	0,247	-	3,0	-	-			
					32,1	41,2	SC	0,40	18,75	15,6	26	11	0,343	44	4,5	2,11	-	GWTAbv		
					31,5	52,5	SC	0,95	18,75	15,4	27	13	0,413	42	9,0	1,20	-	Normal		
					53,5	47,6	CL	0,70	17,95	8,3	32	14	0,262	40	12,0	1,35	NOT	Normal		
					38,0	40,5	SC	6,00	18,95	6,7	29	14	0,368	37	14,5	0,98	LIQ	Normal		
D 02	4497435,00	323245,00	37T	8	15,5	31,0	GC	1,60	15,93	6,4	30	11	0,710	-	1,5	-	-		6,00	**LIQ.**
					17,0	34,5	GC	0,10	18,75	6,1	24	9	0,529	-	3,0	-	-			
					24,5	44,5	SC	0,50	18,25	12,9	28	14	0,571	52	4,5	1,95	-	Normal		
					31,0	42,0	SC	0,20	18,30	13,7	30	13	0,419	44	9,0	1,15	LIQ	Normal		
					12,0	26,0	GC	0,10	18,75	5,7	28	10	0,833	41	12,0	0,48	LIQ	Gravel?		
					28,5	51,5	SC	0,10	18,35	7,2	24	9	0,316	38	14,5	0,80	LIQ	Normal		
D 03	4497202,00	324181,00	37T	10	38,0	48,5	SC	0,10	18,22	9,8	27	12	0,316	-	1,5	-	-		3,63	**SAFE**
					56,6	40,3	ML	0,025	17,59	11,0	32	9	0,159	-	3,0	-	-			
					27,2	40,1	SC	0,50	18,21	11,2	29	14	0,515	20	4,5	2,08	-	GWTAbv		
					32,6	40,1	SC	0,80	18,32	8,7	15	11	0,337	32	9,0	0,63	LIQ	Normal		
					27,5	32,0	GC	2,25	18,58	8,1	31	16	0,582	38	12,0	0,94	NOT	Gravel		
D 04	4496801,00	324510,00	37T	10	33,0	38,5	SC	0,65	18,32	11,3	27	11	0,333	-	1,5	-	-		2,23	**SAFE**
					31,4	36,7	SC	0,90	18,32	12,2	27	11	0,350	-	3,0	-	-			
					27,0	59,1	SC	0,026	18,41	13,6	31	8	0,296	17	4,5	1,47	-	Normal		
					28,5	41,0	SC	0,30	18,15	14,6	27	9	0,316	14	9,0	0,84	-	GWTAbv		
					27,5	32,0	SC	1,00	18,19	9,9	31	13	0,473	16	12,0	0,89	LIQ	Normal		
					30,0	39,0	SC	0,70	18,27	9,6	31	11	0,367	27	14,5	1,15	LIQ	Normal		
D 05	4496659,00	324275,00	37T	7	33,0	44,5	SC	0,60	18,35	13,2	31	13	0,394	-	1,5	-	-		0,00	**SAFE**
					44,4	47,7	SC	0,19	18,48	13,5	31	17	0,383	-	3,0	-	-			
					20,5	39,5	SC	0,75	18,69	10,8	28	9	0,439	23	4,5	1,57	-	Normal		
					19,9	23,6	GC	5,50	18,35	9,5	27	9	0,452	26	9,0	1,42	LIQ	Normal		
					54,5	42,4	CL	0,03	17,69	15,5	33	17	0,312	41	12,0	1,29	NOT	Normal		
D 18	4495452,52	325409,20	37T	7	61,6	27,5	ML	0,02	17,67	15,9	37	11	0,179	-	1,5	-	-		8,95	**LIQ.**
					33,0	49,5	SC	0,016	18,35	11,6	33	15	0,455	-	3,0	-	-			
					54,5	41,8	CL	0,017	17,67	15,7	31	8	0,147	27	4,5	0,22	-	GWTAbv		
					34,8	59,1	SC	0,15	18,55	14,0	32	15	0,431	29	9,0	0,25	LIQ	Normal		
					37,5	26,0	GC	0,40	18,75	11,0	21	16	0,427	41	12,0	1,06	LIQ	Gravel		
					23,0	30,0	GC	3,25	18,70	7,3	28	11	0,478	38	14,5	0,69	LIQ	Gravel		
D 21	4495175,00	324934,00	37T	4	20,5	68,0	SC	0,70	18,35	8,8	20	7	0,341	-	1,5	-	-		4,35	**LIQ.**
					22,1	58,2	SC	0,80	18,30	21,4	29	13	0,588	-	3,0	-	-			
					20,5	57,5	SC	1,50	18,48	23,7	26	11	0,537	23	4,5	1,40	NOT	Normal		
					11,5	34,0	GC	5,00	18,69	7,5	24	12	1,043	21	9,0	0,75	LIQ	Gravel		
					18,4	43,3	SC	2,00	18,45	6,9	26	12	0,652	25	12,0	1,22	LIQ	Normal		
					45,5	52,0	SC	0,16	18,50	24,4	30	9	0,198	14	14,5	0,76	LIQ	Normal		

Chine: Chinese criteria for fines, D&T S: Method of Ishiara (1985)