MORPHOLOGICAL ANALYSES IN HATTUSHA
(BOĞAZKALE-TURKEY)

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ABSTRACT

MORPHOLOGICAL ANALYSES IN HATTUSHA
(BOĞAZKALE-TURKEY)

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The purpose of this study is to investigate the morphological properties of the ancient city Hattusha and its surroundings. To achieve this, the analyses are conducted on the digital topographical maps at 1/25000 and 1/1000 scales.

Results of the analyses reveal that Hattusha is located over a north facing surface with slope values of 6 to 15 degrees within an elevation range of 1000 to 1250 m. All main building complexes are confined to a narrow slope interval of 2 to 15 degrees. Five regions are detected where the city wall deviates from the topographic divide resulting in a shorter path and addition of certain areas to the city. The volume of the city wall between Lion and King's gates is estimated to be 613966 m^3 and covers an area of 130682 m^2. Capacity of the eastern and southern ponds is estimated 15400 m^3 and 22160 m^3, respectively. Two potential dam sites are suggested outside the city with a total drainage basin of 0.2713 km^2. For the visibility analysis performed inside the city, no relation is found between the visibility and the elevation of points.

Keywords: Geoarchaeology, GIS, Morphology, Water resources, Hattusha

ÖZ

HATTUŞAŞ'TA MORFOLOJİK ANALİZLER
(BOĞAZKALE-TÜRKİYE)

Dündar, Pınar
Yüksek Lisans, Jeoloji Mühendisliği Bölümü
Tez Yöneticisi : Prof. Dr. Vedat Toprak
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Bu çalışmanın amacı Hattuşaş antik kenti ve dolayındaki morfolojik özellikleri araştırmaktır. Bu amaç doğrultusunda alanın 1/25000 ve 1/1000 ölçeklerindeki dijital topografik haritaları üzerinde analizler gerçekleştirilmiştir.

Bu çalışmanın sonuçları, antik kent Hattuşaş'ın, çoğunlukla kuzeye dönük, eğimi 6-15 derece arasında değişen ve yüksekliği 1000-1250 m arasında olan bir alan içerisinde yer aldığını göstermektedir. Başlıca yapı komplekslerinin tümü 2-15 derece arasında değişen dar bir eğim aralığında yer almaktadır. Şehir surunun topografik bölüm çizgisinden saptığı 5 bölge tespit edilmiş, bu sayede sur uzunluğunun azaltıldığı ve belirli bölgelerin şehre dahil edildiği belirlenmiştir. Kral Kapı ve Aslanlı Kapı arasında şehir surunun hacmi yaklaşık 613966 m^3, alanı ise 130682 m^2 olarak tespit edilmiştir. Doğu ve güney havuzlarının sırasıyla 15400 m^3 ve 22160 m^3 kapasiteye sahip olduğu tahmin edilmektedir. Şehir dışında, drenaj havzaları toplamı 0.2713 km^2 olan iki potansiyel baraj bölgesi tespit edilmiştir. Şehir içinde belirli noktalardan görülebilen

alanların araştırılması sonucunda, görünebilirlik ve yükseklik arasında bir ilişki olmadığı belirlenmiştir.

Anahtar kelimeler: Jeoarkeoloji, CBS, Morfoloji, Su Kaynakları, Hattuşaş

To my beloved family

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CHAPTER 1

INTRODUCTION

1.1. Purpose and Scope

Hattusha was the capital city of Hittites during the period about 1650/1600 to 1200 BC. The remains of this antique city including the city walls, the gates, the temples and the palaces awaiting visitor today are the proofs of the magnificent period of the city, 13th century BC. There was also the substantial settlement here belonging to the later “Phrygian”, Hellenistic, Roman and Byzantine periods (Seeher, 2005).

The capital city Hattusha was also a cult centre for the Hittite Empire, one of the greatest powers of the ancient world alongside Egypt, Babylonia and Assyria during the 14th and 13th centuries BC. Thirty-one temples have been excavated in Hattusha up to now. The city is mentioned as ‘thousand gods of Hatti’ in many texts. Moreover, the treaty of Kadesh, which is important as being the world’s first official written agreement, was signed between the Hittite King Muwattalli II and Egypt Pharaoh Ramses II in 1259 BC (Canpolat, 2001). These specific features of Hattusha, reflects the city’s importance in the antiquity.

The objective of this study is to investigate the morphological properties of the ancient city Hattusha and its surroundings. In this frame, morphological analyses are conducted based on the digital topographical maps of the region. The main reason for the selection of this topic is that, despite the long term excavation history of site, there has been no particular analysis on morphological features. At the end of the analysis it is expected to derive some conclusions that will shed light on the interaction between the human and the use of topography. The scope, therefore, is limited with morphological aspects and other geological features (such as rock types, geological structures) are left out of the scope.

1.2 Study Area

Hattusha lies in northern Central Anatolia within the Çorum province in the close vicinity of Boğazkale county (Figure 1.1). It is about 210 km away from Ankara along the road from Yozgat to Ankara-Çorum highway.

Study area is covered in four topographic maps at 1:25000 scale, namely, H33-d3, H33-d4, I33-a1 and I33-a2 (Figure 1.2). This area which is more than 600 km2 is used in the analysis at regional scale. The city itself, however, which is bounded by the city wall, is used for the analysis at local scale.

1.3. Geology of the Study Area

Ancient city Hattusha, at regional scale, is located within an ophiolitic belt known as "Izmir-Ankara-Erzincan suture zone" that extends in E-W direction. There is not however detailed studies on the geology of the area in relation to the city of Hattusha. The only detailed geological map is the one prepared by Kazancı et al (2008) as a guide prepared by the Turkish Association for the Conservation of Geological Heritage as an excursion guide. Geological information provided here is compiled from this guide. Geological map of the site is given in Figure 1.3.

The oldest rock units exposed in the area belong to the Devecidağ Complex that comprises various metamorphosed clastic rocks of Triassic age. Dominant rock types in this complex are phyllites, meta-sandstones, conglomerates, meta-diabase and spilites. One common feature of the sequence is the presence of limestone and marble blocks of pre-Triassic age. The city of Hatusha (including Yazılıkaya) is mostly located within this sequence and the blocks observed within the city are interpreted as olistoliths

(Figure 1.4). Both limestone and marble blocks are white-gray, sometimes pinkish, massive and in breccia form from place to place. They are mostly crystallized and have a coarse grained texture (Kazancı et al., 2008).

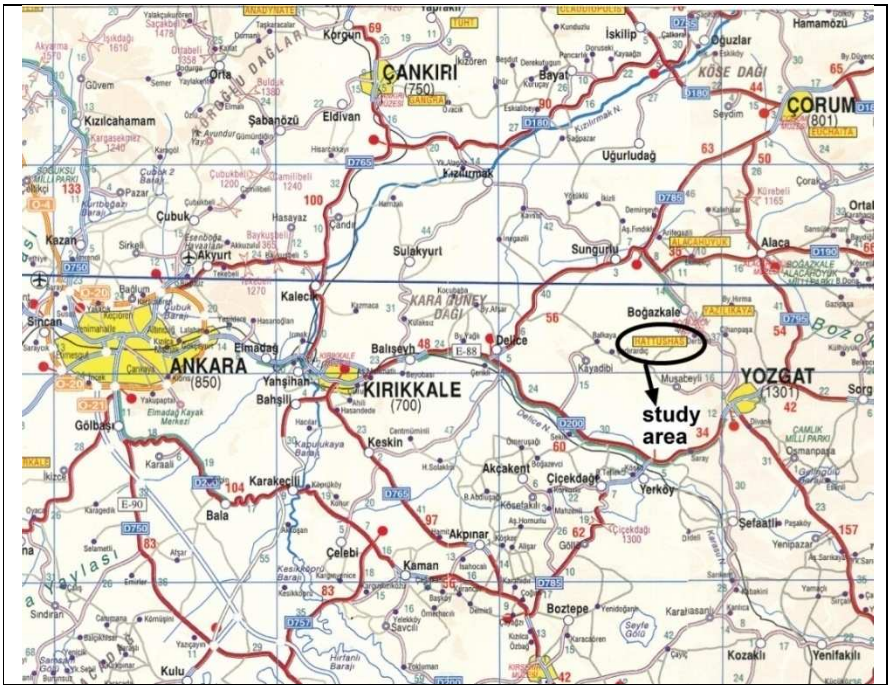


Figure 1.1 Location map of Hattusha

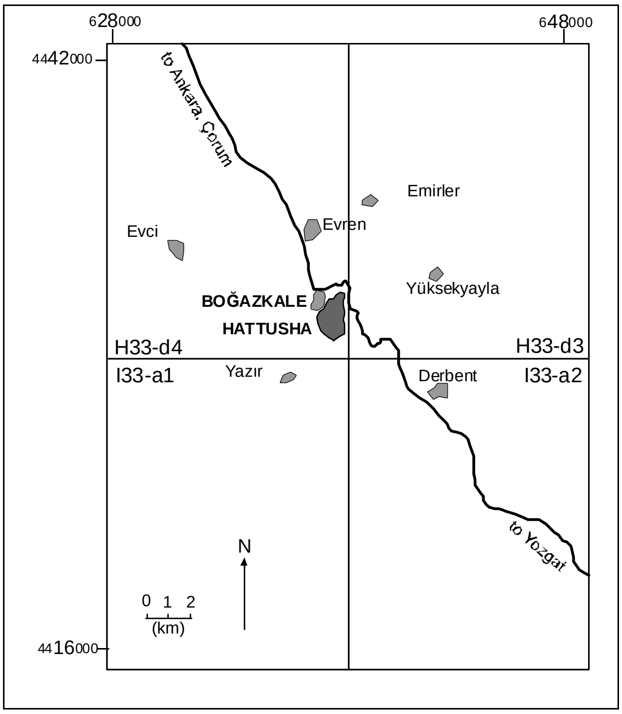


Figure 1.2 Boundary of four 1:25000 scale topographic maps covering study area.

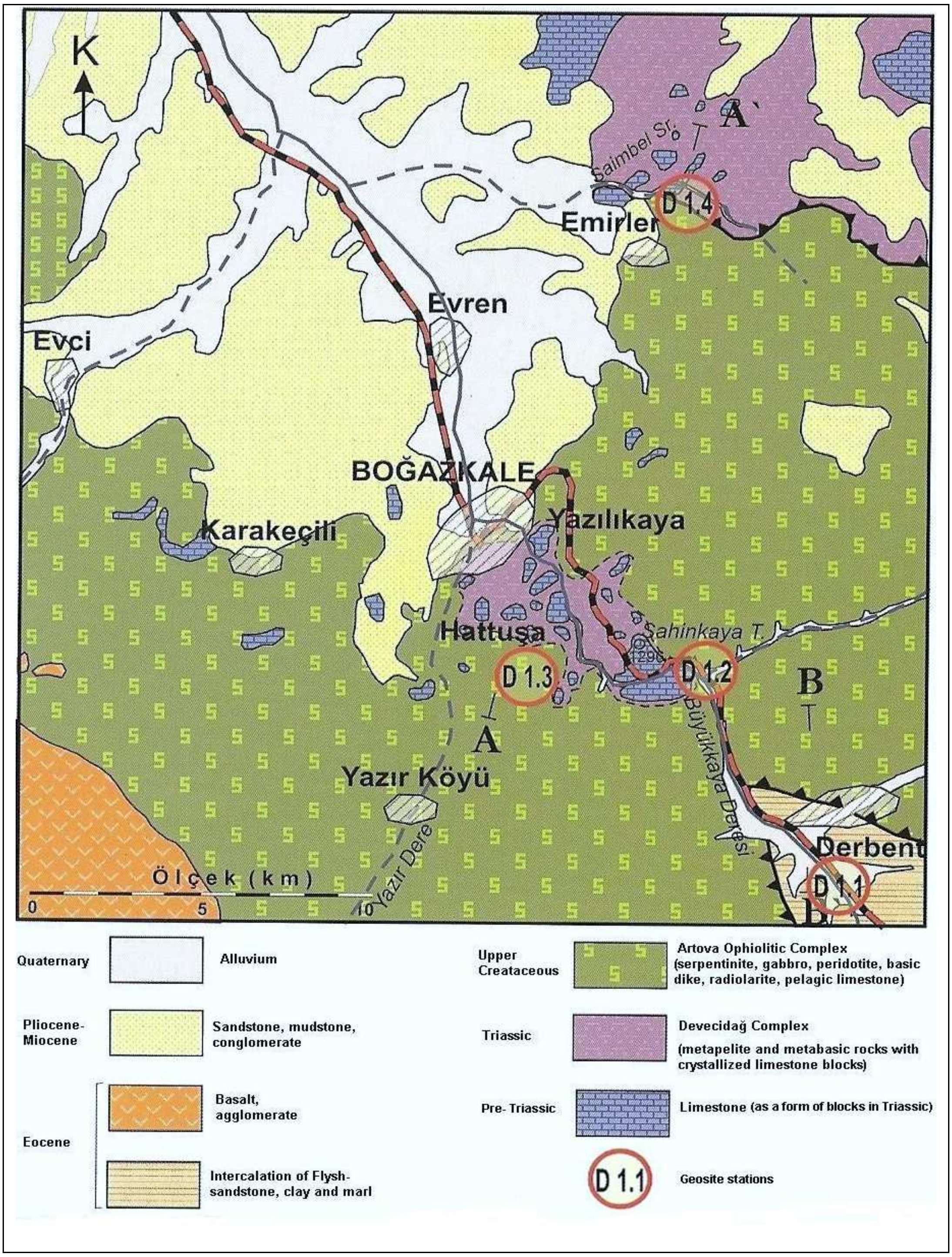


Figure 1.3 Geological map of Boğazkale and its vicinity. "Geosite" term in the figure represents a natural phenomenon that shows a specific geological event or process. (from Kazancı et al., 2008)

Figure 1.4 General view of limestone blocks (olistoliths) of Devecidağ Complex (Kazancı et al, 2008) extensively observed within the city of Hattusha.

According to Kazancı et al. (2008), Artova Ophiolitic Complex that thrust over the Devecidağ Complex covers large areas in the close vicinity of Hattusha (Figure 1.5). The dominant rock types existing in the complex are serpentinite, gabbro, peridotite, mafic dykes, radiolorite and pelagic limestone. Age of this complex is assigned as Late Cretaceous. Outcrops of older Devecidağ Complex are observed in a tectonic window below the ophiolitic rocks (Figure 1.3).

Vertical cliffs and deep canyons are developed within the limestone blocks particularly along Büyükkaya stream which is located at the eastern side of the city. Lithological properties of the Ophiolitic Melange can be distinguished along this valley. In the construction of the ancient city, these limestone olistoliths were used dominantly. In addition, gabbros are rarely used in the construction of Temple 1. One attractive rock mass is the cubic green nephrite (60*60*80 cm) which is rarely found in the nature (Figure 1.6). This rock type occurs in the serpentinites and is formed by metamorphism (Kazancı et al., 2008).

Figure 1.5 A general view of ophiolitic melange (Artova Ophiolitic Complex by Kazancı et al, 2008) observed in the vicinity of Hattusha. The stream in the Figure is Yazır stream flowing west of Hattusha.

Figure 1.6 A view of the nephrite (metamorphosed serpentinite) located within the Temple 1 in Hattusha.

Kazancı et al. (2008) states that Eocene clastic sedimentary and volcanic rocks (basalt lava flows and agglomerates) are exposed about 7-8 km SE and SW of Hattusha, respectively. The youngest units (Mio-Pliocene continental clastics and Quaternary alluvium) are exposed in the low topography NW of Hattusha (Figure 1.7).

Figure 1.7 General view of low topographic region NW of Hattusha where Mio-Pliocene clastic rocks (low hilly areas) and Quaternary alluvium are deposited. Picture is taken from Hattusha toward NW.

1.4. Historical Background of Hattusha

The Hittites ruled over northern Syria and a large part of Anatolia in the second millennium BC. Because the language they spoke belongs to Indo-European group, it is known that they came from outside Anatolia. They are thought to have arrived in Anatolia in small groups a few centuries before the founding of their kingdom and, gradually gaining power, to have established the Hittite state (Canpolat, 2001).

Hattushili, meaning ‘one from Hattusha’, founded the first Hittite Kingdom at Boğazköy/Hattusha within Çorum province in the period 1600-1650 BC. During the reign of his successor Mursili I, the kingdom spilled over the boundaries of Anatolia, taking Aleppo in the South and extending as far as Babylon. The Hittites lived their brightest period during the reign of the young Suppiluliuma I, who became the king in the mid-14th century BC. On the political front, the ‘Hittite Kingdom’ of the 17th-15th centuries BC turned into the ‘Hittite Empire’ of the 14th-13th centuries after conquering the neighbouring regions. During the 14th and 13th centuries BC, the Hittite Empire was one of the greatest powers of the ancient world, alongside Egypt, Babylonia and Assyria (Canpolat, 2001). The map of Hittite world is shown in Figure 1.8.

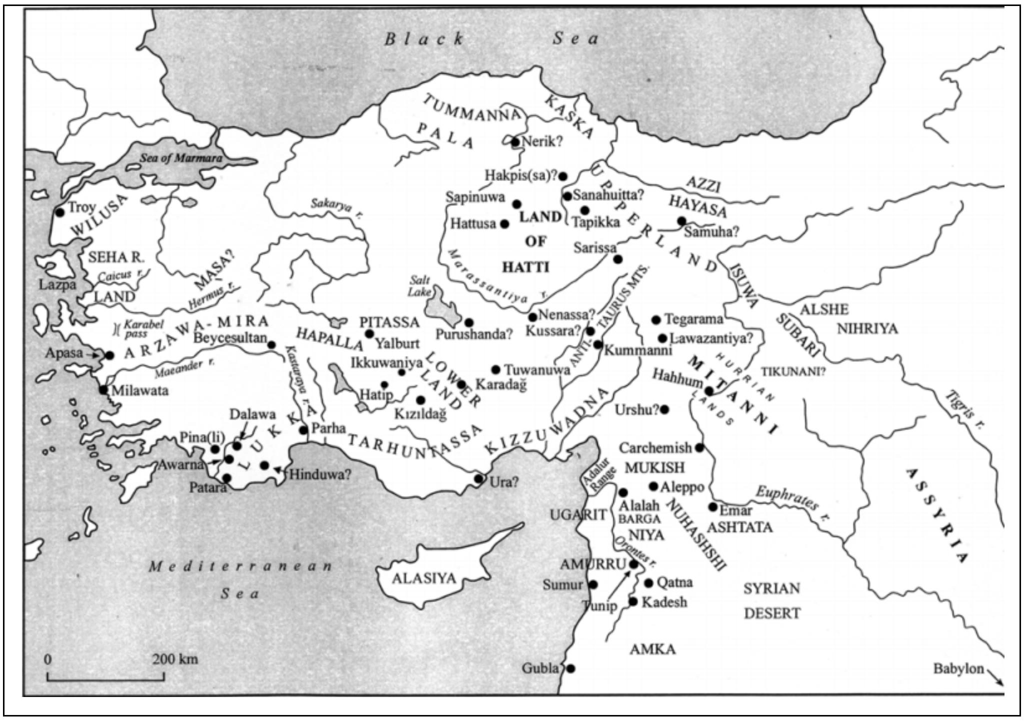


Figure 1.8 The world of the Hittites (from Bryce, 2005)

The Hittite state, one of the leading empires of the Near East and a virtual superpower of its day, was engaged in a conflict with Egypt, which wants to show its power in the Eastern Mediterranean. This conflict is resulted in a battle in 1275 BC. The Hittite army under the command of Muwattali II and the Egyptian army commanded Ramses II fought at Kadesh in Northern Syria. The Treaty of Kadesh, signed following this war in around 1259 BC. It is important as being the world's official written agreement between two nations. (Canpolat, 2001).

Some short time after Treaty of Kadesh, the Hittite Empire was destroyed around 1200 BC because of the internal and external unrest, and the capital at Hattusha was abandoned. (Canpolat, 2001).

Following the collapse of the central Hittite state, which is also known as the end of Bronz Age and the beginning of the Iron Age, a period called Dark Age began in the area that lay within the curve of Kızılırmak, the Empire's nucleus. During this period semi-nomadic chieftains established a number of sparse settlements. Meanwhile in southern Anatolia a group of small city-states known as the Late Hittite Kingdoms continued to exist from 1100 to 700 BC. (Canpolat, 2001).

According to Canpolat (2001), Hittite settlements were either in step rocky regions or on flat plains and the city walls with towers constructed at regular intervals were the common characteristics of Hittite sites. The capital city Hattusha is known as the best example of rocky regions and the entrance to the city was provided through gates; Lion Gate, the King's Gate and the Sphinx Gate at Hattusha.

The northern part of the capital, dates back to the Old Kingdom, was dominated by the royal acropolis, known today as Büyükkale ('Big Castle'). Here the palace and chief administrative buildings of the capital are located. To the north-west of the acropolis, the city's largest and most important temple, the Great Temple is located (Bryce, 2005).

In the thirteenth century, the city underwent an extensive building programme, with the redevelopment of the palace complex on the acropolis and a massive expansion of the city to the south. The new area is called as the Upper City (Bryce, 2005).

1.5 Method of Study

This study is composed of three steps; literature survey, fieldwork and office work. In the literature survey part, documentary research and readings have been done on the history of the ancient city Hattusha, interaction of archaeological studies to geosciences and GIS, and previous geoarchaeological works in Hattusha. In the field work part, reconnaissance survey is conducted first in 2008, second fieldwork in 2009 is carried out to investigate general features of the ancient city.

During the office work, which is the main body of this thesis, collection and evaluation of data are carried out. 1/25000 scale topographical maps are obtained from General Command of Mapping and a topographic map of the study area at 1/1000 scale obtained from Hattusha excavation team.

MapInfo Professional software (version 7.5) is used in the registration of topographical maps, preparing morphological analyses, performing GIS analysis and production of output maps. Photoshop is used in combination of the 1/25000 scaled topographical maps. Microsoft Excel 2007 is used in the organization of data and preparation of histograms. MS DOS QBasic is used to write some programs for the handling of voluminous data obtained from MapInfo that could not be opened by Excel.

CHAPTER 2

BACKGROUND ON THE GEOARCHAEOLOGICAL INVESTIGATIONS

In this chapter a brief background information will be given on various aspects of geoarcheological investigations considering the scope of the thesis. The chapter is organized into four sections. In the first section the scope of geoarchaeology will be given. The second and the third sections deal with the morphological and GIS applications in the archaeological sites. Finally, in the last section, geoarchaeological studies carried out in Hattusha will be mentioned.

2.1. Scope of Geoarchaeology

Geoarchaeology is defined as the contribution from earth sciences to the solution of geo-related problems in archaeology (Gladfelter, 1977; Hassan, 1979, Rapp and Hill, 1998; Jones, 2007). Huckleberry (2000) claimed that geoarchaeology is both an interdisciplinary and specialized science and that this does not weaken the discipline. Accordingly, the discipline helps to blend sciences and humanities and in this way it will play a large role in the success of the discipline.

Rapp and Hill (1998) claimed that interactions between archaeology and geosciences can be classified into three overlapping periods. In the first period, the main concern was with the evidences for human antiquity. Therefore, the nineteenth century has been characterized as a period when early human occupation of Europe and America during Ice Age is focused on. During the second phase, including the end of 19th century and the first half of 20th century, interest in paleoenvironmental and paleoclimatologic conditions expanded the overlapping part of archaeology and geosciences. Sedimentary sequences or stratified deposits continued to be studied, but with additional use of geoscience methods to evaluate the paleoclimatic and geochronological contexts of archaeological sites. Finally, the third phase of interaction began around the second half of the twentieth century. In this period, a trend toward theoretical convergence developed. One of the main reasons of transformation from a period of collaboration to a period of theoretical convergence was the realization by archaeologists of how much paleoanthropology depended on an understanding of the geologic context of an archaeological deposit. The critical component was the geoscience perspective. This awareness caused an attempt to formulate a theoretical framework in archaeology that allows geoarchaeological perspective.

According to French (2003) the main objective of geoarchaeology is to contribute to archaeological data and enable to make interpretation about the data obtained. In order to achieve this, geoarchaeology benefits from earth-science disciplines such as geomorphology, petrography, stratigraphy, geophysics etc. and uses many techniques vary from remote sensing to geophysical surveys. These techniques have an important role in different steps of archaeological studies from the discovery of archaeological sites to understanding the relation between human and surrounding landscape.

French (2003) claimed that, geoarchaeology is mainly concerned with the investigation of at least three major and interlinked themes. First, there is recognition and decipherment of landform formation and transformation. This involves, for example, the effects of tectonics (uplift/subsidence), sea level change and glacial/periglacial processes on the actual form of the landform that we see and study**.** Second, effects of humans on the landscape change is mainly concerned. The purpose here is to produce long term and detailed pictures of landscape and land-use change, and to identify interrelationships between the land, climate and humans. Third, reveal the effect of hydrological regime and burial regime on an environment and to establish how has that effected the preservation in the area over the long term.

Beach et al. (2008) states that, at a local scale, site-formation processes are mainly discussed in most geoarchaeological studies. These processes can be described as the interaction of geomorphic and cultural variables hidden in archaeological materials in a unique sedimentary matrix.

2.2. Morphology Applications in Archaeology

Morphology of an area from archaeological point of view is important for two reasons: 1) to quantify the landscape for a specific site, 2) to predict the location of unknown sites. A predictive model as described by Kohler (1988) is “a simplified set of testable hypotheses, based on either behavioral assumptions or empirical correlations, which at a minimum attempts to predict loci of past human activities resulting in a deposition of artifacts or alteration of the landscape”. In this context, the prediction of the site is beyond the scope of this thesis, and therefore, the literature about the predictive modeling will not be mentioned. The former purpose, on the other hand, is the main focus of this study. Selected references on the application of morphological aspects are given below in the chronological aspect.

Williams et al. (1973) attempted to identify archaeological sites using certain physical parameter. The suggested that the locus of a site should:

- on a ridge or a saddle.
- relatively flat. (<5% slope)
- in the low foothills. (<250 m above the valley floor)
- within the modern pinion-juniper ecotone (<1000 m)
- near semi-permanent water source (<1000 m)
- minimal distance from this source (>100 m)

Kvamme (1985) lists the parameters and presents an approach in order to detect particular environmental features in the archaeological sites that prehistoric people were influenced in selecting their settlement locations. These features include water source, good view of environment, good shelter characteristics, south facing aspect of settlement, and a gentle local relief.

The model based on observations in the ecological and ethnographic literature views human uses of the environment.

Kvamme (1990) examines several interpolation methods to extract elevation and examines various algorithms in order to get slope data which is believed to be important for archaeological sites. The effects of the differences between methods and algorithms are examined on the results of an archaeological location model developed for an east-central Arizona. He concludes that the accuracy of computer generated data should be questioned.

Dalla Bona (1993) suggested a model for the site selection of archaeological sites dating from 9000 B.P. through the historic period in the Black Sturgeon Lake study area (Ontario). Using the “value weighted method”, five 30-meter-resolution raster layers of environmental parameters are used: 1) proximity to water, 2) soils, 3) drainage, 4) slope, and 5) aspect. Visual possibility of sites is calculated using different weights for each parameter. The resultant map shows the areas with the values ranging from 12 to 140 and classified into three categories as low, medium and high potential areas. The known archaeological sites are used to evaluate the results. Interpretation of the results indicate that 80% of the sites occur in high potential, 19.6% in medium potential and 0.4%in areas of low potential regions.

Kuiper and Wescott (1999) use GIS to locate areas of high potential for archaeological sites. They produce GIS layers representing the distribution of the environmental variables and analyze these layers to identify locations where combinations of environmental variables match patterns of known prehistoric sites. The study is applied to an area where more than 500 known archaeological sites exist (Upper Chesapeake Bay). Three steps in the analysis are: 1) developing an archaeological database, 2) collecting GIS layers representing the distribution of environmental variables (such as site type, distance to water, type of water source, soil type, topographic setting, slope, elevation, aspect and other geomorphic parameters) for the known sites, and 3) examining the data with descriptive statistics. They conclude that good results can be reached only with good and reliable data.

Choquette and Valdal (2000) attempted to develop a model for the site selection criteria for the archaeological sites. They suggested five main parameters to be important in the model. These are; area, topographic slope and aspect of the site, type and nature of the soil and the water resource. Description of these parameters are given in table 2.1. The potential for the occurrence of archaeological sites is evaluated by querying the database. The results of the analysis are categorized into two classes as "potential" indicating that the area is potentially significant to archaeology, and as "non-potential" for the rest of the area.

Table 2.1. GIS layers and their description as defined by Choquette and Valdal (2000) for the selection criteria of archaeological sites.

Predictor (GIS layer)	Description
Slope	Group 1: 0-10% - Highly significant Group 2: 11-30% - Moderately significant Group 3: 30+% - Not significant
Aspect	Group 1: Flat, South and Southwest - Highly significant Group 2: West and Southeast - Moderately significant Group 3: All other aspects - Not significant
Soils - Sediments	Group 1: Soils of glacio-lacustrine terraces - High significance Group 2: Soils of gravelly fluvi-oglacial terraces and fans - High significance Group 3: Soils in fine reworked fluvial/aeolian veneers - High significance Group 4: Soils of floodplains - High significance Group 5: All other soils - Not significant
Soils-Microenvironment	Group 1: Orthic brown chernozem, orthic melanic brunisol - High significance Group 2: Orthic eutric brunisol - Moderate significance Group 3: Subalpine brunisol, cumulic humic regosol - Less significance Group 4: All other soil types - Not significant
Water Buffers	Lakes 200m Marshes > 1ha 200m Marshes < 1ha 100m Major rivers 200m Definite streams 200m Indefinite streams 50m

Meybeck et al. (2001) suggest a new classification of landforms with 5 main morphologic parameters and define them as:

1) Plains correspond to sub-horizontal terrain,

2) Lowlands have a very low degree of roughness,

3) Platforms and hills have a greater degree of roughness,

4) Plateaus have a medium degree of roughness from 5 to 40‰),

5) Mountains differentiated from hills by their higher mean elevation and from plateaus by their greater roughness.

They later divide these quantitative classes into 15 classes and then cluster into 9 basic types. Their study is applied to the Tibet and Altiplano areas characterized by very high plateaus that lack mountains according to their classification.

2.3. GIS in Archaeology

GIS is described as "an information system designed to work with data referenced by spatial or geographic co-ordinates. In other words, a GIS is both a database system with specific capabilities for spatially referenced data as well as a separate operations for working(analyses) with the data (Star and Estes 1990). Burrough (1986) defined GIS as "...a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes".

According to Jardine and Teodorescu (2003) , GIS is related with creating maps on a computer for various purposes including both descriptive and analytical. With these properties, GIS help users to better understand spatial phenomena by visualizing the data.

According to Okabe (2006), as a discipline, archaeology includes various kinds of surveys from site surveys to excavation. The storage of collected data has an important role for each step. For instance; during excavation, it is important to record location and direction of artifacts and spatial relationships, arrangement and position of remains. Since GIS provided a systematic integration of different kind of datasets including archaeological, geographical, and environmental information, archaeologists began to use GIS in their researches.

Wheatly and Gillings (2002) emphasized that archaeology deals with enormous amount of spatial data in varying scales changing from relative locations of archaeological sites on a continental landmass to the positions of artifacts within a specified excavation area. Beside the position of feature, site or artefact itself, there may be other spatial relationships between them and the other “things”. The “things” here, may refer to environmental features (rivers, springs, mountains etc.) as well as other archaeological features such as hearths or mounds. This is where GIS starts to take place in archaeological studies. In 1990s, many archaeologists responsible for regional archaeological records were evaluating GIS, which was an attractive technology for offering map-based representation of site locations. Although a number of techniques developed in 1970s and 1980s, the first remarkable efforts are shown to exploit visual characteristics or properties of locations began in the early 1990s.

According to Ebert (2004), GIS use in archaeology can be described by recognizing three levels of application in this discipline. These are; visualization, management and analyses. Visualization is creating better maps, in other words preparing “pretty pictures”. Because it focuses on graphical functions of GIS, it requires little analytical capability. Therefore, it can be defined as “read-only” shape of GIS. Secondly, management is described as the “read-write” mode of GIS because it is possible to enter and edit data in this step. Although it is more complex than visualization, it still doesn’t allow full analytical capabilities of GIS. Finally, analyses, which is described as the top level of application of GIS, helps to generate or test theory.

Gaffney and Stancic (1991) investigated some specific archaeological areas of the island of Hvar in Dalmatia, Yugoslavia by using GIS techniques. They tried to reveal the interaction between human and nature by using both environmental and archaeological databases.

Bal et al. (2003) studied two ancient city which are the Luwian settlements of Kelenderis (modern Aydıncık) and nearby Nagidos (Bozyazı) to investigate and quantify the impact of historical land degradation on the Mediterranean coast of Turkey. In order to achieve this, aerial photos, historical maps and field measurements are used in creating GIS database.

Al Bayari (2005) investigated the ancient Roman City Jaresh, located in Jordan, by using both GIS and remote sensing techniques and he analysed the expansion effect of the modern city on the ancient Roman site.
Allen K et al. (1990) claims that the advantage of a GIS approach is that one can ask questions repeatedly in slightly different ways. What if the floods were deeper? Do burial sites of the same period have the same relation to water as the settlements? To find the answers, visualization of data can be generated rapidly, and results can be measured in statistical terms. Once maps and data have been entered into the system, they can be recalled in various combinations. Some exercises could only be performed with the help of a computer. For example, it is possible to display a view of the landscape from a specific location as if there is someone standing there, looking in any specified direction. These kinds of analyses are known as "visibility analyses".

The simplest form of visibility analyses is "line of sight" analysis which detects whether one point is visible from another one (Kvamme, 1999). A more complex type is calculation of viewshed which is a map including visible and not visible areas from a given location. The areas are revealed by the help of digital elevation model (DEM) (Ebert, 2004). Another form of viewshed analysis is "cumulative viewshed" that shows the sum of the areas visible from a number of individual locations (Kvamme, 1999 ; Wheatly, 1995).

Chapman (2003) investigated the morphology of a Neolithic monument by using cumulative viewshed analyses to understand whether there is a visual relationship between its morphology and past monuments.

Viewshed analyses also help to understand social landscape from the point of the relationship between visual dominance and territoriality (Lock and Harris, 1996). For example, according to Lock and Harris (1996), viewsheds of Neolithic long barrows in the Danebury area did not overlap ensuring a representation of highly visible territorial markers.

Although visibility analysis is a very useful tool in GIS softwares, some methodological problems exist in this process. One of them is the problem of which the calculated viewshed is different from the actual area or location can be seen by the observer (van Leusen, 1999). What causes this problem is that the viewsheds are created as if the landscape was flat, so the tree or vegetation factor is out of consideration (Ebert, 2004). In order to handle this problem and to model the tree height in the study area, the observer height can be raised or lowered (Maschner, 1996 ; Wheatly, 1996). Another problem in viewshed analysis is the decrease of visual acuity as the distance increases (Wheatly, 1996). In order to overcome this problem, a more complex form known as “fuzzy viewsheds” can be used, which introduce a possibly visible areas by using a distance decay function (Maschner, 1996). As Ogburn (2006) states, the fuzzy viewshed method is based on the fact that an object can be seen in different clarity degrees by the same observer under various conditions or by different observers under the same conditions.

From the first years to present, GIS use in archaeology is increasingly developed and perspective of GIS application in this discipline changed from just creating a database or simple mapping to performing complex analyses.

2.4. Previous Geoarchaeological Investigations in Hattusha

In Hattusha, there is not any detailed geoarchaeological study in the previous excavation periods. Ozulu (2005) studied the archaeological sites in Çorum province by using remote sensing and GIS techniques and Emre (1993) studied the Hittite dams.

Ozulu (2005), carried out change detection analyses using aerial photographs for the period between 1977 and 1990. Considering the changes and comparing them with present-day situation of the area, he suggested to make excavations in some parts of Hattusha. Moreover, he compared the archaeological sites and randomly selected points with respect to their slope, aspect values and their distance to rivers. Accordingly, he found that there is a consistency between almost half of the randomly selected points and the archaeological sites. By using statistical analyses, he stated that there is a relation between the potential of being an archaeological site and the distance to rivers.

Emre (1993) discussed the ancient dams from the Hittite period in Anatolia. The dams he discussed are Karakuyu, Gölpınar, Köylütolu, Eflatun Pınar, Boğazköy and Yalburt with respect to their historical and geological properties.

CHAPTER 3

CHARACTERIZATION OF TOPOGRAPHY

This chapter explains major properties of the topographic data and its derivatives used in the study. The chapter is divided into three sections: In the first section, the regional study area will be described with respect to the topographic data at 1/25.000 scale and elevation, slope and aspect properties of regional and local area will be compared. The regional area covers four topographic sheets obtained from General Command of Mapping (Turkey). In the second section, topographic data and its derivatives of the local study area which is bordered by the city wall at 1/1000 scale will be introduced. In the third section, the city components (city wall and main building complexes) will be introduced. In addition, the main building complexes will be investigated with respect to their morphological parameters (elevation, slope and aspect) together with those of the local area.

3.1. Regional Study Area

Topographic data for the regional study area is obtained from General Command of Mapping (GCM) both in digital and analogue format that possesses topographic contours at 10 m interval. Four topographic maps (H33-d1, d2 and I33-a1, a2) are selected so that Hattusha is almost at the centre (Figure 3.1). Digital data are already registered by the GCM and could directly be used. The analogue maps on the other hand are registered using the Universal Transverse Mercator (UTM ED-50, Zone 36) coordinate system. During this process, each topographic map is first registered using four ground control points selected from four corners with an error of one pixel or less. Four sheets are then merged to get a continuous data layer.

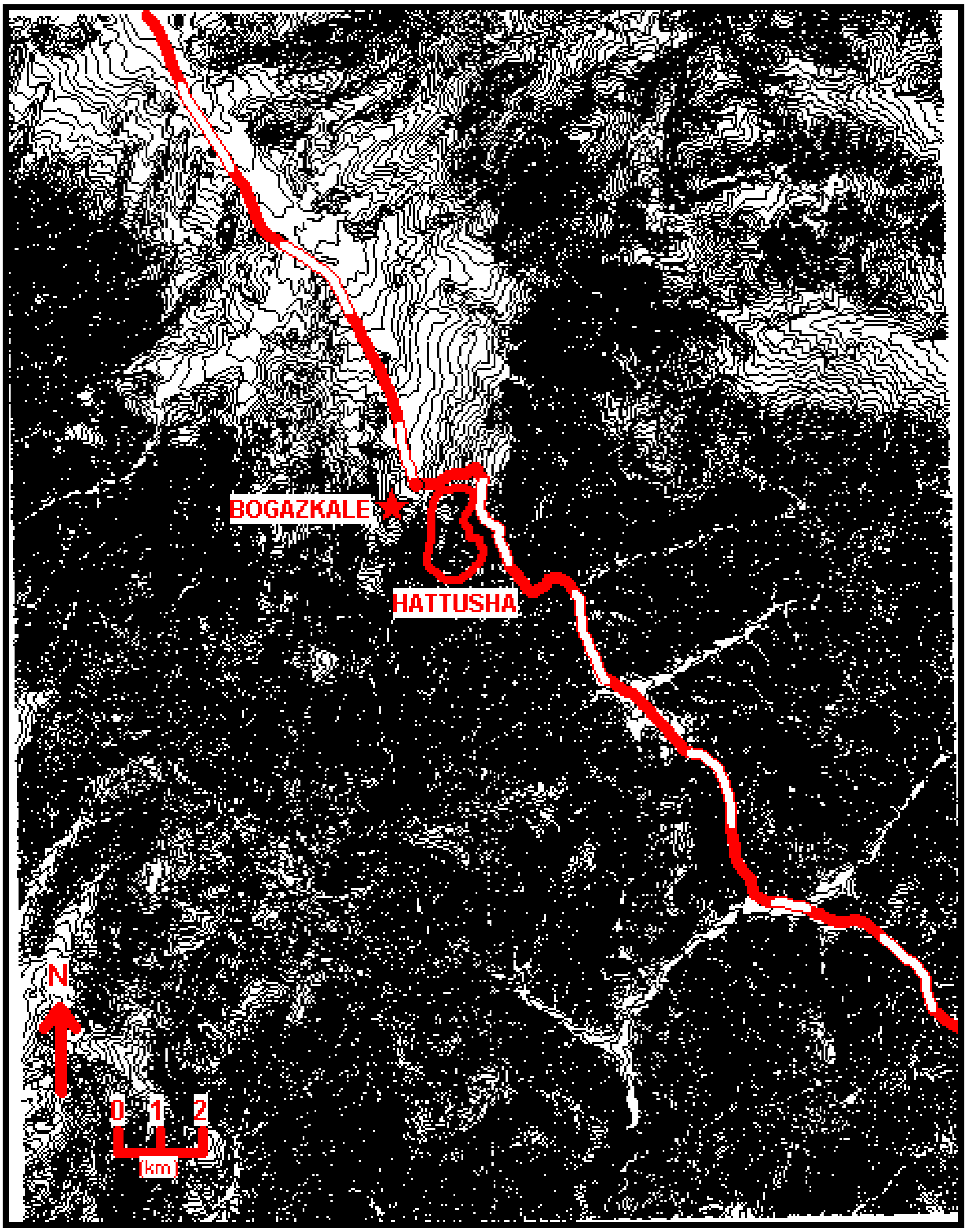


Figure 3.1 Contour map of regional study area obtained from General Command of Mapping. The area is covered by topographic sheets H33-d1, d2, I33-a1, a2. Note that contour interval is 10 m.

Digital data is used for morphological analysis; the analog data on the other hand is used for extracting certain information (such as drainage) that does not exist in the digital one.

The first step in the preparation of the data is the generation of Digital Elevation Model (DEM). This DEM is used for extraction of elevation, slope and aspect maps as explained below. The DEM and its derivatives in this study are prepared using MapInfo Professional software. First the “contours” are converted to “points” to generate a base data for further processes. Then “triangulation with smoothing” operation is used in the interpolation that creates a triangular mesh by using the point data. The cell values in the triangle are calculated based on the three data points making that triangle (MapInfo Professional Tutorial, 2001).

Size of the raster cell in the final DEM is 25 by 25 m. Although this size can be adjusted by the user for smaller and larger values, it is decided that 25 m is the optimum value for 1/25000 scale maps because 25 m will correspond to 1 mm on the map. A larger cell size will reduce the resolution and might miss some topographic detail. A smaller cell size, on the other hand, produces extra detail and increases the volume of data to be processed. Accordingly, the resultant maps have 880 columns and 1131 rows.

3.1.1. Elevation Map

The first product of the DEM is the elevation map as shown in Figure 3.2. Elevation ranges from blue (low values) to red (high values). The area is characterized by a topographic ridge that extends almost in E-W direction, south of Hattusha. Therefore the lowest elevations of the area are observed in the northern and southern parts. The solid black line is the drainage divide that defines the boundary of streams (blue lines) flowing towards north and south. The red polygon shows the local study area corresponding to the outer city wall of the ancient city Hattusha. The city is located at the foot of the slope facing north.

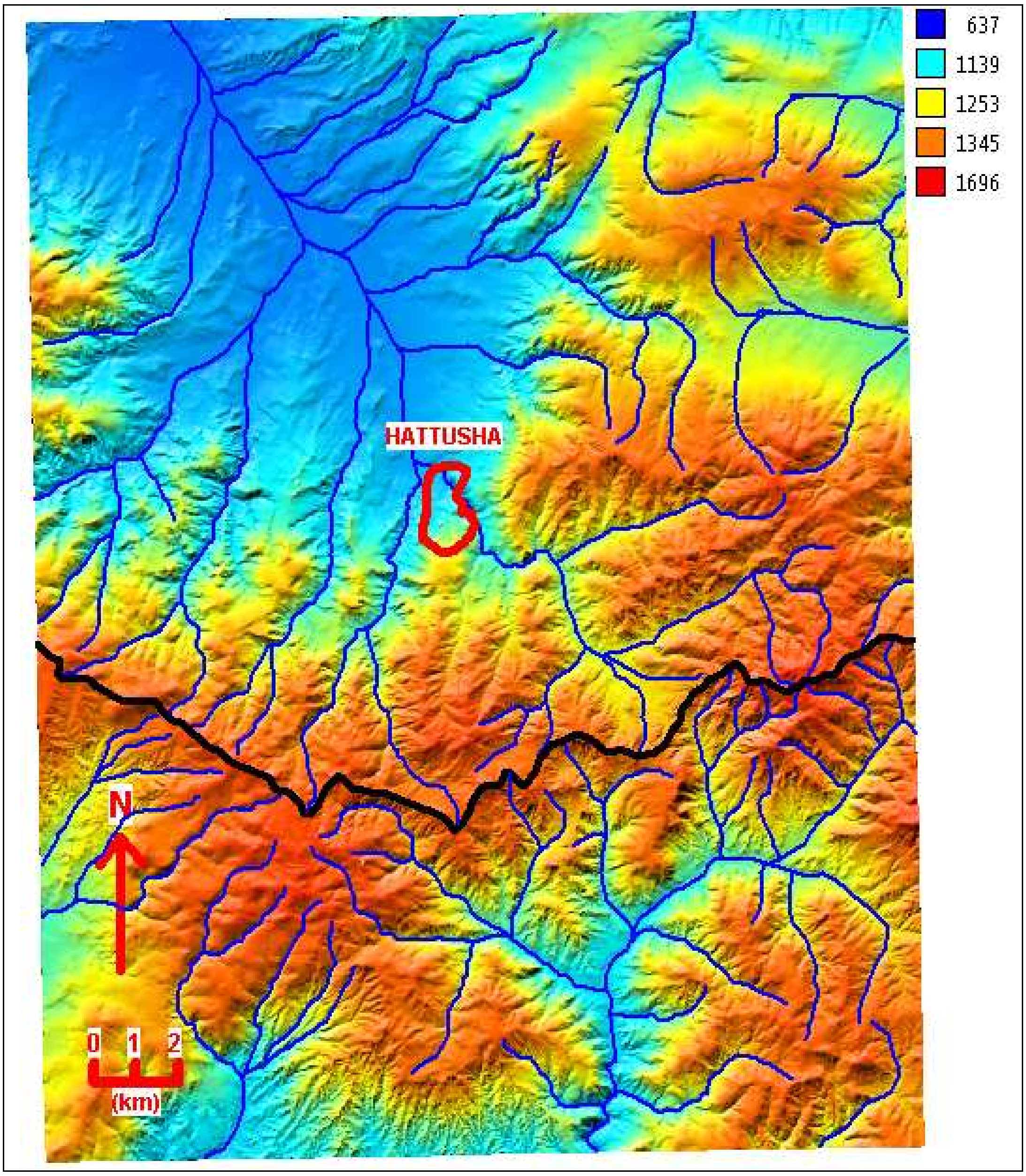


Figure 3.2 Colour coded elevation map of regional study area prepared from 1/25000 scale topographic map. Black line is the drainage divide of northern and southern basins. Blue lines are streams.

The minimum and the maximum elevations of the area are approximately 638 m and 1697 m, respectively. A histogram is prepared from elevation map for 50 m interval in the range of 600 and 1700 m (Figure 3.3.). Accordingly, elevations from 1150 to 1450 m cover almost 70% of the area. The maximum percentage with 14 % is observed at the interval of 1250-1300 m and the average elevation of the total area is 1230 m.

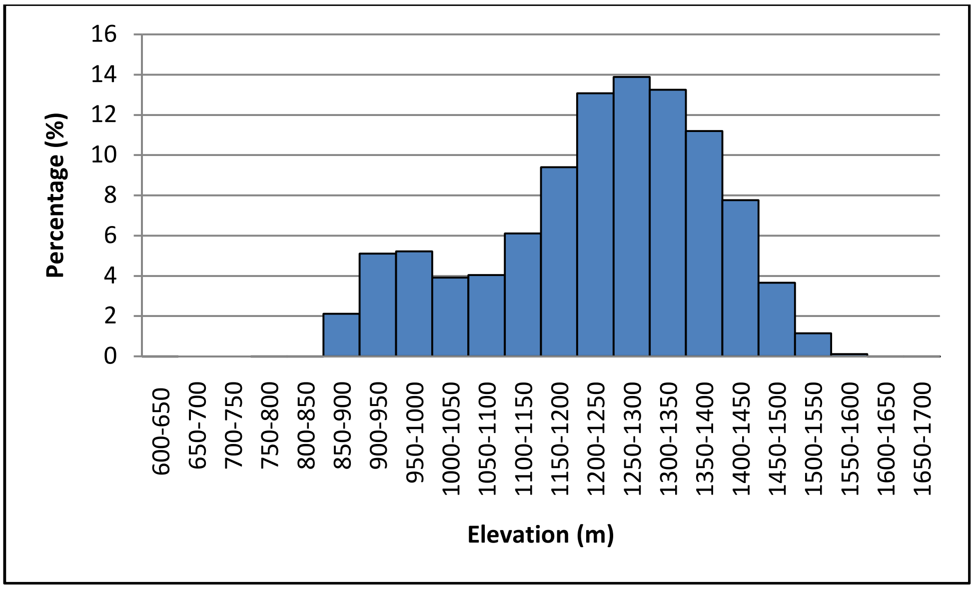


Figure 3.3 Histogram of the elevation map of regional area.

Hattusha covers only a small portion of the regional study area. To be able to make a comparison of the topographic properties of Hattusha in relation to its environs, the boundary of the city (based on the city wall) is clipped out and similar maps and histograms are generated for this subset.

Colour coded elevation map and its histogram are illustrated in Figures 3.4 and 3.5, respectively. Since the colours are recoded, the colour pattern looks different than the map in Figure 3.2. As seen in the histogram the city is located only a certain range of the elevation. The minimum elevation is 999m, while the maximum elevation is 1284 m approximately. The pixels within the two dominant intervals in the histogram (1100-1150 and 1150-1200) cover almost 48% of the area.

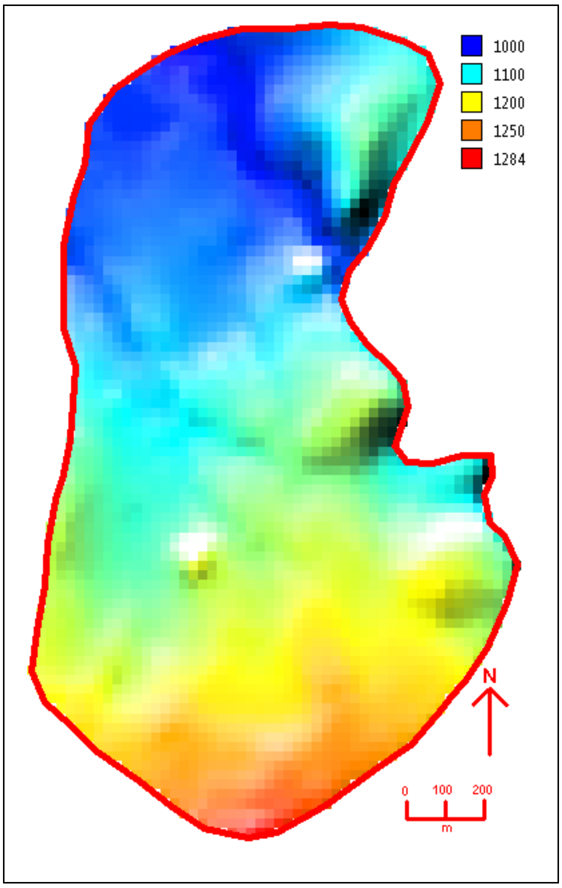


Figure 3.4 Colour coded elevation map of Hattusha prepared from 1/25000 scale topographic map. The boundary of the area is defined by the outer city wall shown as red line.

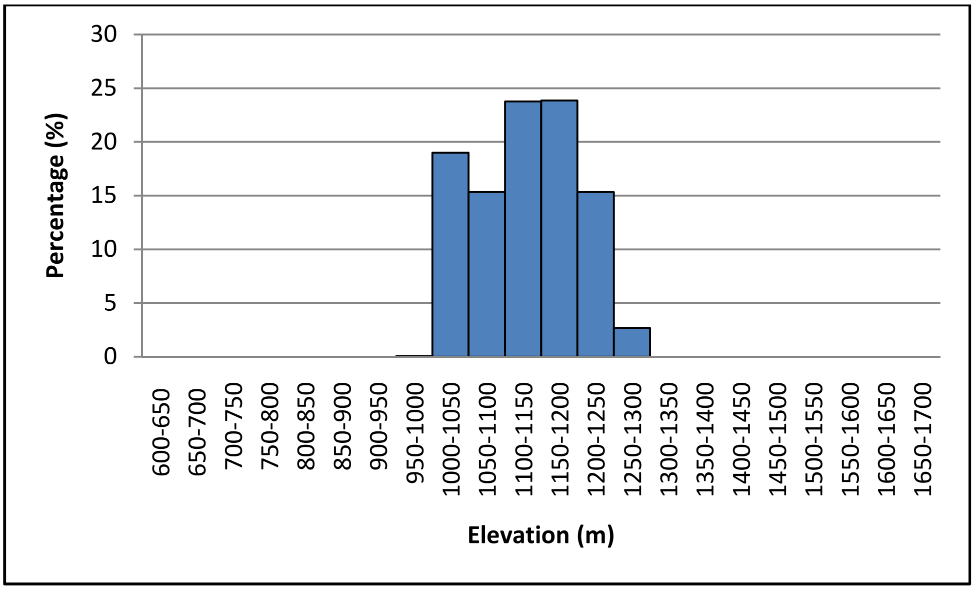


Figure 3.5 Histogram of the elevation map of Hattusha prepared from regional area.

The two histograms (Figure 3.3 and 3.5) of regional and local study area are subtracted from each other in order to comment on the elevation of Hattusha. In the resultant histogram (Figure 3.6); negative, positive and zero values are obtained. Positive values indicate that the percentage of the elevation values of the local area is greater than the percentage of the regional area for this particular interval. In this condition, it can be claimed that people chose this elevation to settle on purpose. However, the negative values in the resultant histogram suggest that the elevations in that interval are not preferred to settle. Finally, the zero values indicate that percentages of elevation values for both regional and local areas are equal.

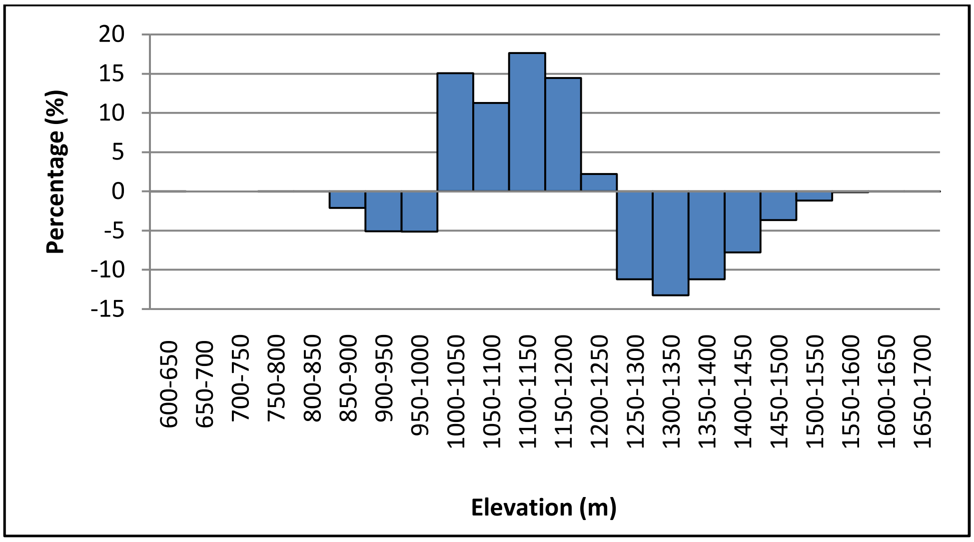


Figure 3.6 Subtracted histograms of regional and local area for elevation

According to the resultant histogram in Figure 3.6, it can be clearly seen that the interval of 1000 to 1250 m has a positive value of 60%. On the other hand, negative values occur in two intervals which are 850-1000 m and 1250-1550 m. The values of these intervals are 12% and 46% respectively. For the other intervals, the values are too small, so they can be neglected. As a result, histogram suggests that the interval of 1000-1250 m is preferred to settle. On the other hand, elevations between 850-1000 m and 1250-1550 m are mostly avoided.

3.1.2. Slope Map

Slope is defined as the surface inclination at any point, therefore is a measure of the “steepness” of the surface. Theoretically, the slope value ranges from 0 to 90 degrees. Because it applies to grid geometry here, slope is a measurement of the steepness of a grid cell in three dimensional space. Colour coded slope map of the regional area is shown in Figure 3.7. Six colours used in the map correspond to yellow (0 degree), cyan (0 to 2 degrees), green (2 to 5 degrees), blue (5 to 10 degrees), red (10 to 25 degrees) and black (> 25 degrees). Area covered by these colours depends on the percentile of that specific interval.

As seen in the slope map flat areas (zero degree) are confined to flood plains mostly observed in the northern parts of the area. The steepest slopes, on the other hand, are observed as elongated features that represent ridges oriented in various directions. Hattusha is located almost at the transition from cyan to blue to red suggesting that the northern parts are characterized by gentle and the southern parts by relatively steep slopes.

The histogram of regional slope map is prepared for 1 degree interval (Figure 3.8). Slope amount changes from 0 to 84 degrees, however, percentage of the slope values greater than 34 degrees are negligible and therefore are not shown in the histogram. The histogram shows that the dominant concentration is between 1 and 15 degrees which covers almost 75 % of the pixels. The maximum slope values are observed at 7-8 degrees with percentages 5.5.

For Hattusha, the slope map is obtained by clipping out the boundary of city wall over the regional map (Figure 3.9). In this map, blue color shows gentle slopes whereas the yellow and orange colors represent the steeper slopes in the city. According to the histogram prepared from this map for 1 degree interval (Figure 3.10), slope amount is changing from 1 to 51 degree. The dominant concentration is within the interval of 6 to 15 degrees with 75%. There is no pixel with a slope value of zero in the city.

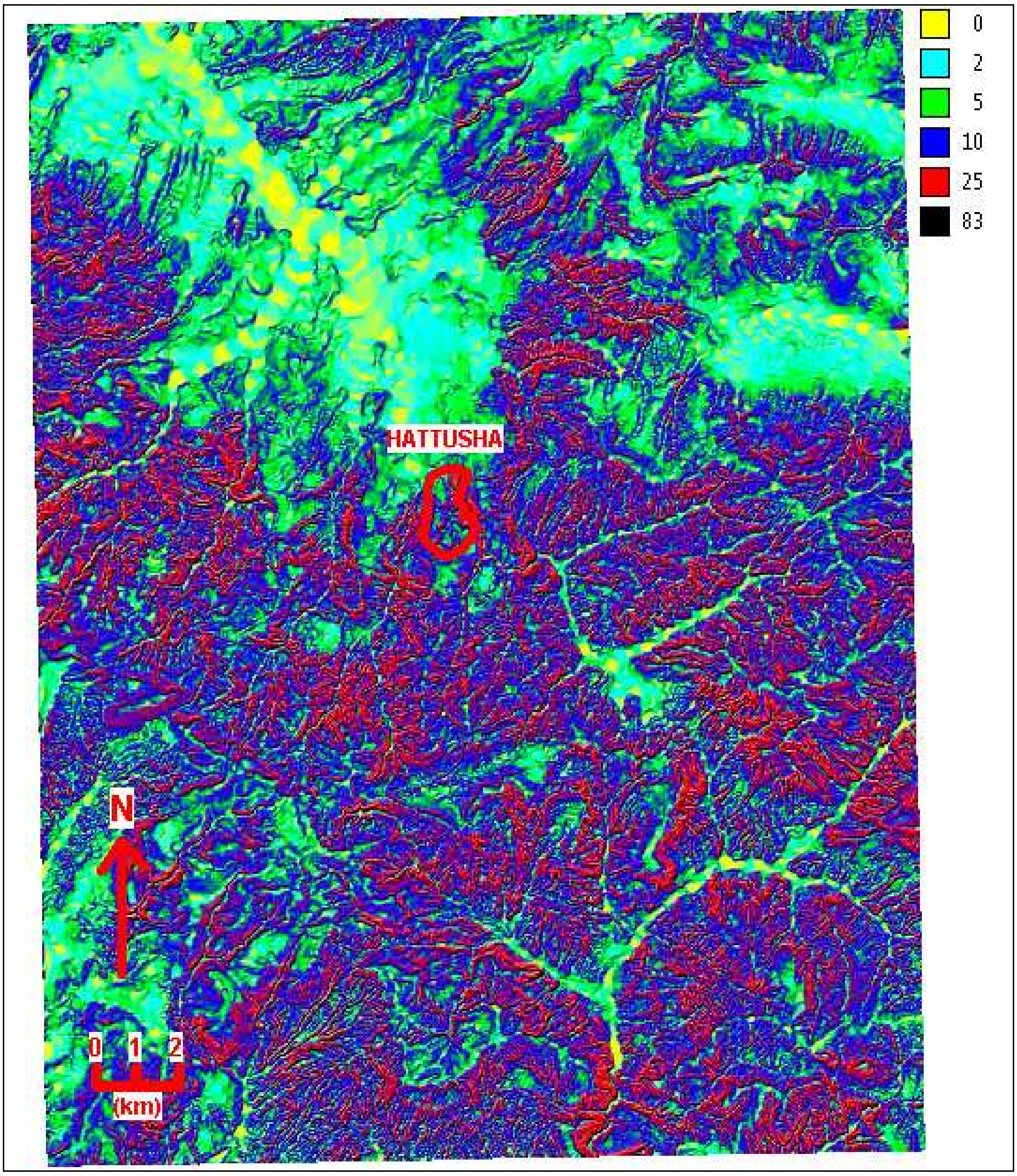


Figure 3.7 Colour coded slope map of regional study area prepared from 1/25000 scale topographic map. For the simplicity of map, the colours are adjusted only for four six intervals.

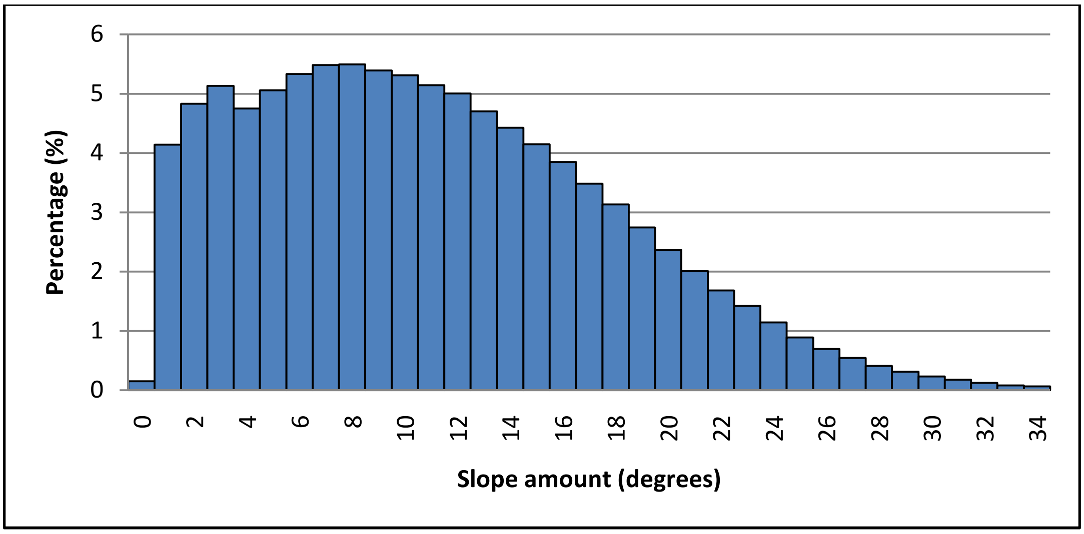


Figure 3.8 Histogram of the slope map of regional area.

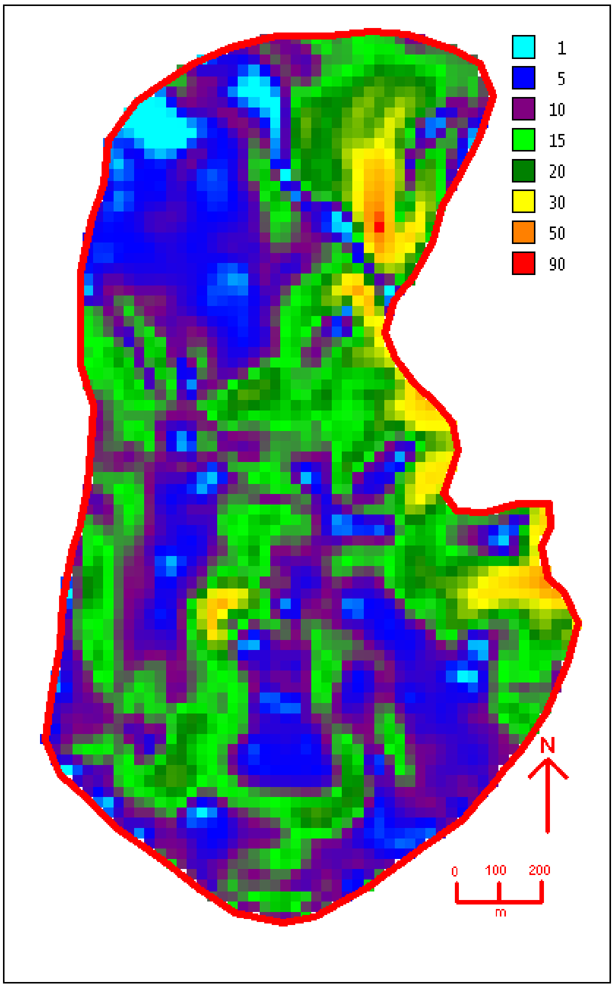


Figure 3.9 Colour coded slope map of Hattusha prepared from 1/25000 scale topographic map. The boundary of the area is defined by the outer city wall shown as red line.

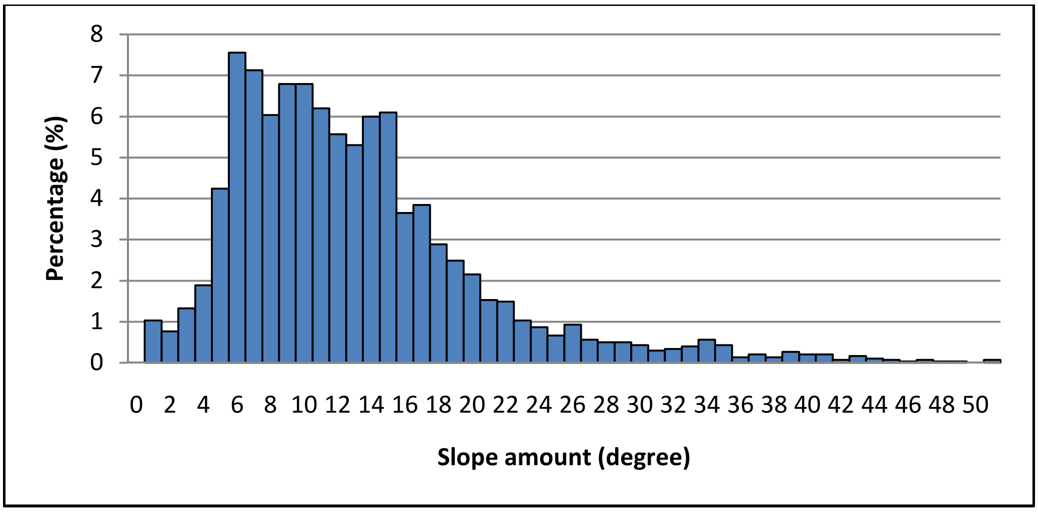


Figure 3.10 Histogram of the slope map of Hattusha prepared from the regional area.

For the comparison of slope data, a histogram is created again by subtraction of percentage values of local area from those of the regional one. The resultant histogram prepared for 1 degree intervals can be seen in Figure 3.11. As the percentages of pixels having slope amount above 51 degree is zero for both maps, histogram is prepared up to 51 degree and rest of it is neglected.

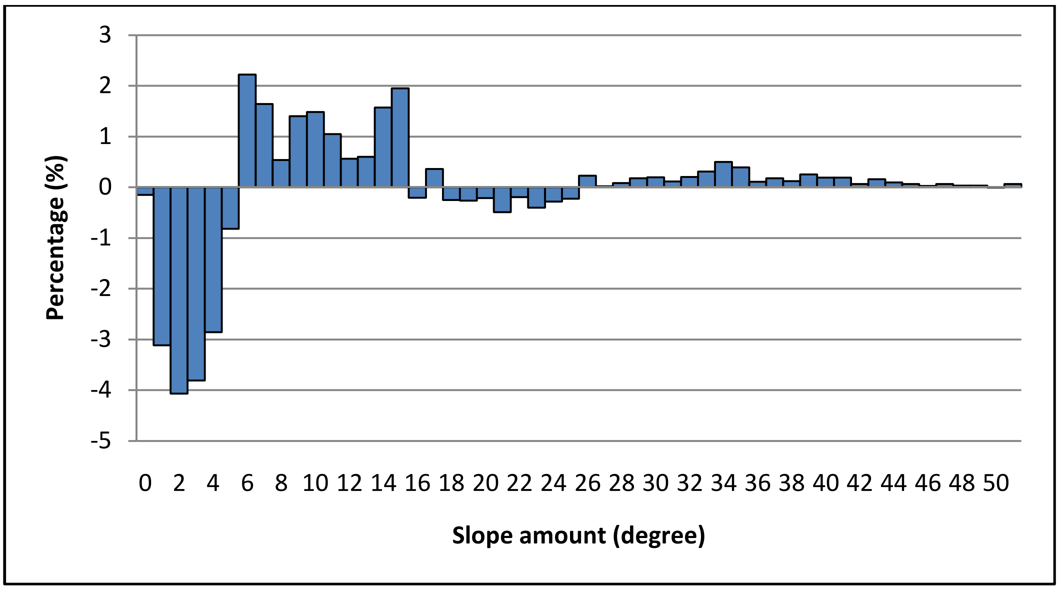


Figure 3.11 Subtracted histograms of regional and local area for slope

Positive values in the resultant histogram shows the areas where the slope values of local area are greater than those of regional one. In other words, it shows the dominant slope range where Hattusha city is settled. According to the histogram, slope values within a range of 0 to 5 degrees in regional area are much greater than the local one. In contrast, slope values between 6 and 15 degrees is more abundant in the local area. These values suggest that the low degree slopes especially from 6 to 15 degrees are mostly preferred to settle. On the other hand, lower slopes within a range of 0 to 5 degrees, which can be considered nearly flat areas, are avoided. For the values greater than 15 degrees, difference is not as significant as these two intervals.

3.1.3. Aspect Map

Aspect refers to the direction of slope in relation to north and ranges from 0 to 360 degrees. So the aspect map shows the orientation of the surface. Aspect map of the regional area is shown in Figure 3.12. In this map only four principal directions are shown as indicated by green (east), yellow (south), red (west) and cyan (north).

Two properties of the aspect map that should be kept in the mind are: 1) Slope values that have 0 degree are flat surfaces and should not have aspect values. These pixels are not shown in the map but will be discussed below, 2) while defining the principal directions the range is determined by plus and minus 45 degrees from that direction. Therefore, the direction east refers to the range of 045N - 135N, south to 135N - 225N, west to 225 – 315N and north to 315N – 045N. The sharp boundaries between the colours correspond to either ridges or valleys that define the change in the orientation of the surface. The histogram created from aspect map for 10-degree intervals is shown in Figure 3.13. The first interval, however, as indicated by “flat” represents the pixels having no aspect value. In this study the slope amount less than 2 degrees are assumed to be flat.

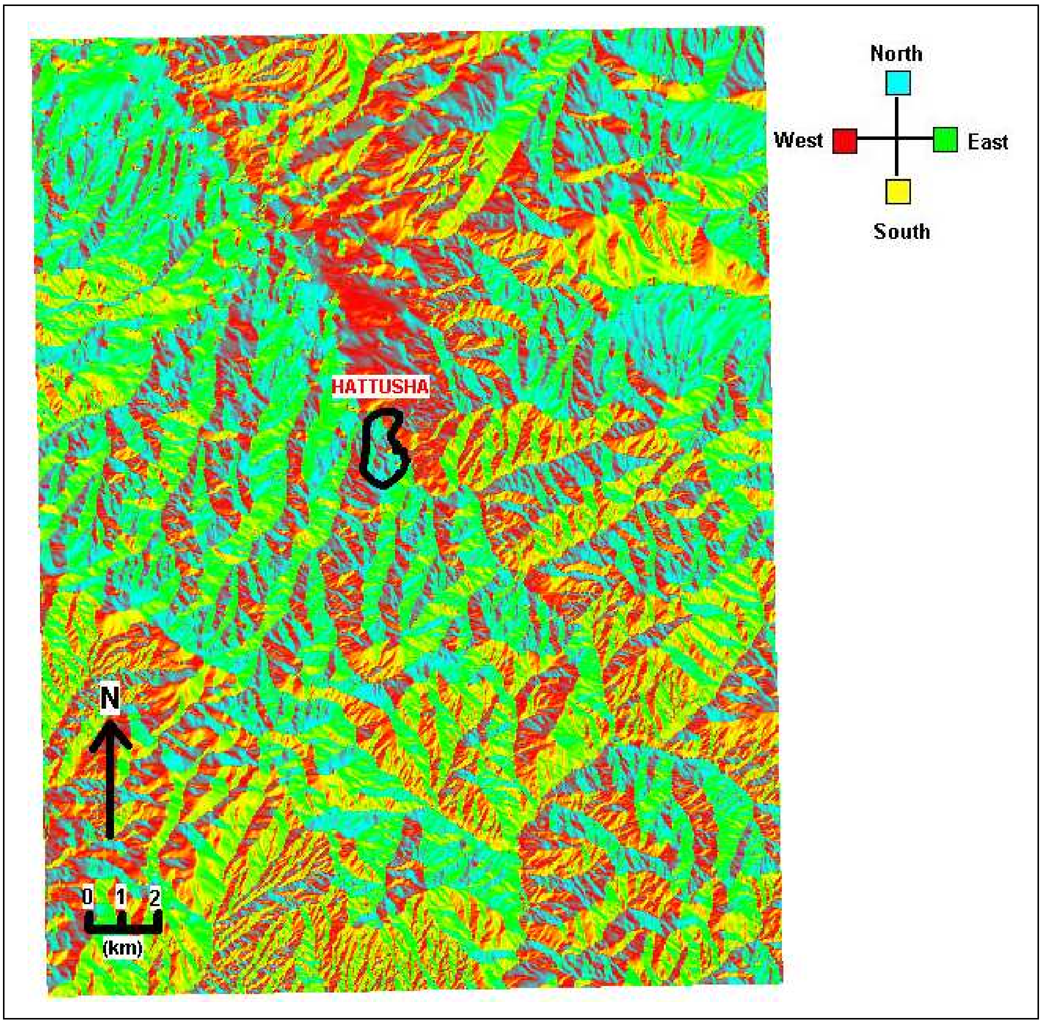


Figure 3.12 Colour coded aspect map of regional study area prepared from 1/25000 scale topographic map. For the simplicity of map, the colours are adjusted only for four principal directions.

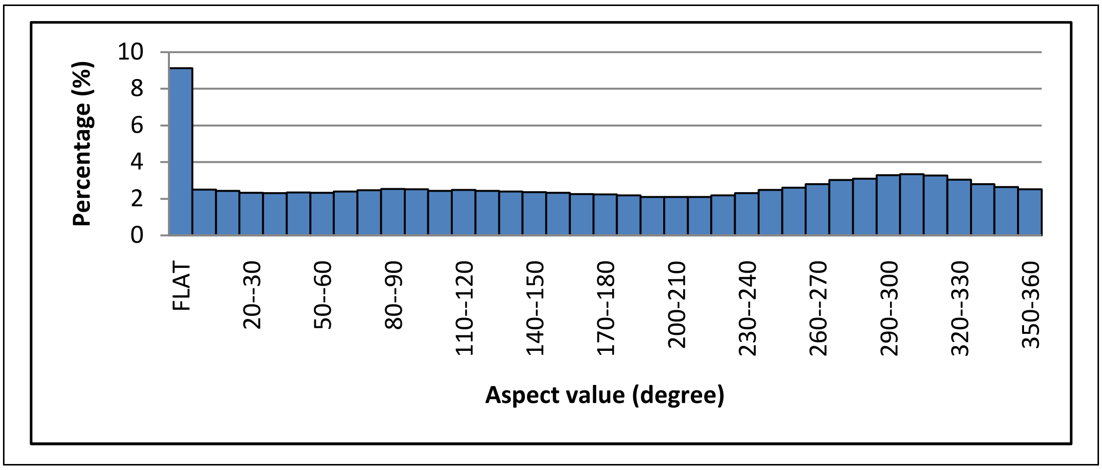


Figure 3.13 Histogram of the aspect map of regional area.

Flat areas in the region have the greatest percentage with 9%. The percentages of other directions have a range from 2.1 to 3.3. Especially the northwest facing slopes are dominant among these directions.

Aspect map of Hattusha is prepared by clipping out the boundary of the city over the regional map and shown in Figure 3.14. According to the histogram of aspect values with 10-meter interval (Figure 3.15), the dominant slope directions are north, northeast and northwest. Almost half of the pixels fall into the intervals of 0 to 40 together with 330 to 360. In contrast to the regional area, flat areas cover only 1.8% of the total pixels.

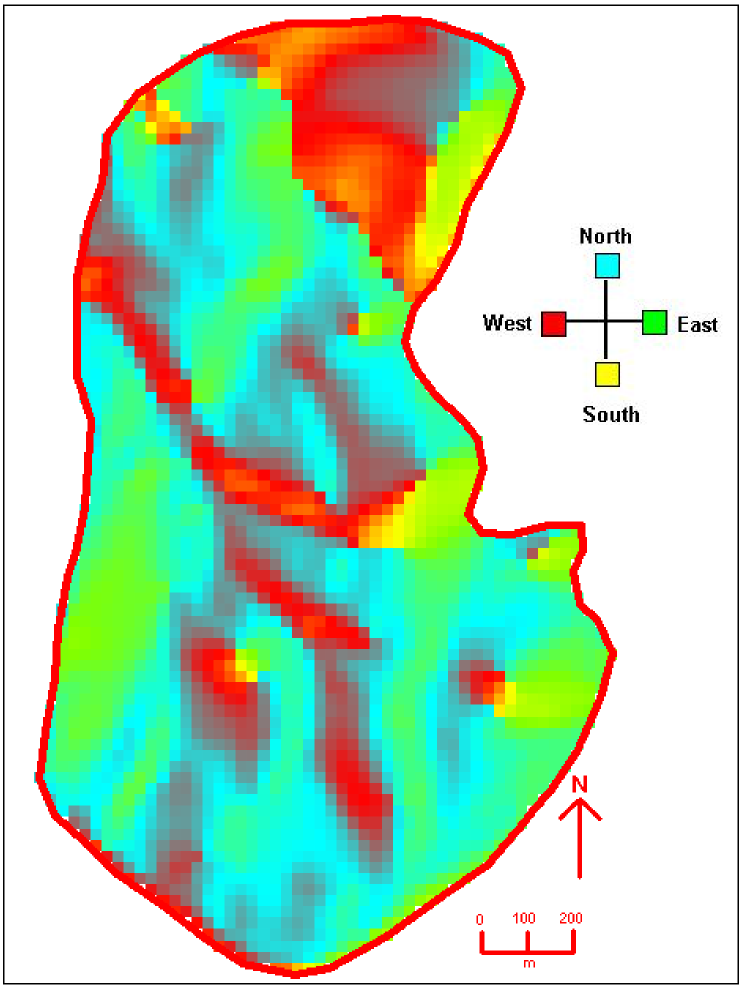


Figure 3.14 Colour coded aspect map of Hattusha prepared from 1/25000 scale topographic map. The boundary of the area is defined by the outer city wall shown as red line.

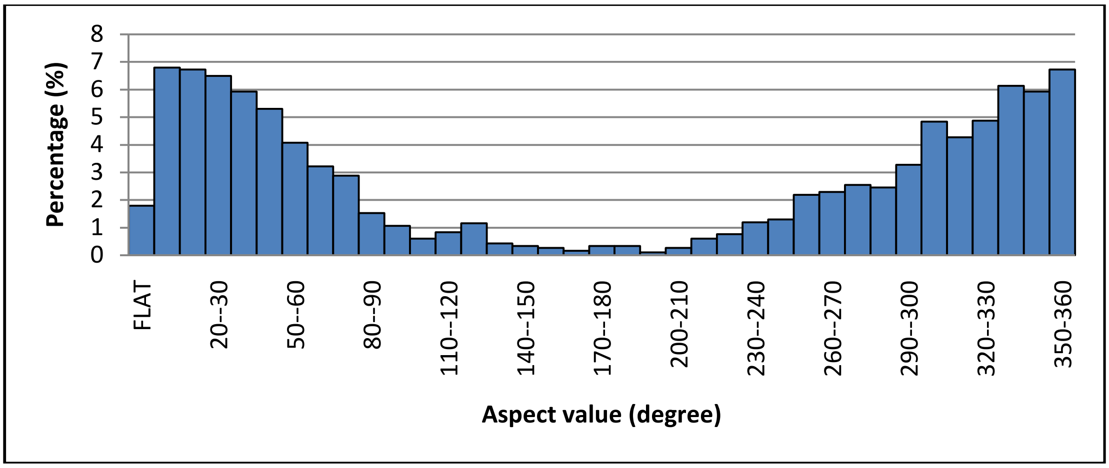


Figure 3.15 Histogram of the aspect map of Hattusha prepared from the regional area.

According to the subtracted histograms prepared for aspect values of regional and local study area, the dominant direction of slope in Hattusha city is North, Northeast and Northwest (Figure 3.16). Elevation map of the local area is also supporting this result as it shows a decreasing attribute in elevation values from North to South. However, percentages of aspect values for East, South and West directions are greater in regional area relative to the local one.

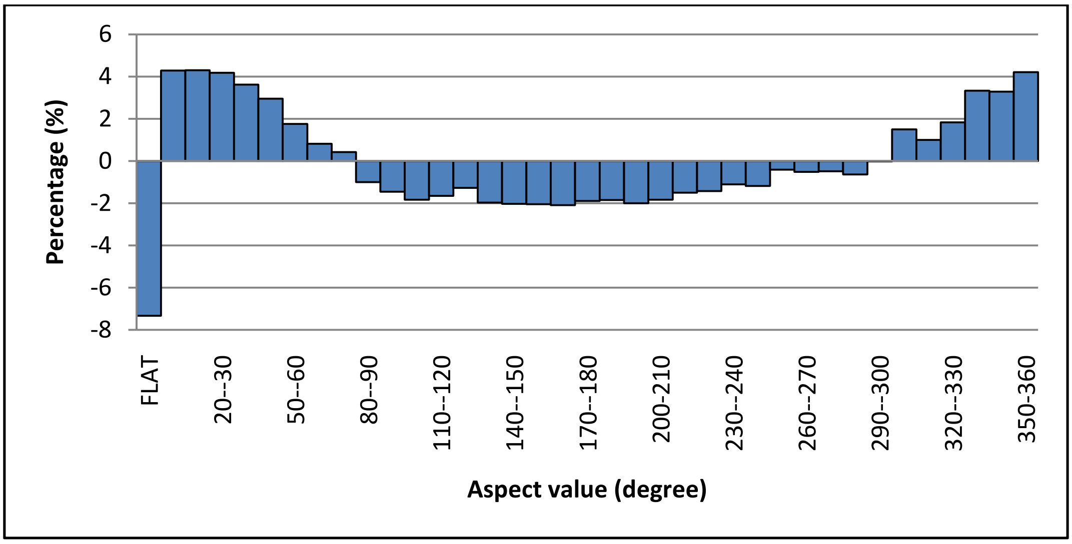


Figure 3.16 Subtracted histograms of regional and local area for aspect

Another significant value in the histogram is the difference in percentage of the flat areas where the slope amount is between 0 to 2 degree and the assigned aspect value is -1. As the histogram shows, ratio of the flat areas in regional area is much greater than the local area.

According to the resultant histogram, it can be claimed that north, northeast and northwest facing slopes are preferred for Hattusha city to settle. On the other hand, the other directions and flat landforms are avoided.

3.2. Local Study Area

Topographical data explained in the previous section is generated from 1/25000 scale. A second set of topographic data is available at more detail (scale approximately 1/1000) for the city. The boundary of this area, named as local study area here, is defined almost by the outer city wall of the Hattusha. This data is obtained from the Hattusha excavation team and is represented in Figure 3.17. Contour interval for this data is 1 m that enables for more detailed analysis.
Two basic differences of the regional and local topographic data are:

1) Regional data has UTM coordinates; however, the local data has a different (local) reference system;

2) Elevation values (z-values) are different in two data sets. It was estimated that the regional topographic elevations are about 40 m higher than the local ones.

Generation of the DEM for the local area is the same as the procedure applied for the regional one. The raster cell size for the local map is 1 m. Similar what is done for the regional data, for the local data elevation, slope and aspect maps are prepared. Details of these are given below.

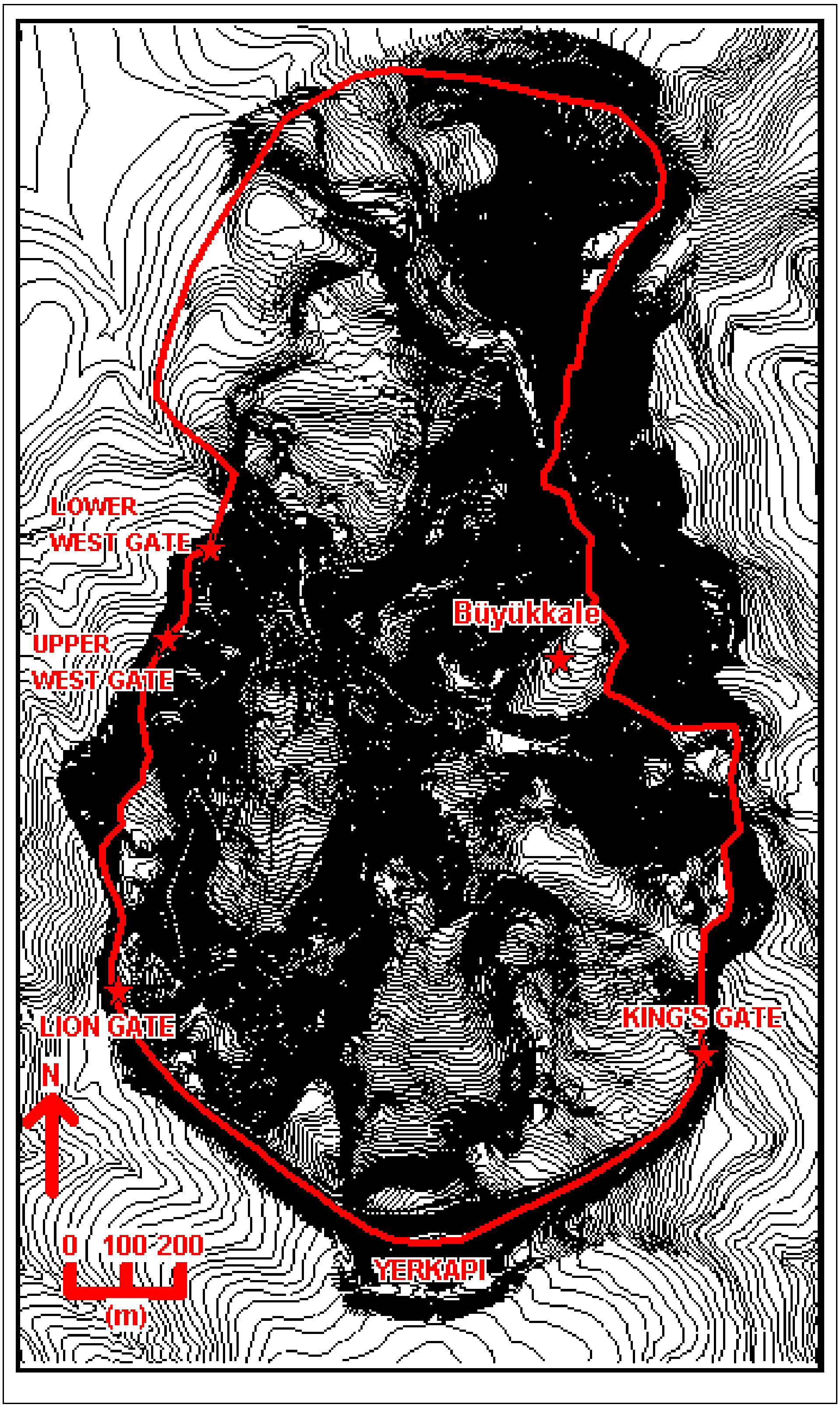


Figure 3.17 Contour map of local study area obtained from Hattusha excavation team. The red line represents the city outer wall which defines the boundary of the local study area.

3.2.1. Elevation Map

In order to investigate the morphology of the inner city, DEM of the local study area is created from Hattusha topographic map at 1-meter contour interval (Figure 3.18). TIN process is again utilized where the resolution is 1m (cell size is 1m). Elevation of the local area changes from approximately 943 to 1237 meters. The highest elevations are represented as red colour, while the lowest topography is in blue colour. Elevation is decreasing from the northern to southern part of the area, so the colour is changing from red to blue. The other morphological analyses including the visibility analyses, investigation of the city wall, analysis on water resources and comparison of city with the main building complexes are carried out by using the DEM of local area and they will be discussed in detail in following section and in Chapter 4.

3.2.2. Slope Map

Colour coded slope map of the local area is shown in Figure 3.19. Eight colours used in the map correspond to slope amounts. Area covered by these colours depends on the percentile of that specific interval.

According to the slope map, the steepest slopes are mostly observed in north-eastern and central parts of the city. However, the pixels having a gentle slope value (from 0 to 25 degrees) are dominant in the area.

3.2.3. Aspect Map

Aspect map of the local area is shown in Figure 3.20. The colours used for the representation of directions are the same with the aspect map of regional area. As the Figure 3.20 indicates, local area is characterized by north and west facing slopes.

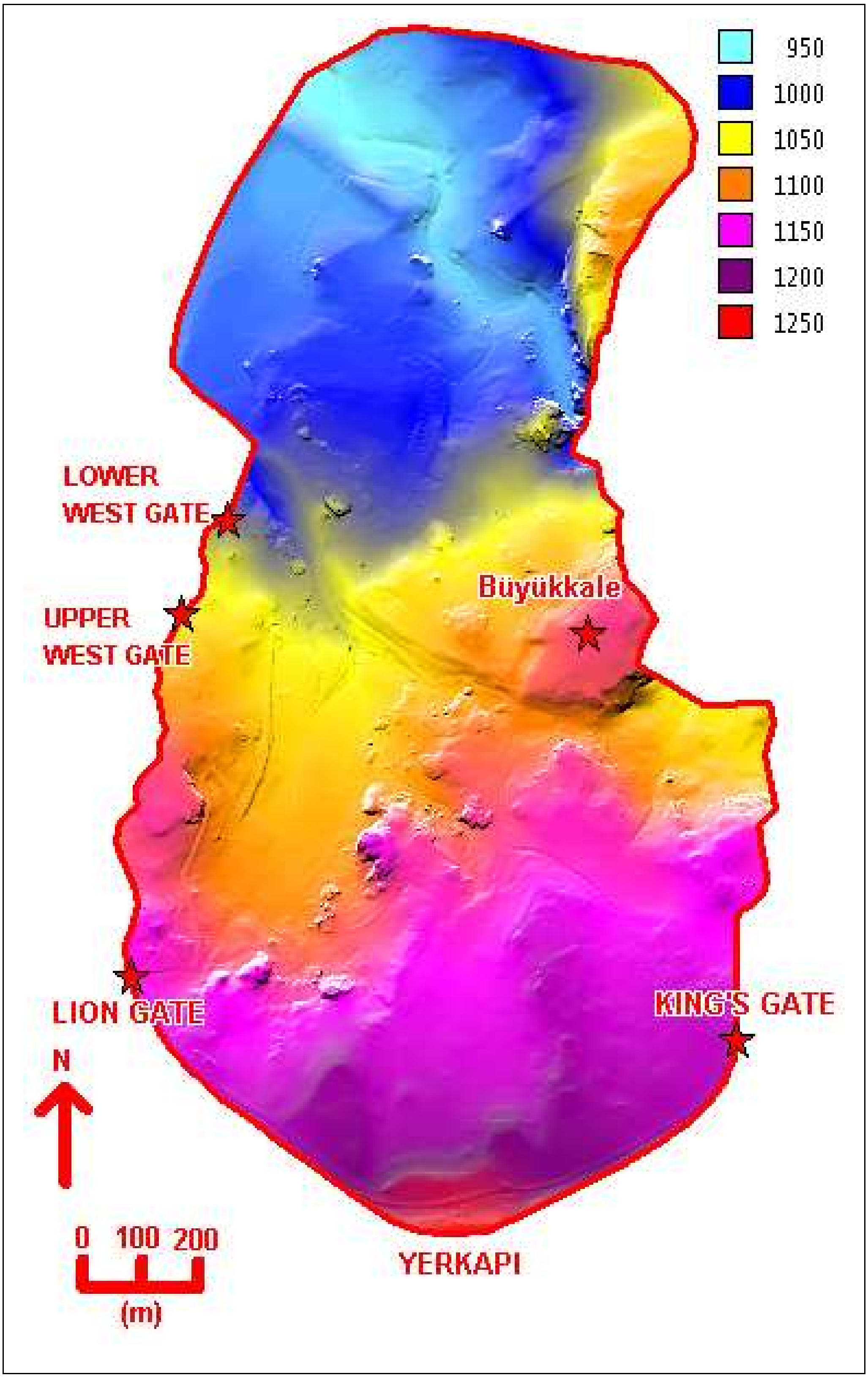


Figure 3.18 Colour coded elevation map of local study area prepared from 1/1000 scale topographic map. The red line represents the city outer wall which defines the boundary of the local study area.

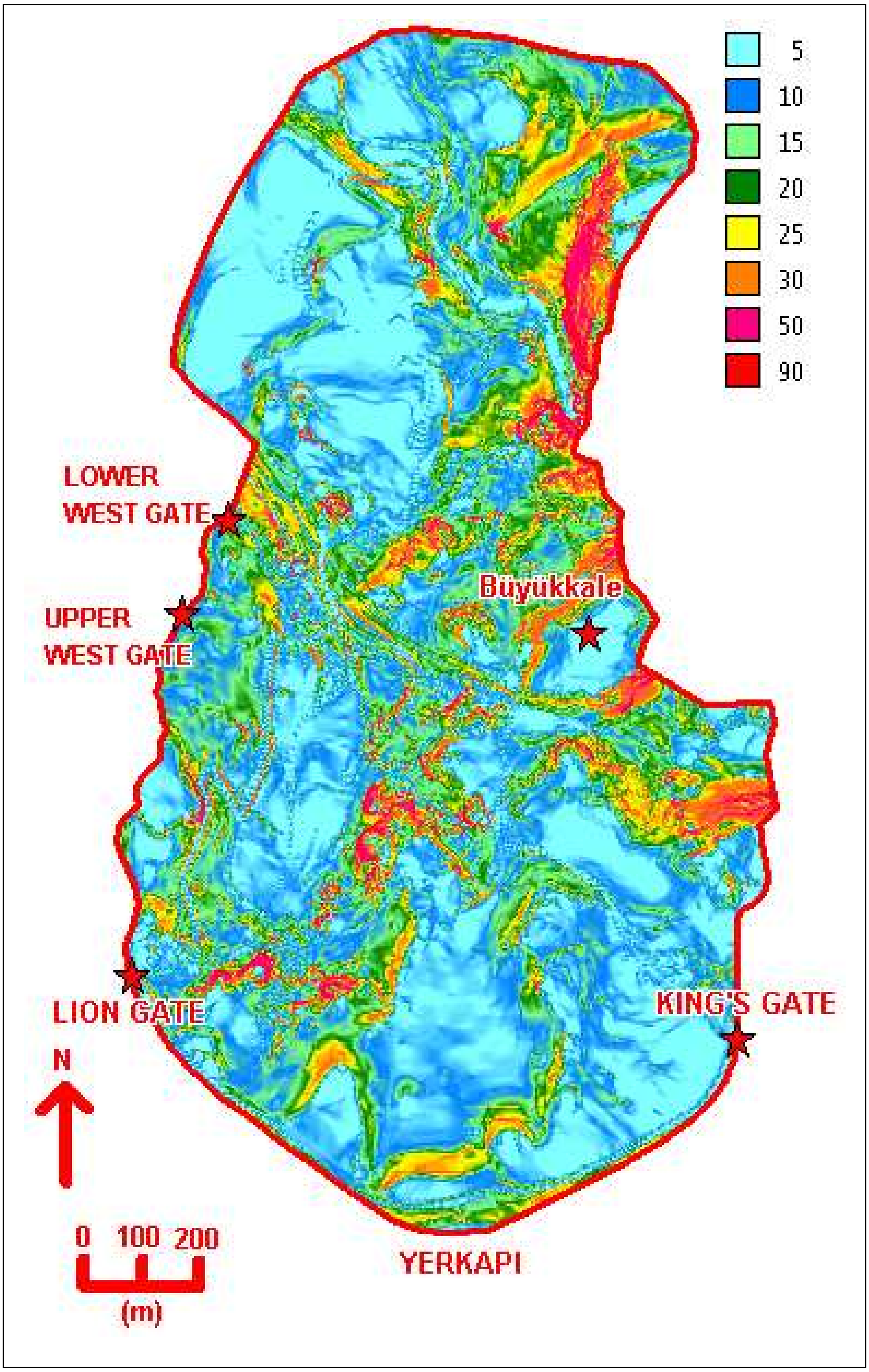


Figure 3.19 Colour coded slope map of local study area prepared from 1/1000 scale topographic map. The red line represents the city outer wall which defines the boundary of the local study area.

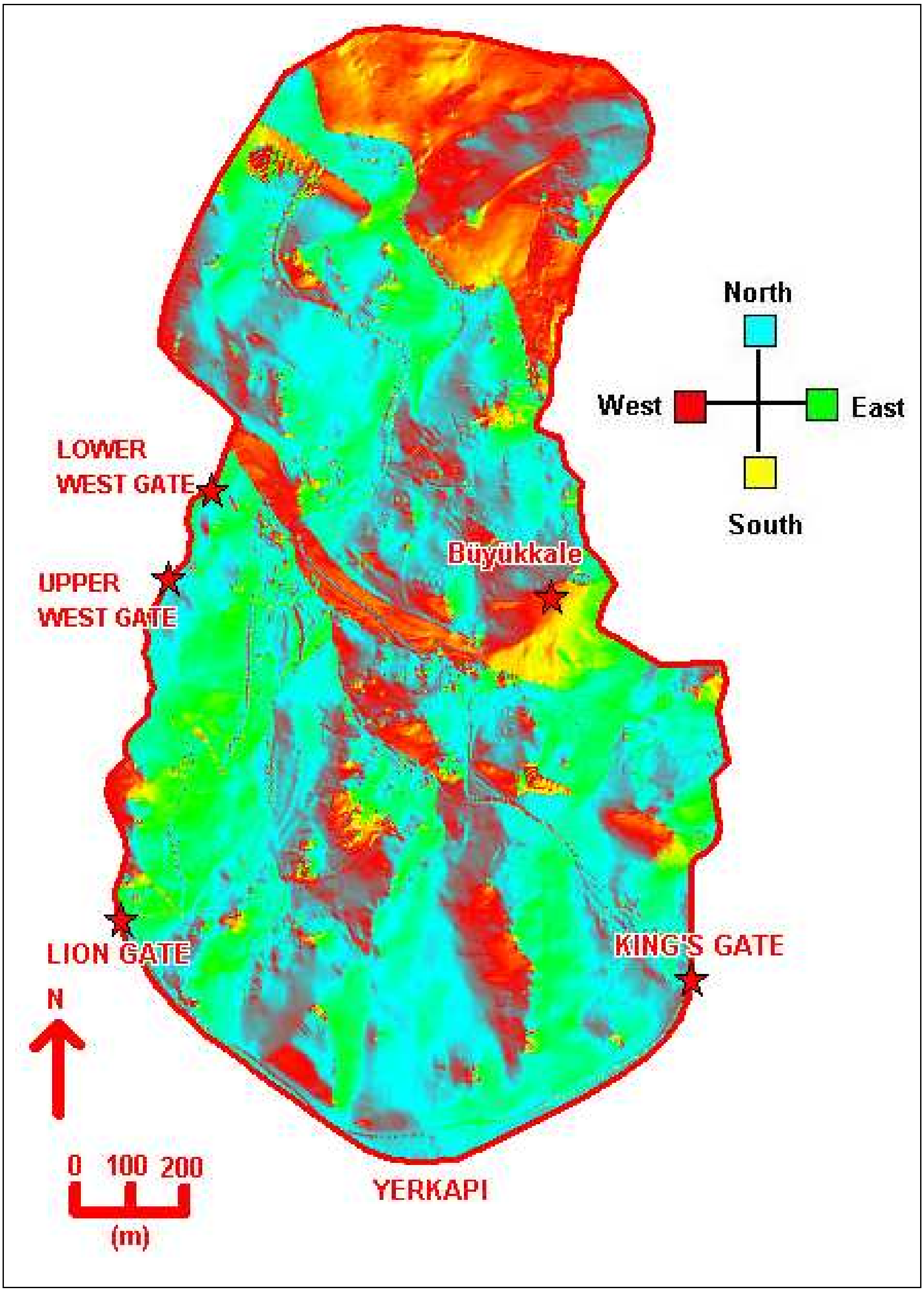


Figure 3.20 Colour coded aspect map of local study area prepared from 1/1000 scale topographic map. The red line represents the city outer wall which defines the boundary of the local study area.

3.3. City Components

The main components of the city used in this study are the city wall and the main building complexes.

3.3.1. City Wall

The Old Hittite city was protected by a massive fortification wall (Figure 3.21) and comprised an area of almost 1 square kilometer. There was a residence of the Great King on the high ridge of Büyükkale, and the city lay on the slope below to the northwest, reaching to the valley below. By the time of progress, the Upper City which is located at south of the Old City (Lower City) was included into the city limits through the construction of a new 3.3-km long defence wall consisting several gates. After this new city wall is built, the size of the city became 182 hectares. Within the wall, many houses and temples were built (http://www.hattuscha.de/English/cityhistory1.htm, accessed on 10 May 2009). At the northern part of the city wall, the three main gates exists namely King's Gate, Sphinx Gate (Yerkapı) and Lion Gate. The latest condition of the city wall together with the inner wall is shown in Figure 3.22.

Figure 3.21 SE segment of the city wall of Hattusha (from Yerkapı towards east)

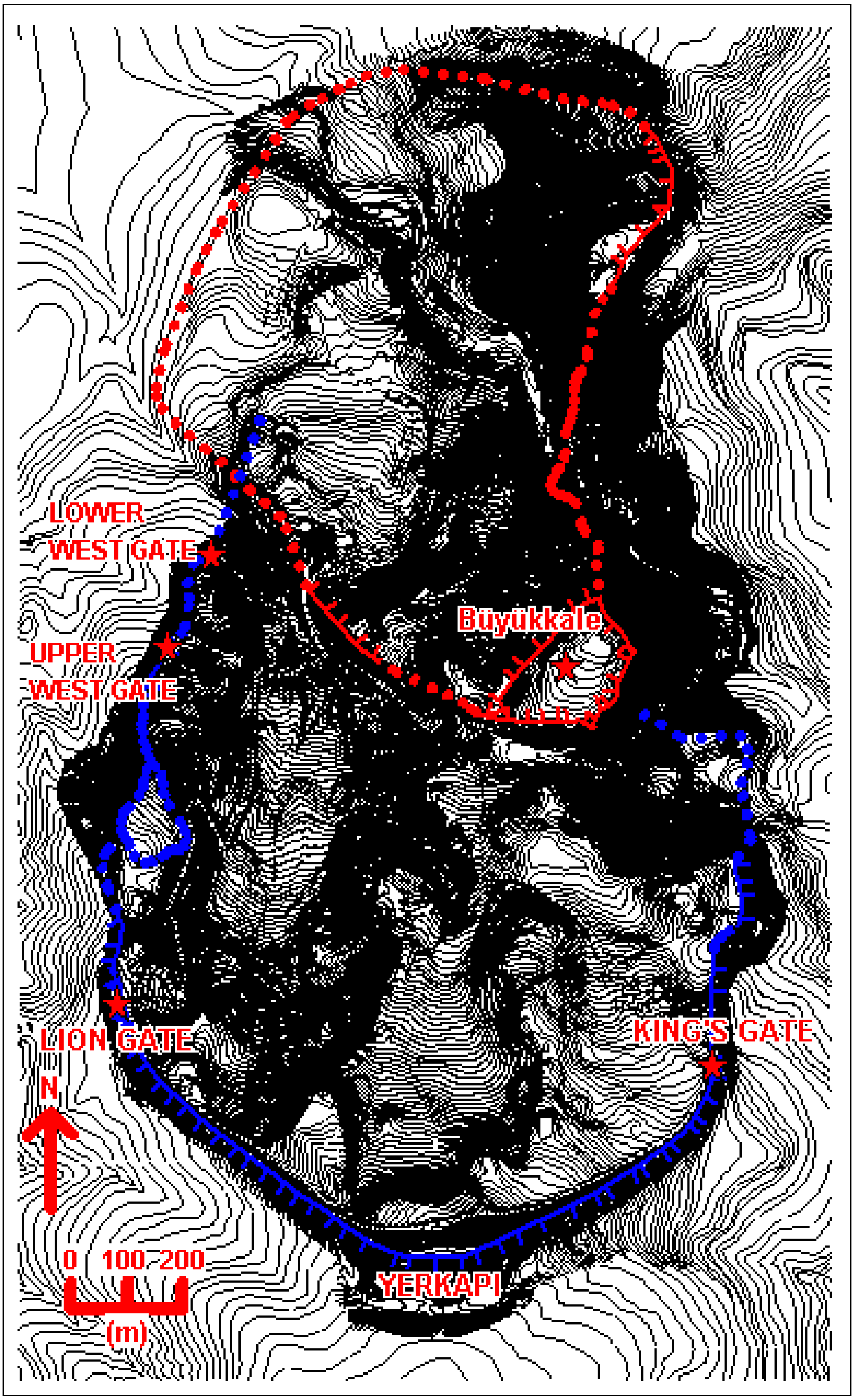


Figure 3.22 Topographic map of the area showing the oldest and latest condition of the city wall. Red line represents the older city wall while the blue one shows the extended wall after the city was enlarged. The wall is dotted where probably located.

3.3.2. The Main Building Complexes

Within the city wall of Hattusha, there are many temples and buildings. In order to investigate the intensity of the city components versus various elevation, slope and aspect values, three main building complexes are selected. These are; Büyükkale, Temple 1 (Great Temple), and the Temple district (Figure 3.23).

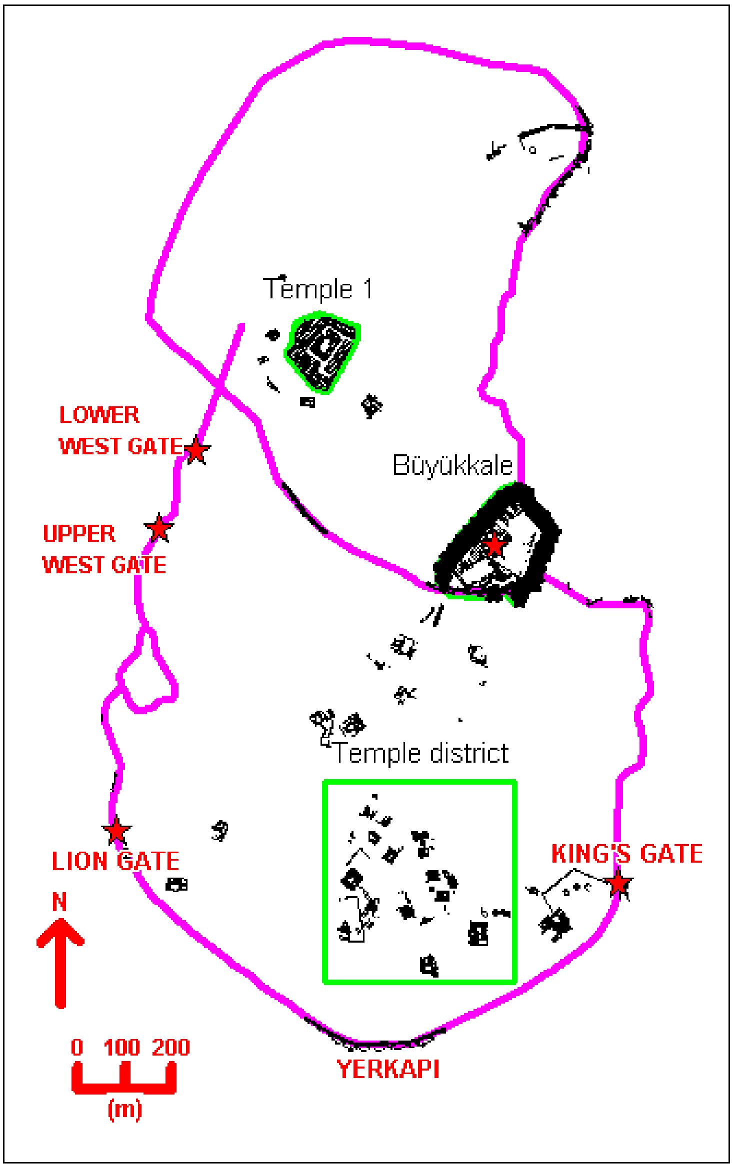


Figure 3.23 Three main building complexes (Büyükkale, Temple 1 and Temple District) within the city indicated by green colour boundaries. The purple line shows the inner and outer city wall.

Temple 1: The Temple 1, also known as The Great Temple is the largest building structure in the city with its area of approximately 14.500 m^2 (Figure 3.24). Although there is no dedicatory inscription, it is estimated to be built in the Empire Period (Seeher, 2005).

Figure 3.24 Temple 1 from North.

The Royal Citadel of Büyükkale: Büyükkale was a royal residence located on a plateau with a relatively flat surface with surrounding steep slopes. (Figure 3.25). It was inhabited as early 3rd millennium BC by people of the Early Bronze Age; after than the Hittites developed Büyükkale into a well fortified citadel in the 13th century (Seeher, 2005). The total area of Büyükkale is almost 40.000 m2 based on the polygonal area calculated in MapInfo Professional.

Figure 3.25 Royal citadel of Büyükkale

The Temple District: By the period of the Hittite Empire, after the erection of the great city wall, southern part, in other words the Upper City, grown into a cult centre with many temples. The outlines of almost all of the foundations in the hollow located just at the northern side of Yerkapı are Hittite temples and here is the temple district (Figure 3.26). The dimensions of temples vary greatly from 400 m^2 to 1500 m^2 (Seeher, 2005).

Figure 3.26 Temple district located in the Upper City

For the description of the morphological properties of temple district with those of local area, analyses are carried out not for each temple here, but for the whole area that the temples cover.

In order to comment on the morphological properties of these complexes in relation to the city's properties; elevation, slope and aspect maps and their histograms are created for each of them. Morphological layers will be represented as letters A), B) and C) for Temple 1, Temple district and Büyükkale respectively in the following figures.

Elevation

Elevation maps of the building complexes are shown in Figure 3.27. It should be noted that the elevation scales are different for different complexes. In the first two maps (Temple 1 and Temple District) the elevation gradually decreases from south to north. In the last map, however, for the Büyükkale complex, the colour pattern for the elevation suggests a hill elongated in NE-SW direction.

The composite histogram of these three elevation maps is given in Figure 3.28. Four items shown in this histogram are: the elevation of the local area (red bar) and three building complexes. According to the histogram, topography of the local area ranges from 943 to 1237 m and the percentages of the intervals are close to each other. In other words, the area is distributed over the whole region homogeneously. However, it can be seen that the three main regions are located on specific elevation intervals within the local area. Temple 1 covers only the interval of 980-1019 m, Büyükkale, where the royal citadel is built; falls in the interval of 1100-1139 m. And lastly, the Temple district exists at the highest elevation interval (1140-1219 m) relative to the other features.

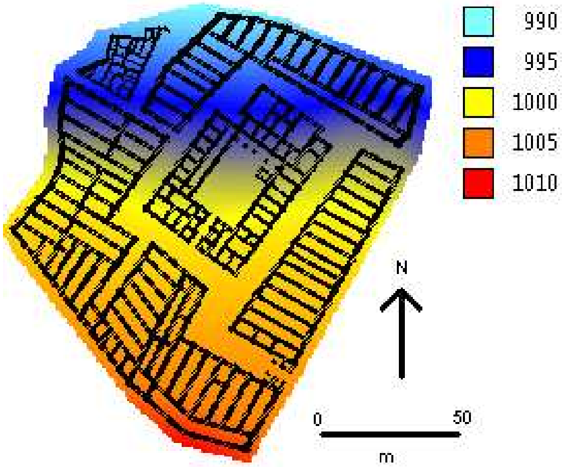
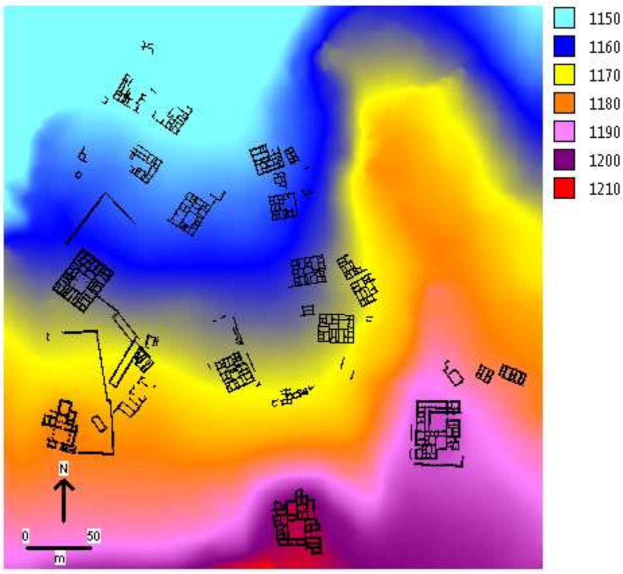
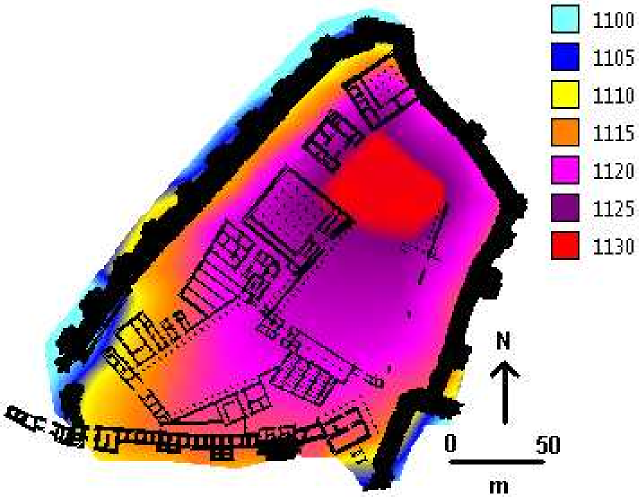
Temple 1	
Temple district	
Büyükkale	

Figure 3.27 Elevation maps of the selected regions together with the remains of the walls. For the elevation map of the local area see Figure 3.18.

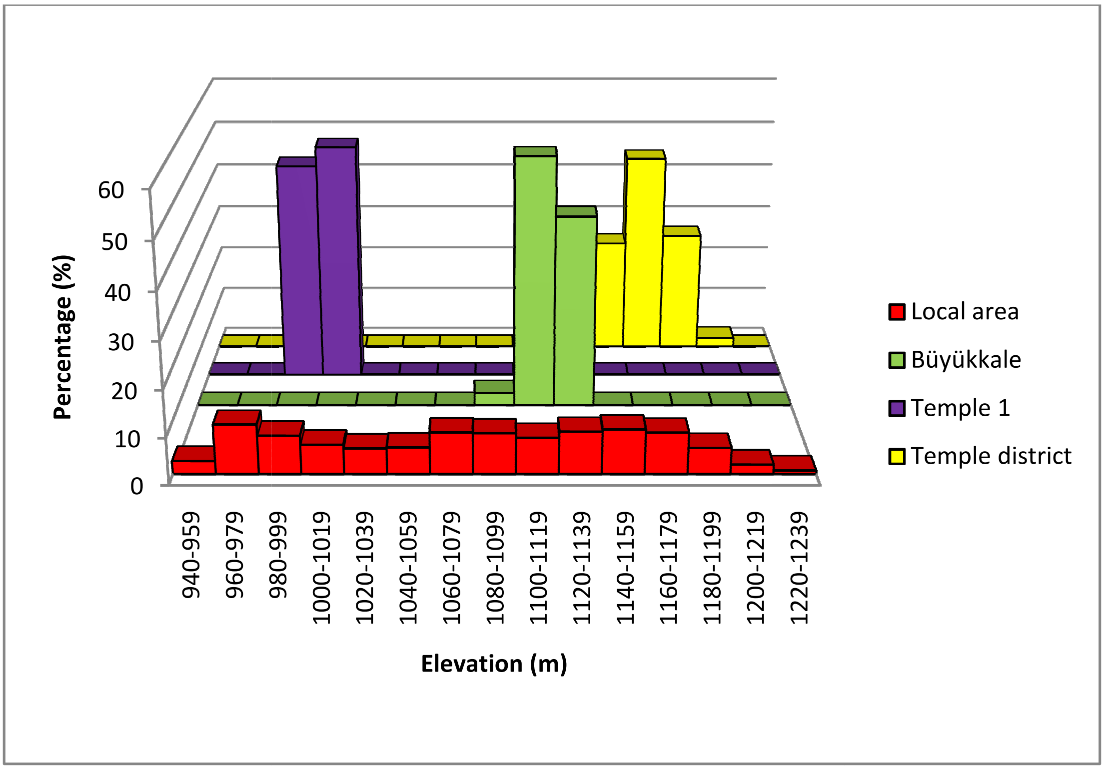


Figure 3.28 Elevation histograms of the selected regions together with the local area

Slope

Slope maps of the main building complexes are shown in Figure 3.29. As the histogram in Figure 3.30 shows, the local area has a wide range of slope value from zero to 65 degrees. It has the greatest percentage value of 6 degree with 7% and 75% of the pixels fall into the range of 4 to 21 degrees.

For Büyükkale, slope values change from 0 to 38 degree according to the histogram. 64% of them is between the degrees of 3 and 15 where the greatest value occurs at 4 degrees with 9%.

The slope values in the region of Temple 1 are confined to a narrow interval relative to the other regions. The values change from 2 to 10 degyees where the maximum percentage occurs at 4 degrees with 25%.

Within the temple district region, the pixels having slope value from 4 to 14 degrees cover almost 80% of the area. Pixels with slope of 6 degree have the greatest percentage with 15%.

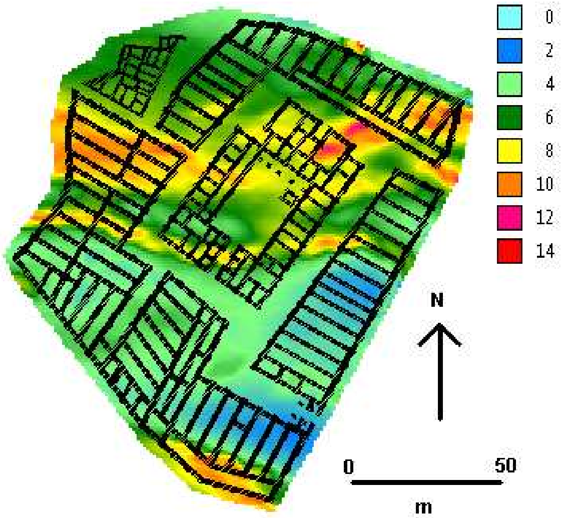
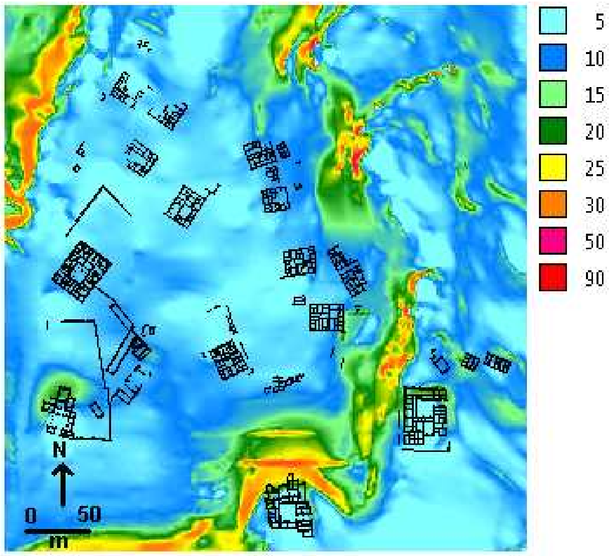
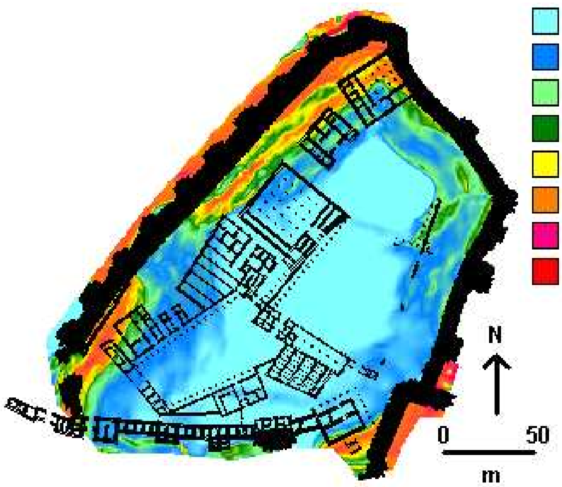
A) Temple 1	
B) Temple district	
C) Büyükkale	

Figure 3.29 Slope maps of the selected regions together with the remains of the walls. For the slope map of the local area see Figure 3.19.

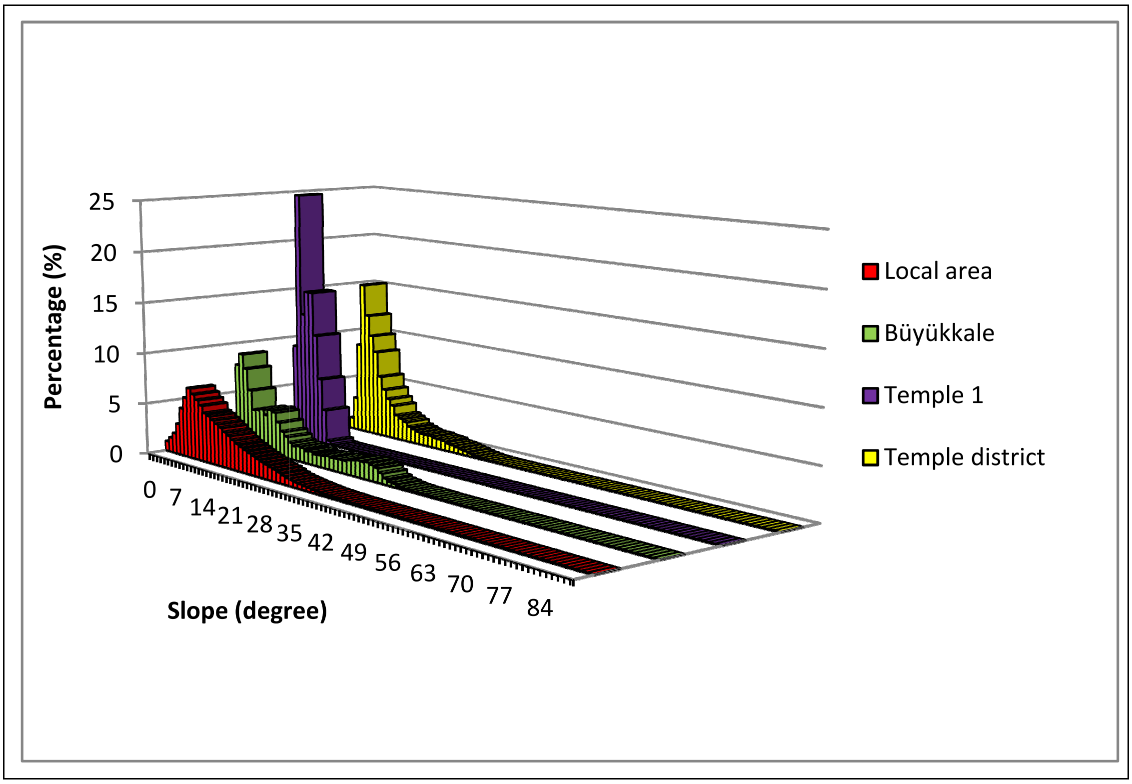


Figure 3.30 Slope histograms of the selected regions together with the local area.

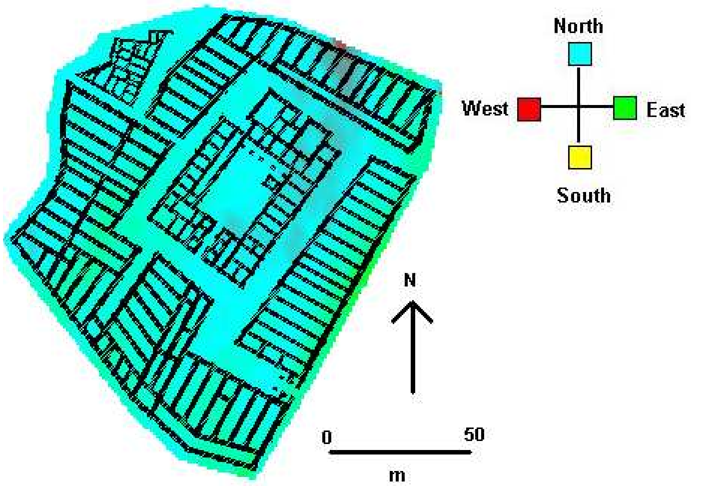
Aspect

Aspect maps of the building complexes can be seen in Figure 3.31.

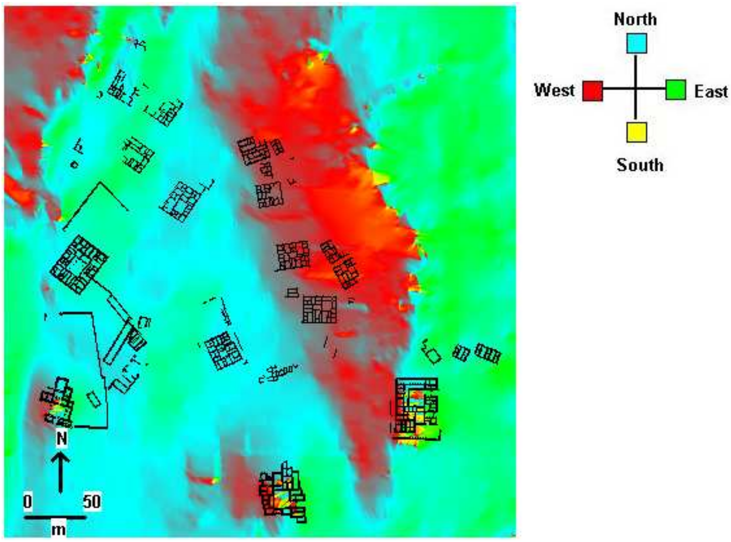
In the histograms of aspect values (Figure 3.32), flat bar shows the percentage of the pixels having slope value smaller than 2 degrees.

For the local area, most of the pixels have northern slope directions. Areas of Temple 1 and Temple district shows similar pattern with the local area. The slope directions of the pixels are mostly toward northern directions within these regions. Within the region of Temple 1, there is almost no pixel considered to be flat. Büyükkale shows a heterogeneous distribution in slope directions and the values change from flat to 360 degrees. The greatest percentages occur in northwest, west and south, while there are fluctuations between these directions.

A) Temple 1



B) Temple district



C) Büyükkale

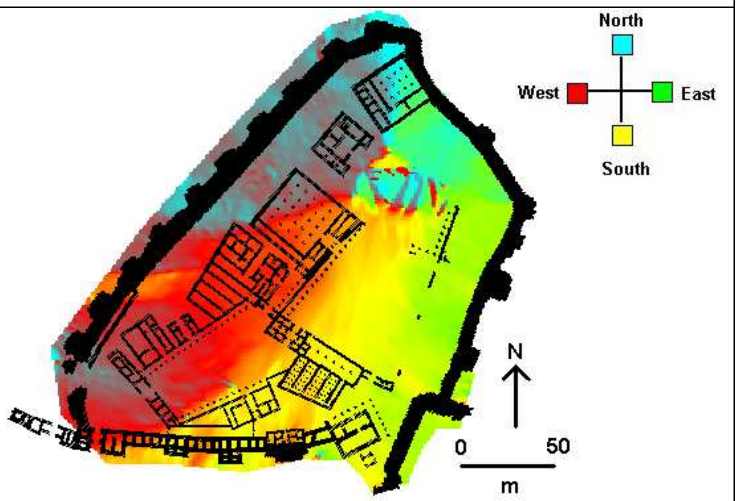


Figure 3.31 Aspect maps of the selected regions together with the remains of the walls. For the aspect map of the local area see Figure 3.20.

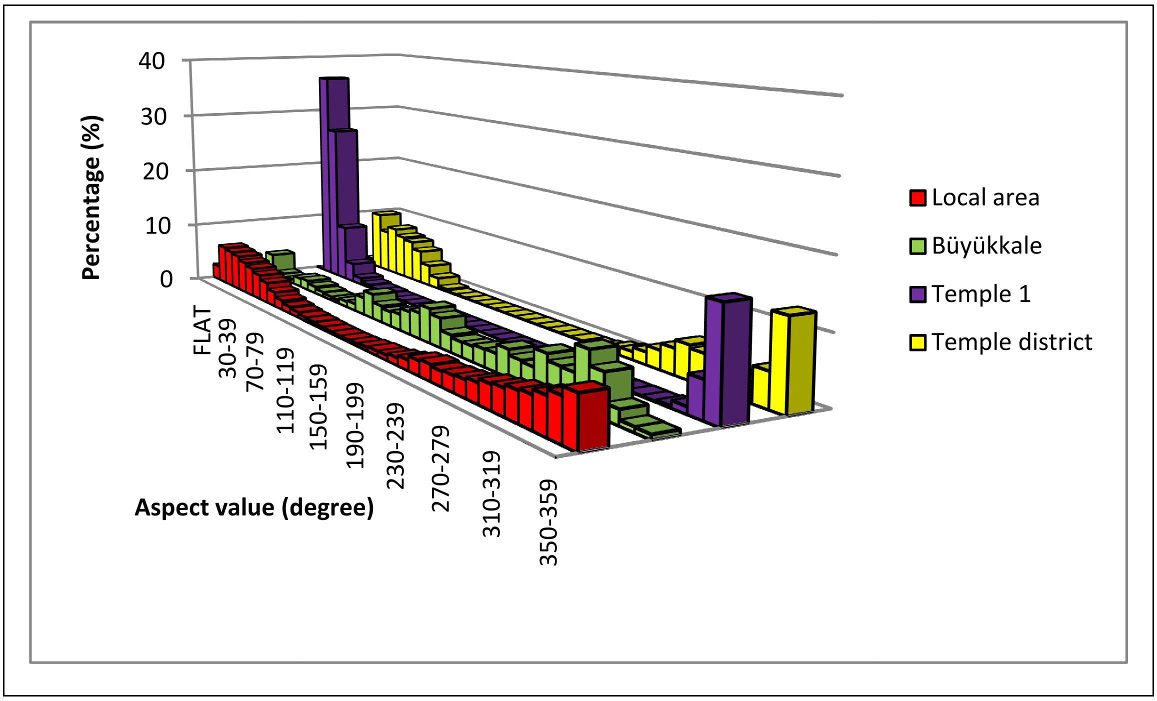


Figure 3.32 Aspect histograms of the selected regions together with the local area.

CHAPTER 4

MORPHOLOGICAL ANALYSES

In this chapter three analyses will be carried out using morphological characteristics of the area. These analyses are about 1) city wall, 2) water resources, and 3) visibility of the site.

4.1. The City Wall of Hattusha

The city wall of Hattusha is investigated from two aspects. In the first part, the path of the wall is examined with respect to topography in order to investigate how it fits to topography. The investigation is carried out by considering both the earlier city wall and the additional wall which shows the latest boundary of the city.

In the second part, the volume of the city wall at Yerkapı rampart and its close vicinity (approximately between King's gate and Lion gate) is estimated that considers a modification of the topography before the wall was built.

4.1.1 Position of City Wall with respect to Topography

According to the topographic map of the area given before, it can be concluded that the city wall generally follows the drainage divide (topographic ridge) in the area. However, there are some places where it is obvious that the wall deflects from the divide. In order to test the relationship between the paths of the wall and topography of the area six regions are selected for detailed investigations. These regions are shown in Figure 4.1 as six rectangles and are numbered 1 to 6. The regions are explained below in the order from south to north.

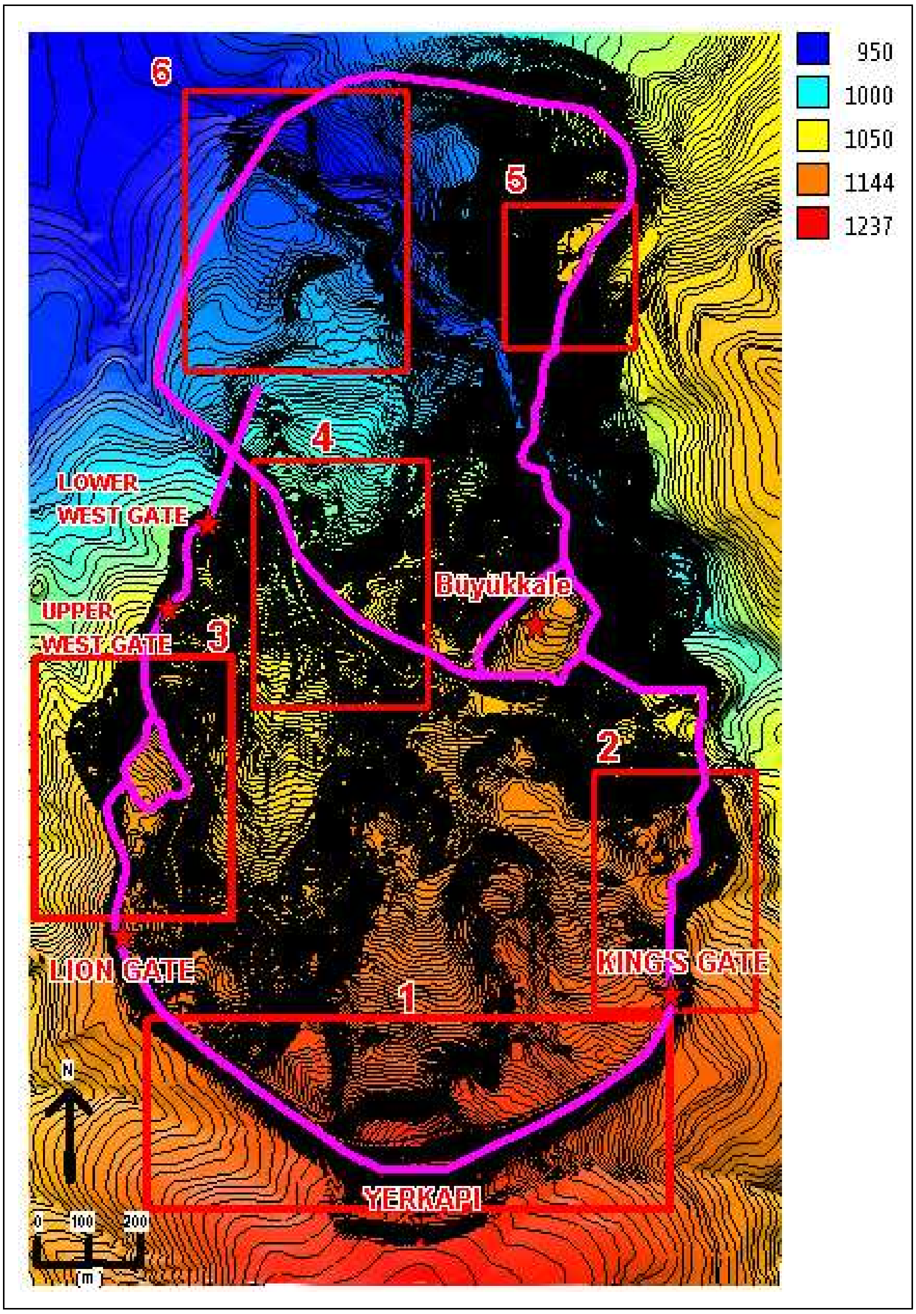


Figure 4.1 Location map for the selected parts of the city wall for detailed investigation. Rectangular boxes (1 to 6) are regions explained in the text. The purple line is the city wall.

The first region covers the southern part of the city wall between Lion gate and King's gate where Yerkapı rampart is located at the center (Figure 4.1, 4.2). This region comprises the best section where the wall remnant is observed both at 1/25000 and 1/1000 scale topographic maps. A careful analysis of the stream channels and the gullies (as indicated by V-shape contours) indicates that the wall in that section is totally built over the topographic divide. The stream in the east flows eastward, the one in the west flows westward; several gullies north of the wall flow northward. Therefore the city wall here is built just above the divide. Probable position of the initial topography of this area will be given in the next section where the estimated volume of the wall will be calculated.

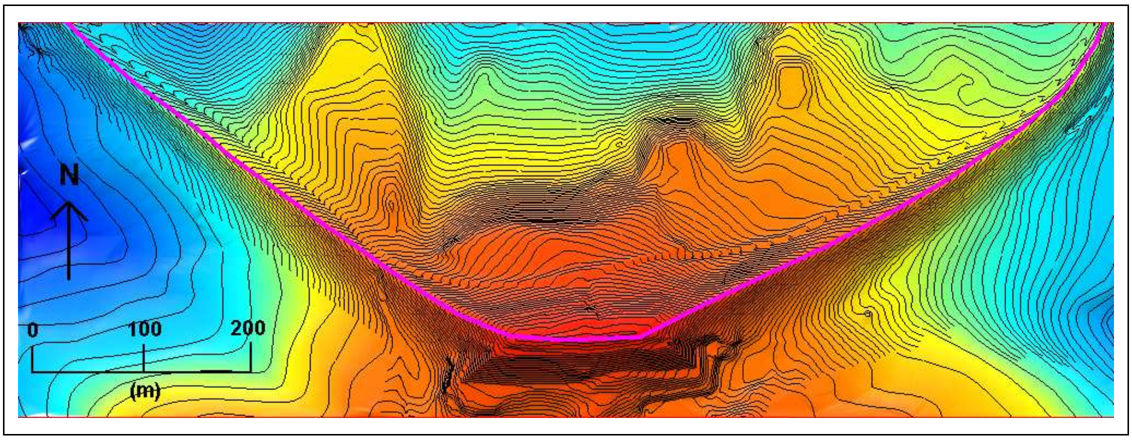


Figure 4.2 Region 1 on the city wall together with contours and the elevation map. Elevation is decreasing from red to blue. Contour interval is 1 m. Purple line is central axis of the city wall. (For location see Figure 4.1).

The second region is located to the north of King's gate. The present path and the position of the divide are shown in Figure 4.3. Characteristics of this section of the wall are as follows:

- This part of the wall shows the maximum deviation from the divide in whole Hattusha.
- The length of the deviated section is 453 m and the length of actual divide in this part is 544 m. Therefore, the wall is 91 m less than the ideal one.
- Deviated wall is built 15 m lower (at its maximum difference) than the ideal wall around location D2.
- By the deviation of the wall a total area of 31132 m2 (about 3.1 hectares) is added to the city. The hill which is elongated in NW-SE direction (top of which the divide passes) is now entirely included within the city.

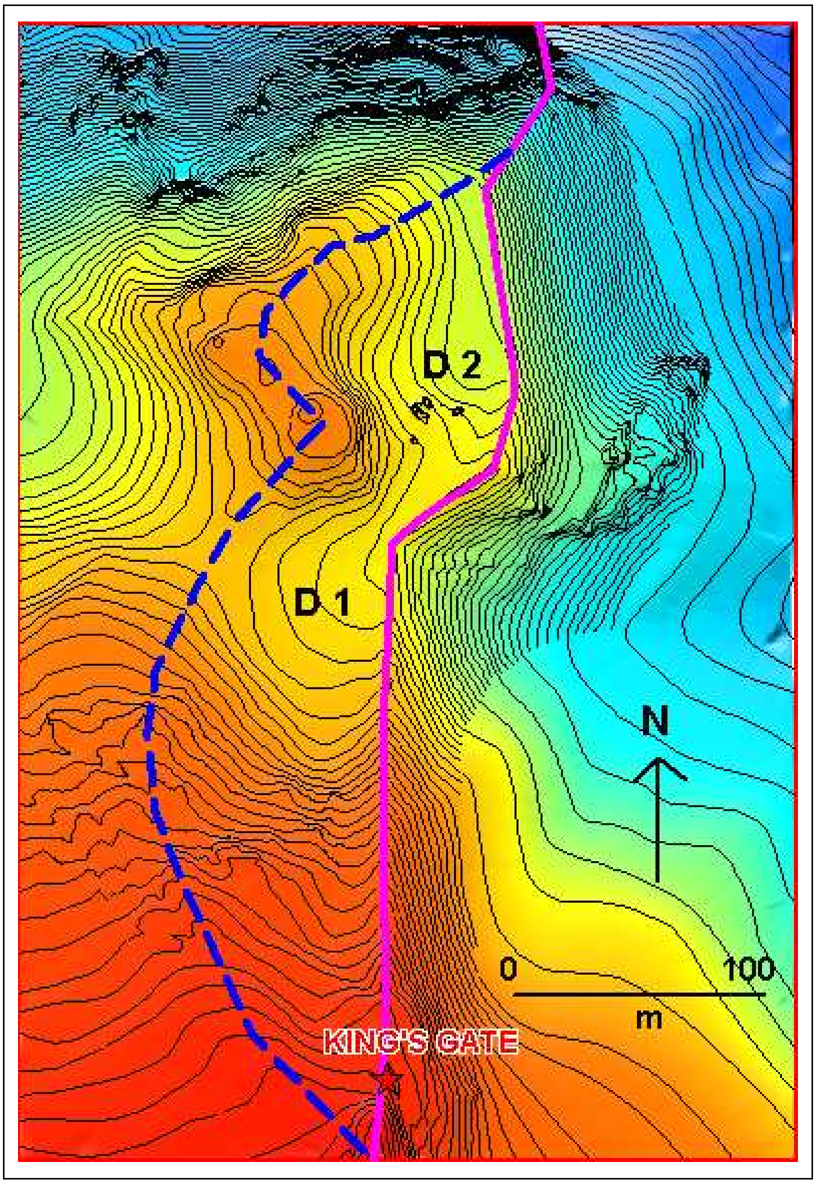


Figure 4.3 Region 2 on the city wall together with contours and the elevation map. Elevation is decreasing from red to blue. Contour interval is 1 m. Purple line is the city wall. Blue line indicates the most suited path for city wall according to topography. Areas indicated by "D1" and "D2" indicate the site of deposition if there is no drainage. (For location see Figure 4.1).

- Natural flow of the surface runoff should be blocked at the lower elevations along the wall. Therefore, if no drainage is provided beneath the wall, sedimentation (deposition) of transported material should be expected in the area. There are such two regions in the area indicated by D1 and D2 in the figure where D1 is about 5 m higher than D2. The gully observed to the south of D1 should be artificial formed after the construction of the wall.

The third region is located to the north the Lion gate (Figure 4.4). In this area too, path of the wall deviates from the divide similar to the case in Region 2 as its mirror image. Major features of this section of the wall can be explained as follows:

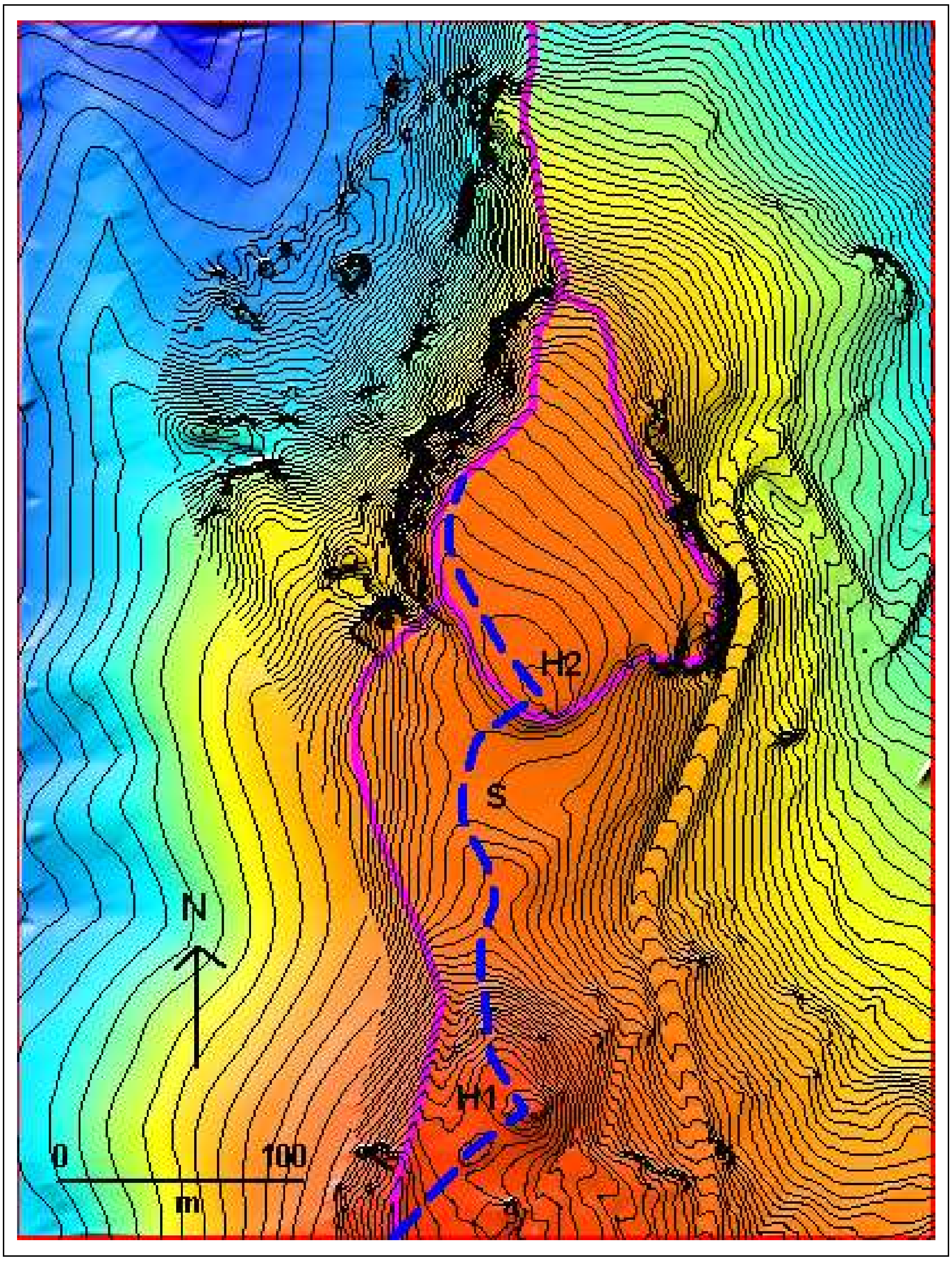


Figure 4.4 Region 3 on the city wall together with contours and the elevation map. Elevation is decreasing from red to blue. Contour interval is 1 m. Purple line is the city wall. Blue line indicates the most suited path for city wall according to topography. “S” is the saddle; “H1” and “H2” are hills mentioned in the text. (For location of Region 3 see Figure 4.1).

- Under normal conditions, the wall should pass through a saddle between two hills (the saddle is marked as “S”; and two hills as “H1” and “H2” in the figure”). By the present path of the wall, the saddle and both hills are added to the city. Area added is calculated as 10085 m2 (1 hectare).
- Length of the actual wall in this section is 353 m. The length along the divide, however, is 383 m. Therefore, the present wall is 28 m less than the ideal one.
- Deviated wall is built 9 m lower (at its maximum difference) than the alternative one.
- Similar to Region 2, in this section also the natural flow of the surface runoff is blocked at the lower elevations along the wall. Therefore, if no drainage is provided beneath the wall, deposition of transported material should be expected near the wall. This area is located to the west of the saddle near the wall.

The city wall in Region 4 (Figure 4.5) divides the city into two parts as “upper” and “lower” city. It marks, therefore, the southern boundary of Hattusha city before the construction of the additional wall. The path of the wall here seems to be along the divide throughout its course. This is evident by the flow directions of small streams or gullies observed on both sides of the wall. A minor deviation of the wall from divide is observed west of Kesikkaya hill. The divide in this locality passes through Kesikkaya hill. However, by shifting the wall to the west, Kesikkaya hill is now totally within the city. Kesikkaya, as the name implies (meaning “the rock cut” in Turkish), is cut in the form of a channel in NW-SE direction. The channel has a length of 38 m, height of 15-16 m and width of 3.3 m at the bottom, 9.4 m at the top (Figure 4.6). Numerical values due to modification of wall around Kesikkaya hill are as follows:

- Length of the wall in this section is 135 m; the length of divide is 176 m. Therefore the wall is 41 m shorter than the second case.
- The area added to the city is calculated as 1972 m^2 (0.2 hectares).

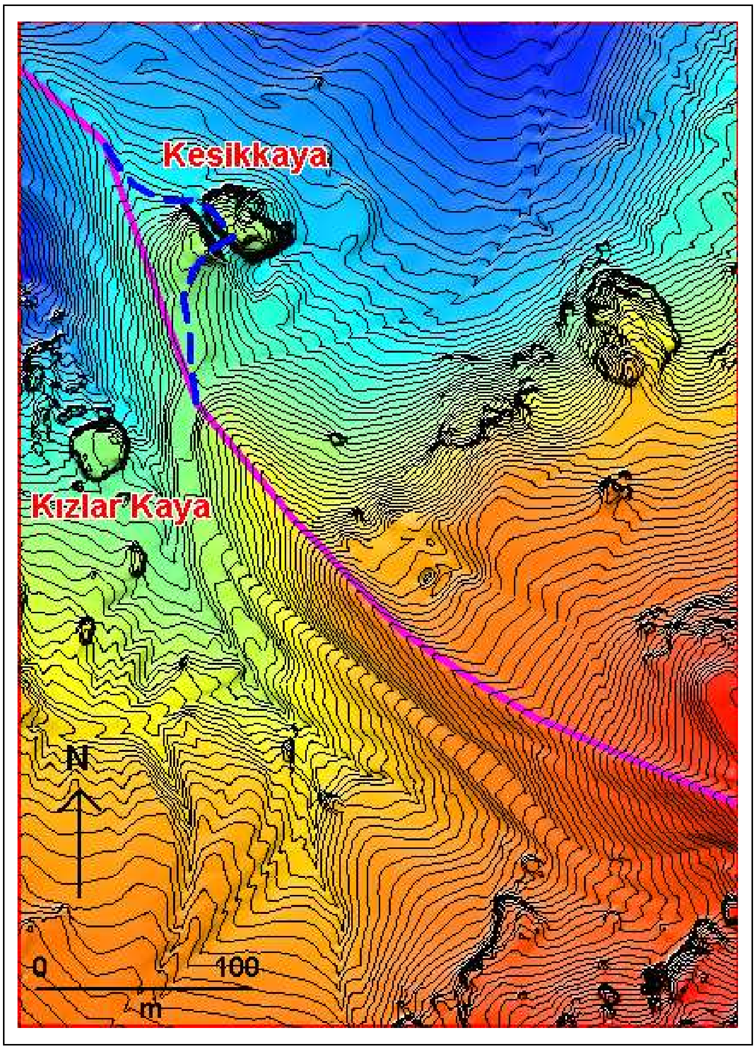


Figure 4.5 Region 4 on the city wall together with contours and the elevation map. Elevation is decreasing from red to blue. Contour interval is 1 m. Purple line is the city wall, blue line is the most suited path for city wall according to topography. (For location see Figure 4.1).

Figure 4.6 General view of Kesikkaya hill shown in Figure 4.5. View to the NW.

Region 5 belongs to a section of the wall in NE corner of the city (Figure 4.7.) Purple line in the figure shows the path of present wall and the blue dash line indicates the most suited path to topography (the divide) for this section. Following observations are made for this section:

- The length of the wall is 170 whereas the length of the most suited wall is 221 m. Therefore, the present wall is 51 m shorter than the one that fits to topography.

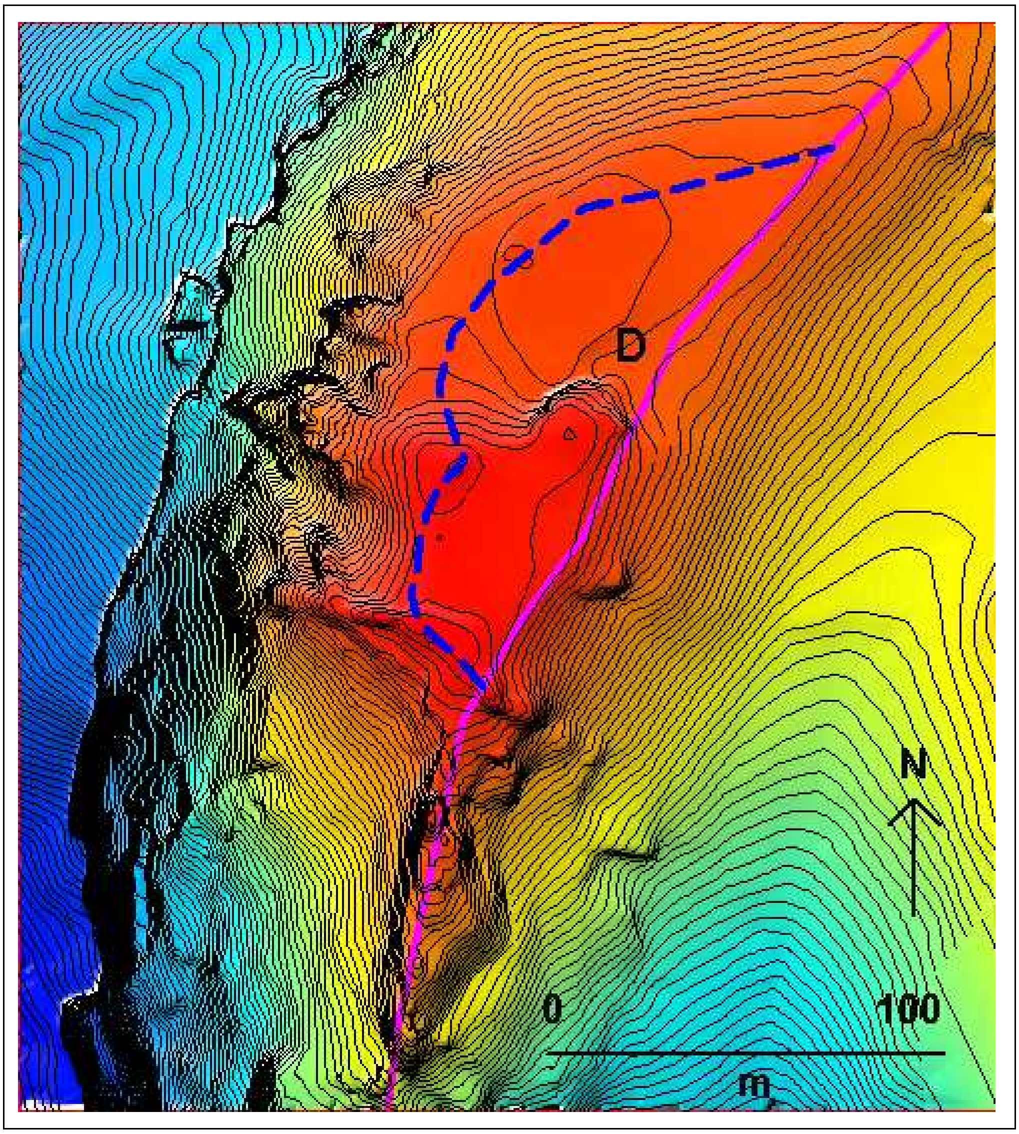


Figure 4.7 Region 5 on the city wall together with contours and the elevation map. Elevation is decreasing from red to blue. Contour interval is 1 m. Purple line is the city wall. Blue line indicates the most suited path for city wall according to topography. “D” stands for depression (For location of Region 5 see Figure 4.1).

- The hill elongated in NE-SW direction is included in the city that covers an area of 5947 m2 (0.6 hectare).
- Similar to Region 2 and 3, a depression is formed between the wall and the hill which is indicated by “D” in the figure.

Region 6 is located to the NW margin of the city (Figure 4.8). This is the section where maximum modification is observed in relation to the topography. Following conclusions can be reached for that section:

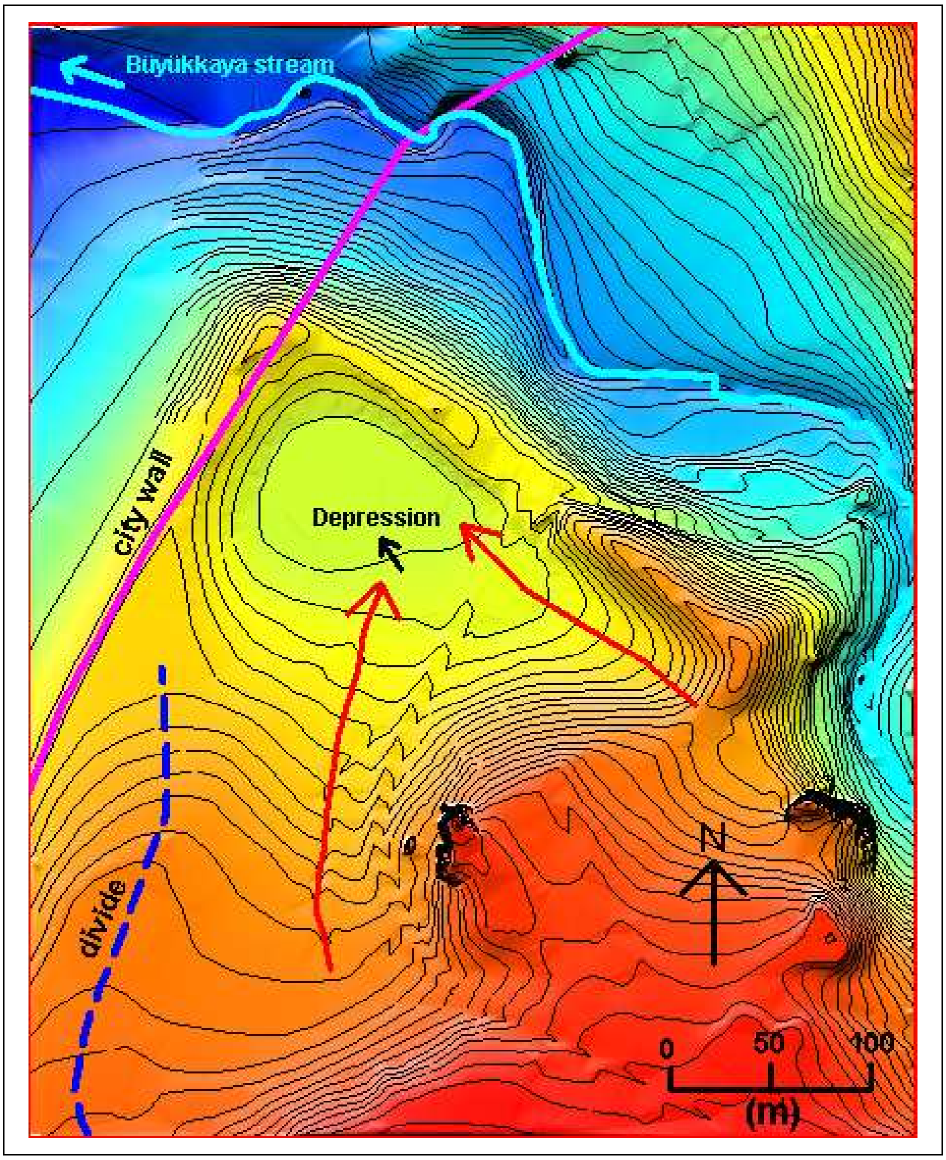


Figure 4.8 Region 6 on the city wall together with contours and the elevation map. Elevation is decreasing from red to blue. Contour interval is one m. Purple line is the city wall and blue dash line is the divide. Red lines show the two gullies. (For location of Region 6 see Figure 4.1).

- There is no relationship between the divide and the wall in this section. This is partly due to the fact that there is not a topographic divide (ridge) in this part. The divide is partly visible in the SW corner of the region elongated in NE-SW direction. This divide disappears (dies out) towards NE where it meets a broad valley. In the upstream direction, the valley is represented by two gullies (red lines in Figure 4.8) flowing towards N and NW. The wall is constructed across this broad valley almost perpendicular the gullies. Therefore, a large depression is formed between the wall and the gullies.
- The depression is elongated in NW-SE direction. It is elliptical in shape with 199 m of long and 131 m of short axis. Present depth of the depression is 3.5 m.

4.1.2. Volume Estimation of the City Wall

In this section, an attempt is made to calculate the volume of the city wall. This volume is obtained by subtracting two surfaces (initial topography and the present topography) from each other. It should be kept in the mind that, the present topography is represented by the ruins of the city wall; therefore, the volume will correspond to the wall after its erosion but not to the volume of the actual walls. Since the wall ruins are best preserved in the northern part of the city approximately between King's gate and Lion gate, only this section of the wall is considered in the calculations.

Before the reconstruction of the initial topography, the present surface of the region is analyzed using the DEM of the Yerkapı rampart area (Figure 4.9) and a profile across the rampart (Figure 4.10). As can be seen from the DEM, the rampart is located at the northern edge of a surface that slopes towards the north. However, as indicated by the eastern and western gullies located on both sides of this surface, there should have been a hill where the rampart is built. Therefore a saddle-like topography existed just north of the area (Figure 4.9, 4.10). Although the real elevations of the hill and the saddle are not known it is estimated that:

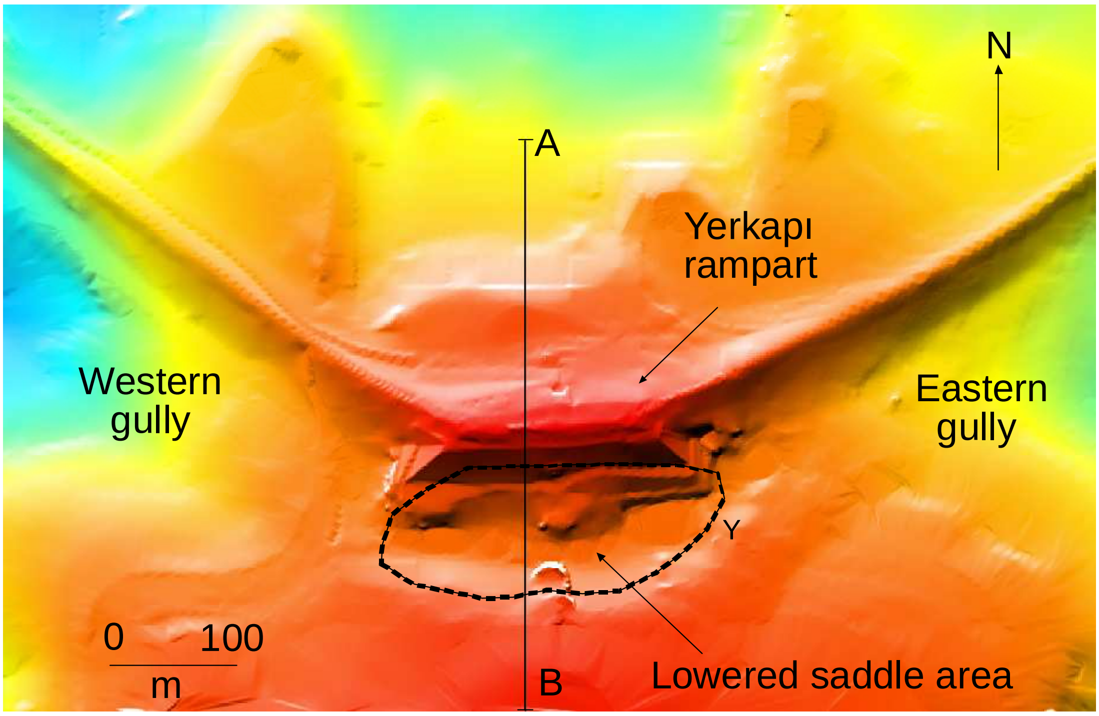


Figure 4.9 Digital elevation model of Yerkapı rampart area showing location of the profile (A-B) across the rampart.

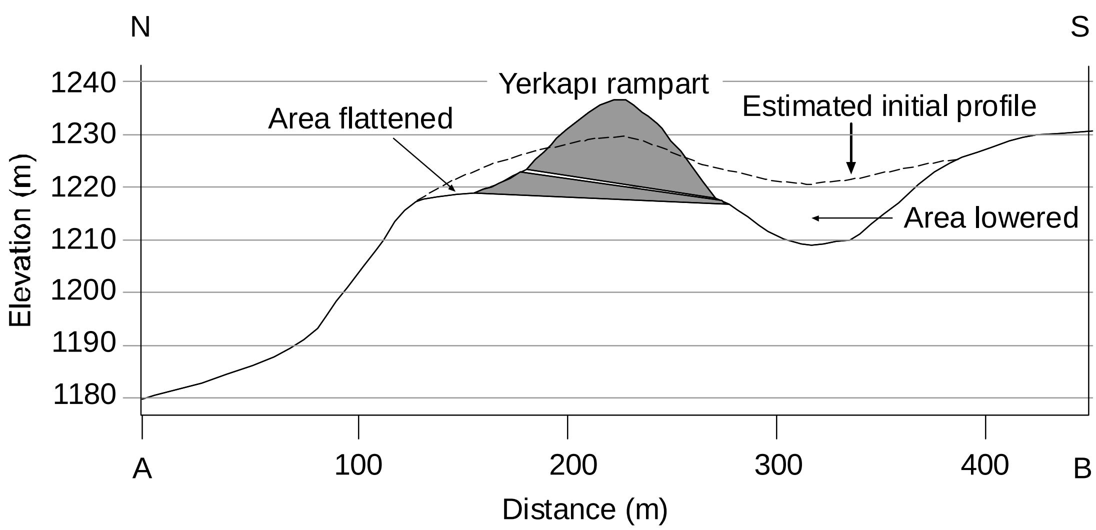


Figure 4.10 Profile A-B across the Yerkapı rampart. See Figure 4.9 for the line of section.

1. The saddle area is not natural considering its shape and comparing its position with respect to the gullies on both sides. It is suggested that the topography of the area between two heads of the gullies is modified by lowering the topography in the form of an ellipse in E-W direction. This ellipse has a length of about 255-260 m and a width of 95-100 m. Initial basal elevation of the saddle is estimated as 1220 m from the profile. The present elevation of the same point is 1209. Therefore, the maximum amount of the lowering is 11 m.
2. Position, shape and elevation of the hill truncated beneath the rampart cannot be exactly estimated. However, based on the slope amounts of the surfaces around the rampart a probable ancient topography can be inferred. This ancient (initial) topography is shown along the profile in Figure 4.10

In order to reconstruct the initial topography, the contours are modified so that the wall is removed from the surface. Therefore two sets of the contours are obtained; the first set belongs to presents topography and the second set belongs to initial topography. An example of these two contours is shown in Figure 4.11 as black and red colours, respectively. Topographic contours of the whole area are shown in Figure 4.12 (A for present topography and B for initial topography).

For an easy calculation of the volume, two surfaces are generated with a pixel size of 1 m. The difference at each pixel, therefore, will directly indicate the volume for this pixel in m^3. These two surfaces are subtracted from each other that will represent the “thickness map” of the wall. The difference map is contoured at 3 m interval to give an idea on the shape of the resultant mass (Figure 4.13).

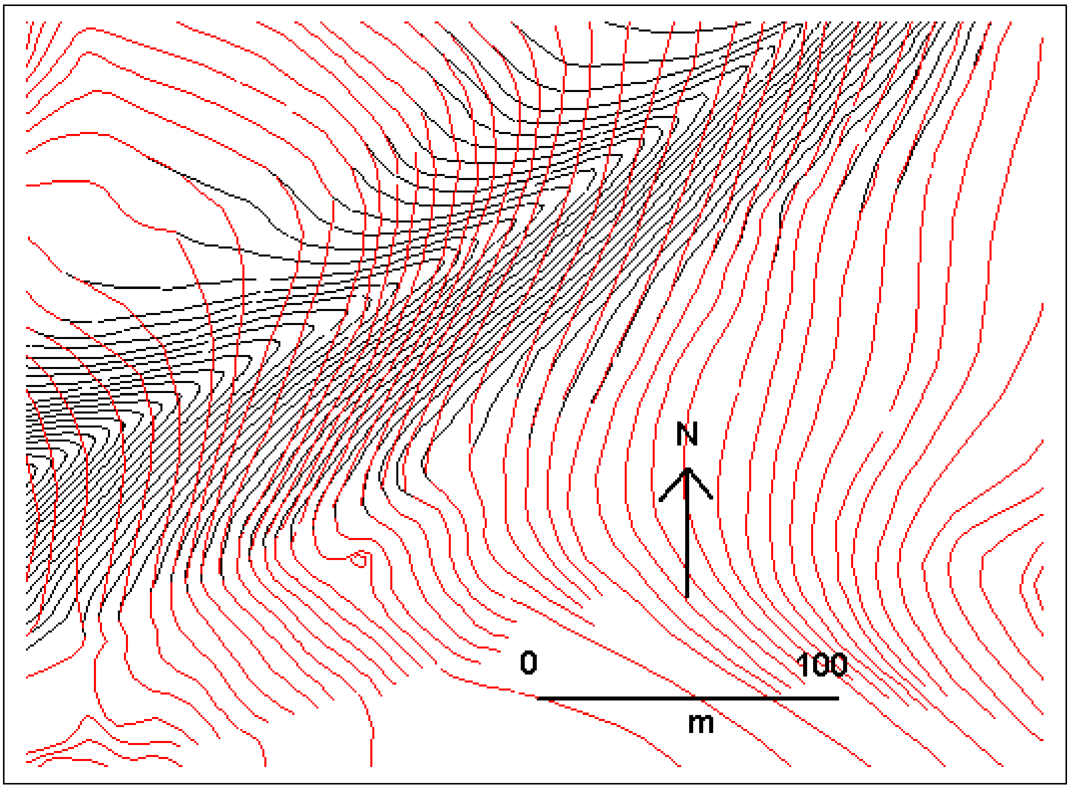


Figure 4.11 A sample area (between Yerkapı and King's gate) showing topographical contours of the present surface (black) and estimated topographic contours of initial topography (red).

The difference map is in the form of a curved belt that fits the present position of the wall (Figure 4.13). The area out of this belt (white region) is the "no change" area indicating that topography before and after the construction of the wall is the same. The "change" area is composed of 130682 pixels; therefore corresponds to 130682 m^2 (13 hectares).

Maximum difference is obtained at the central part of the rampart and has a value of 19.35 m. Thickness of the difference gets maximum along the centre of the belt and gradually decreases towards the periphery everywhere. The width of contour intervals are almost the same suggesting that the resultant body is symmetric (same slope on both sides).

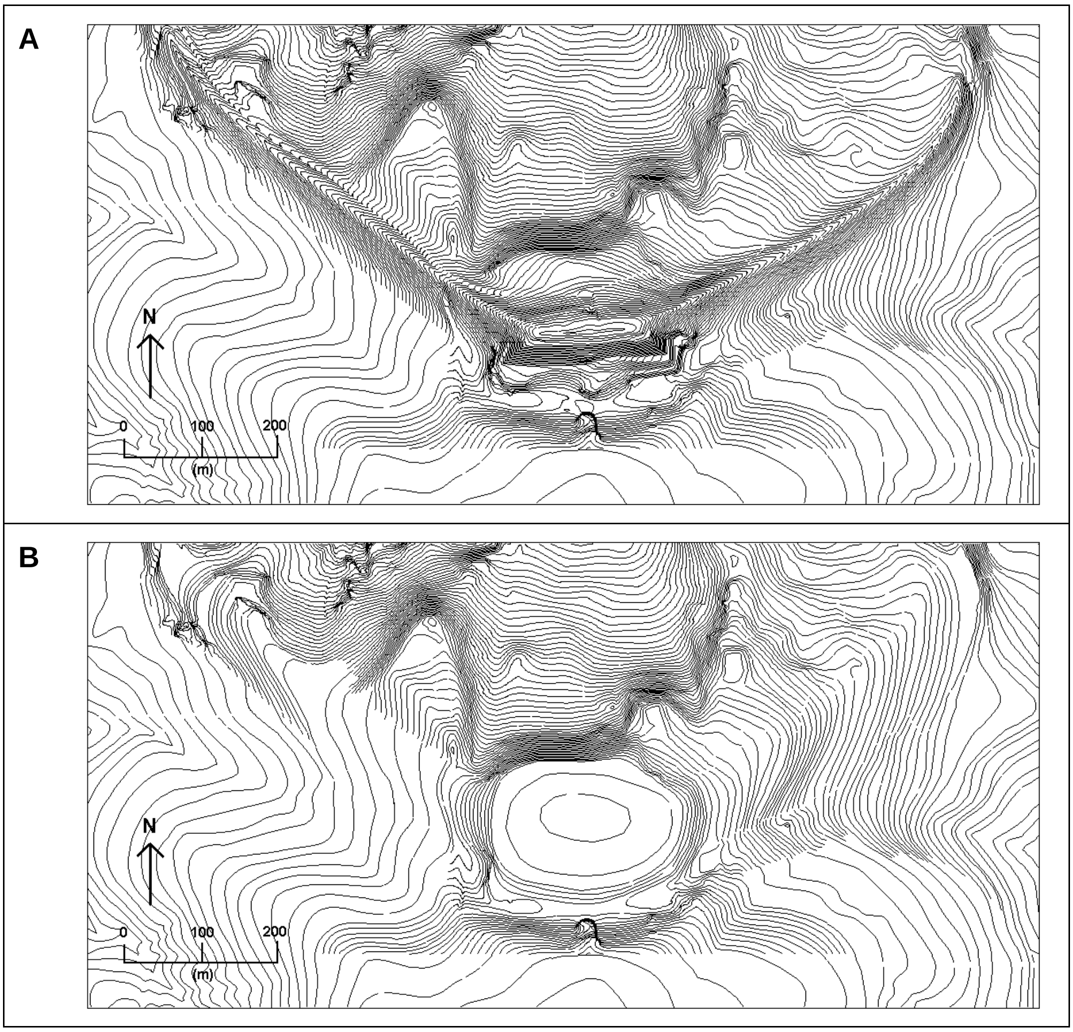


Figure 4.12 Topographic contours of the present (A) and initial topography (B) used to determine the thickness of the wall. Two surfaces generated from these contours are subtracted from each other to determine the volume of the wall.

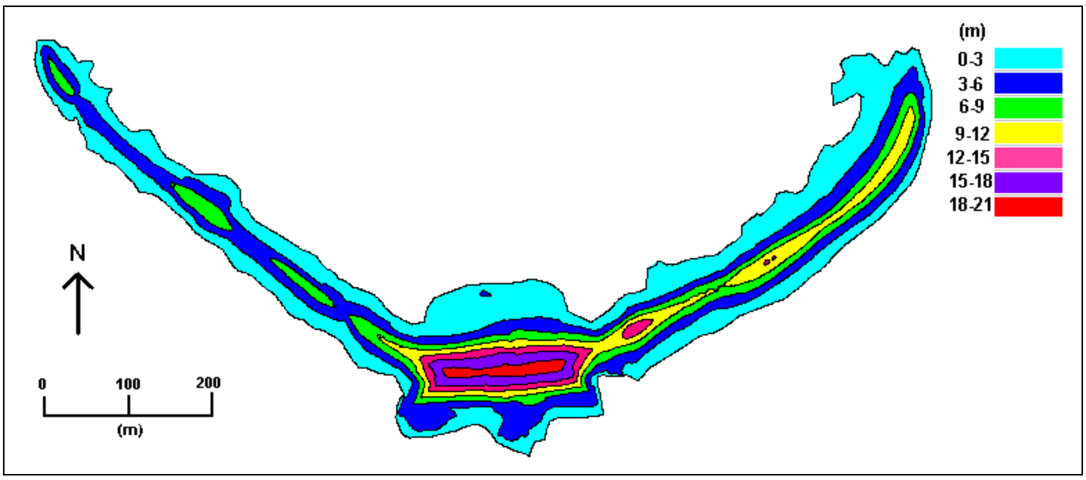


Figure 4.13 Contour map of DEM generated from difference of present and initial surfaces.

Quantification of the wall approximately between King's gate and Lion gate is made by volume and area; and the results are given in two histograms prepared at 1 m interval shown in Figure 4.14 for volume and in Figure 4.15 for area.

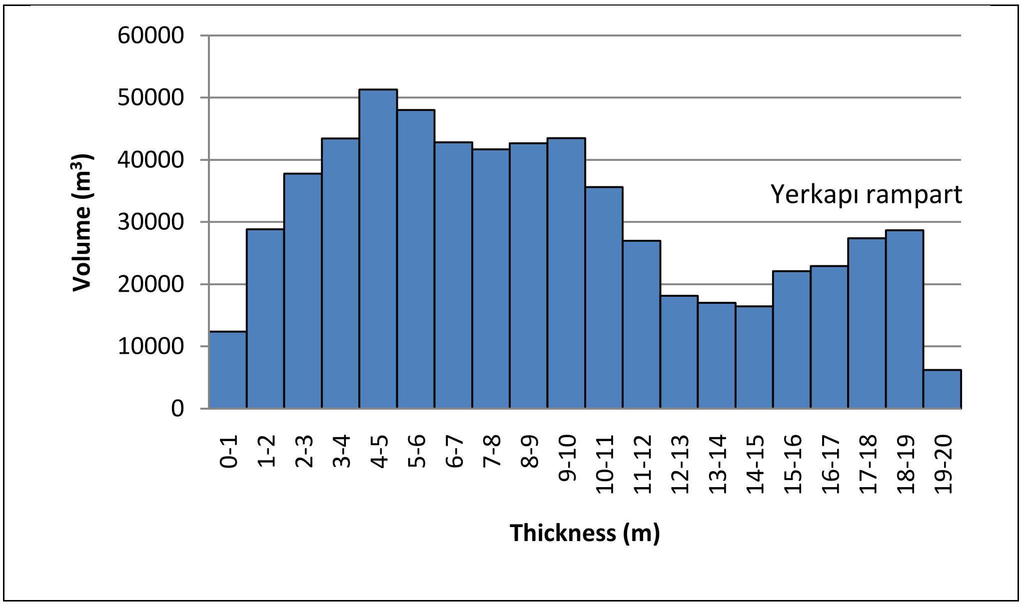


Figure 4.14 Histogram showing the nature of volume of city wall approximately between King's gate and Lion gate.

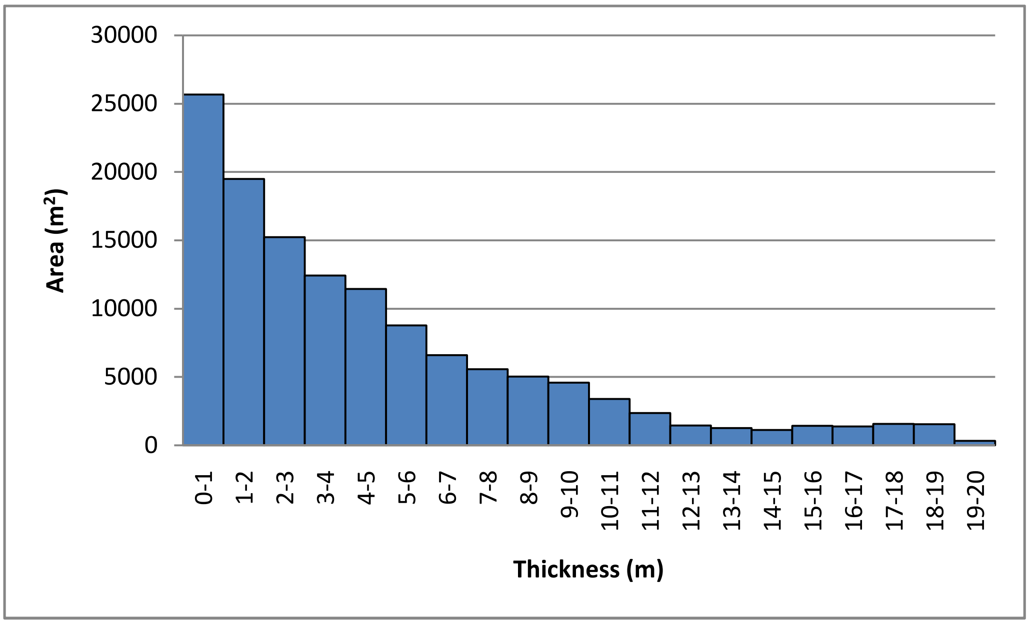


Figure 4.15 Histogram showing the nature of area of city wall approximately between King's gate and Lion gate.

Volume of the wall shows a bi-modal distribution with two extreme values at 4-5 and 18-19 m thicknesses. The shape and percentage of the latter one suggest that this part of the histograms represents the Yerkapı section of the wall because: 1) this is the area where the maximum thickness is obtained, and 2) this area covers a relatively smaller section of the wall. For example, at 18-19 m interval total amount of the wall is about 28.000 m^3. Maximum concentration, on the other hand, observed at 4-5 m interval indicated a volume of 51.000 m^3. In order to find the volumetric change after the modification of topography, elevation differences are multiplied by the correspondent areas. The total change in volume, therefore, is calculated as 613966 m^3.

Change in the area of the wall is illustrated in Figure 4.15. Total number of pixels in the modified region is 130682. Since each pixel has a size of 1*1 m the total area of modified wall section is 130682 m^2 (13 hectares). As seen from the histogram, there is a gradual decrease in the number of pixels as the thickness of the wall increases. The maximum area is observed at 0-1 m thickness with a value of 26000 m^2; the minimum area is at 19-20 m with a value of less than 1000 m^2.

4.2. Water Resources

The water resources for Hattusha are considered in two sections from both regional and local aspects. In the first section, the main streams (Büyükkaya and Yazır) are investigated with respect to their drainage basins. In addition to this, the swamp located in the close vicinity of the ancient city and the springs out of the city is investigated for potential water sources for the city. This section will be investigated under the heading “external water resources”.

In the second section, the ponds existing within the city, particularly those in the eastern and south-western part will be evaluated in detail as potential areas for providing water to the city. This section will be referred to as “internal water resources”.

4.2.1. External Water Resources

Drainage Map

Drainage map of the regional area is prepared from the DEM and the topographic contours at 1/25000 scale. The resultant map is illustrated in Figure 4.16. Blue lines in the map represent the streams in the area regardless of their type as permanent or seasonal. Gullies and minor creeks are neglected during the preparation of the drainage map.

In general a dendritic drainage pattern exists all over the area suggesting a medium slope and absence of major geological structures. This pattern is well emphasized to the northern part of the area particularly at low elevations. To the southeast of Hattusha, several streams are oriented in NEE-SWW direction that may suggest a structural control in this part.

The most striking element of the drainage map is the “drainage divide” that defines the boundary of basins almost in E-W direction south of Hattusha (black line in the figure). North of this divide the streams flow northward; south of it towards the south.

The major stream that drains Hattusha and its vicinity is Budaközü stream. This stream bifurcates into two arms just north of Hattusha that flows along the eastern and western margin of the city. These streams are called as Büyükkaya and Yazır streams, respectively. The drainage divide between these two tributaries passes through the city almost in N-S direction. Therefore, the eastern half of the city is included in Büyükkaya; and the western half in Yazır drainage basin. Boundary of the area covered by these two sub-basins is shown in the figure by green line.

Since two streams meet just NW of the Hattusha city, it can be claimed that the drainage basins of these two streams are potential sources for Hattusha area. The areas of drainage basins of these streams are 62.27 km^2 (Büyükkaya) and 21.5 km^2 (Yazır).

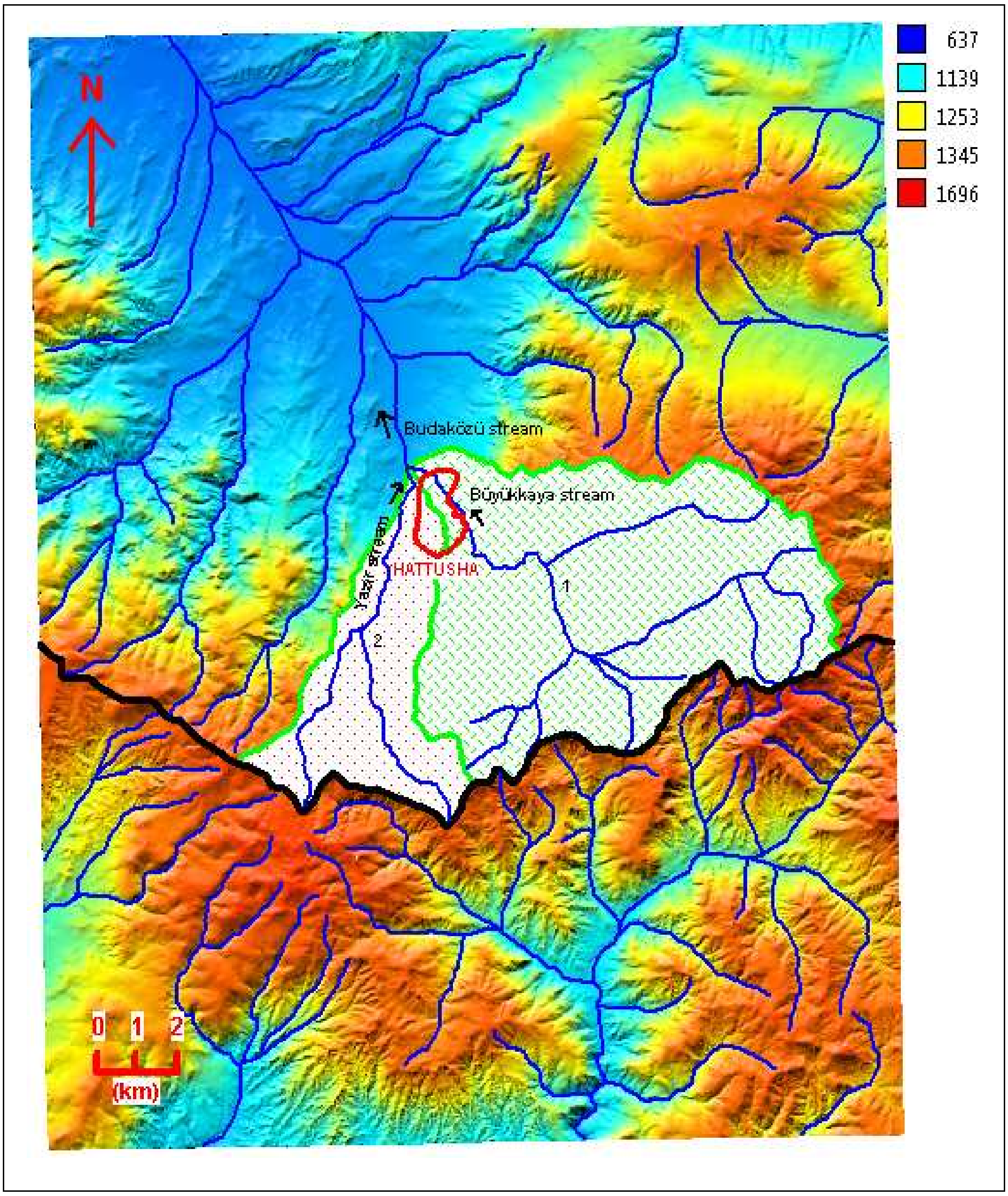


Figure 4.16 Drainage map of the regional study area. Hattusha is located between two sub-basins namely the eastern Büyükkaya (number 1) and the western Yazır (number 2) basins. Solid black line is the major drainage divide of the northern and southern basins. The green line is the boundary of Büyükkaya and Yazır basins.

Estimation of Annual Precipitation

Availability of the water for Hattusha is closely related with the annual precipitation in the region. In order to make an estimation for the water collected in the reservoirs (or dams) used for the city; amount of annual precipitation in the vicinity of Hattusha is provided from Turkish State Meteorological Service. Although in the related web page of the institution the data are available for the period of 1939 to 2007, the data are given as an average of the province such as Yozgat, Çorum and Çankırı. Based on the great variation of the data for the provinces, it is decided to ask for the availability of the data in closer distances. Three stations where meteorological data are measured are Yozgat, Sungurlu and Alaca. The monthly measured precipitation data from these stations are provided from the institution. Original data are shown in Appendix A. A re-organized form of these data is shown in Tables 4.1, 4.2 and 4.3. Major characteristics of the data are as follows:

- The years the data measured from these three stations are not consistent. Yozgat station measured precipitation between 1971 and 2008; Sungurlu station between 1987 and 1995; Alaca station between 1971 and 2007. The last station, however, has missing data for three years in between.
- Some months are missing in all stations. Yozgat station does not provide the data for 17 months; Sungurlu for 2 month; and Alaca for 22 months. To normalize the data, these blank months are assigned the average monthly precipitation. For example, for Yozgat station that misses the data for October 1984, a value of 41.7 mm is assigned which is the average of all October measurements.
- There are considerable differences between the average annual precipitation values for three stations. This amount is 591.4 mm for Yozgat station, 440.5 mm for Sungurlu station; and 398.3 mm for Alaca station.

Table 4.1 Precipitation data from Yozgat station (Source: Turkish State Meteorological Service).

		Months												
		1	2	3	4	5	6	7	8	9	10	11	12	Total
Years	1971	13.7	39.5	99.8	95	39.1	45.2	7.2	44.1	33.5	31.8	75.6	95.9	620.4
	1972	23.5	57.1	12.8	55.1	54.2	60.9	52.9	0.9	14.6	56.3	25	11.2	424.5
	1973	17.2	24.2	59.7	80.6	72.2	42.4	3.6	4.1	0.8	10.9	26	49.3	391.0
	1974	57.3	23	45.3	45.2	62.2	4.4	6.7	7.8	52.5	18	16.9	104.7	444.0
	1975	34.3	41.4	73.4	136.6	134.7	60.6	2.7	18.9	3.9	22	30.4	74.8	633.7
	1976	96.8	59.5	25.4	81.2	46.5	18.7	4.2	1.1	11.8	71.1	80.6	53.2	550.1
	1977	34.7	26.5	80.8	87.3	52.4	32.9	2.7	**13.3**	22.4	57	32.4	51.1	493.5
	1978	104.5	93.2	57.3	83	8.2	5.6	6.4	**13.3**	23.1	35.6	4.6	60.6	495.4
	1979	145.5	73.9	29.6	36	82.6	28	17.9	1	34.4	41.3	70.9	56.7	617.8
	1980	107.8	43.1	76.5	83.2	127.1	24	2.5	0.6	9.5	37.9	122.4	91.3	725.9
	1981	97.7	58.1	107.6	39.2	50.6	87.7	66.1	1	9.4	22.4	42.1	133.4	715.3
	1982	83.6	22.3	61.5	85.5	57.2	47.9	22.1	13	4.2	14.2	15.5	43.2	470.2
	1983	66.5	192.3	62.9	54.1	72.6	42.8	47.4	9.8	9.2	87.9	164.9	47.8	858.2
	1984	59.8	37.2	66.2	133.8	37.1	21.3	6.9	12.1	**22.2**	**41.7**	33.9	63.1	535.3
	1985	106	112.2	47.1	54.5	111.4	6.5	8.1	6.1	**22.2**	109.4	123.7	80	787.2
	1986	79.1	56.3	11.5	53	72.7	103.9	7.9	**13.3**	28.1	7.1	64.2	78.5	575.6
	1987	120.8	70.7	104.7	79.4	39.2	73.9	29.1	12.8	**22.2**	35.5	67	159.3	814.6
	1988	27.3	86.3	74.4	30.4	36.3	97.9	34.6	**13.3**	9	73	108.4	57.8	648.7
	1989	35.5	25.2	28.4	45.7	55.6	27.7	2.8	1	8.8	52.5	171.8	54.1	509.1
	1990	52.6	37.7	25.9	93.8	83.5	27.5	13.7	2.6	22	13.6	27.6	101.3	501.8
	1991	24.3	82.9	29	136.8	92.6	38	2.2	**13.3**	8.1	109.9	48.3	92.1	677.5
	1992	13.9	59.8	61.6	44.3	47.9	103.3	13.2	11.9	21	24.2	109	108.4	618.5
	1993	81.6	91.2	55.1	51.3	98	63.5	**16.5**	7.8	0.2	0.4	49.1	90.2	604.9
	1994	71.1	83.6	62.6	57.1	42.3	1.7	6.3	3.9	**22.2**	43.4	96.6	85	575.8
	1995	51.9	12	109.5	89.9	47.7	52.3	12.5	19.4	18	38.4	127.8	42.9	622.3
	1996	27.4	81.1	135.9	84	51.4	31.1	8	19.1	58.3	55.3	2.8	88.6	643.0
	1997	35.8	54	35	106.3	49.2	54	**16.5**	13.8	6.5	110.4	36.5	140	658.0
	1998	33	52.6	91.9	81.8	157.3	48.4	5	**13.3**	6.3	49.3	86.5	144.3	769.7
	1999	32.8	81.8	91	31.2	47.7	45.1	79.2	56.1	6.2	29.4	29.1	33.2	562.8
	2000	126.9	90.6	64.2	87.7	82.1	42.4	**16.5**	37.4	6.9	28.5	2.5	33.7	619.4
	2001	1.5	65.1	42.1	32.3	80	9.9	5.3	7.4	8.2	4.2	106.2	168	530.2
	2002	94.3	31.9	45.5	133.1	33.3	17	32.2	31.6	31.6	15.3	40.4	42.1	548.3
	2003	81.2	77.8	36.8	78.7	32	8.6	0.9	1.3	77.8	58	31.4	74.6	559.1
	2004	95.7	26.3	38.1	47	37.7	45.8	16.9	25.8	1.4	13.3	89.2	23.3	460.5
	2005	42.2	48.4	106.1	73.6	89.1	12.6	17.9	23	25.5	41.7	102.8	18.4	601.3
	2006	49.6	47.5	72	48.9	30.3	44.5	**16.5**	**13.3**	107.7	53.1	46.1	3.6	533.1
	2007	38.3	42.9	64.5	53.4	20.7	42.6	**16.5**	14.5	7.1	38.5	146.9	75.7	561.6
	2008	50.6	45.3	61.4	54.8	35.6	23.2	0.4	1.2	65	31.3	66.8	80.7	516.3
Average		61.0	59.3	61.9	72.2	62.4	40.6	16.5	13.3	22.2	41.7	66.4	74.0	591.4

Table 4.2 Precipitation data from Sungurlu station (Source: Turkish State Meteorological Service).

		Months												
		1	2	3	4	5	6	7	8	9	10	11	12	Total
Years	1987	62.1	35.0	65.7	78.3	37.5	91.8	43.1	7.7	0.3	29.7	41.8	83.8	576.8
	1988	19.9	78.2	45.5	32.9	42.1	97.6	11.3	**7.3**	7.4	116.3	56.9	57.7	573.1
	1989	24.2	16.8	24.7	20.9	66.7	37.2	4.2	0.8	2.5	43.5	117.3	45.1	403.9
	1990	29.1	9.3	37.5	87.1	117.6	22.5	15.7	3.0	37.1	15.8	12.0	83.1	469.8
	1991	20.7	51.5	25.0	79.4	69.4	22.6	2.9	3.5	9.8	50.7	23.1	46.9	405.5
	1992	3.1	14.3	36.7	35.9	18.6	59.8	12.2	12.6	15.8	31.2	62.2	60.8	363.2
	1993	36.7	58.4	20.2	38.6	101.7	29.9	**14.0**	19.5	2.1	1.7	35.5	45.2	403.5
	1994	49.3	28.3	25.3	19.3	44.3	1.6	3.4	4.7	6.9	24.5	61.7	36.8	306.1
	1995	31.3	12.8	77.9	57.7	50.0	61.9	19.1	6.4	31.6	27.1	78.0	9.1	462.9
Average		30.7	33.8	39.8	50.0	60.9	47.2	14.0	7.3	12.6	37.8	54.3	52.1	440.5

Table 4.3 Precipitation data from Alaca station (Source: Turkish State Meteorological Service).

		Months												
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
Years	**1971**	9.9	15.5	24.9	69.6	85.3	39.4	14.3	19.3	50.9	18.3	31.8	37.7	416.9
	1973	11.8	15.2	25.5	56.5	53.9	35.6	**16.4**	2.3	2.1	6.5	7.6	25.1	258.5
	1974	7.6	10.6	20.7	13.4	58.1	4.8	21.0	12.2	48.0	0.8	19.7	73.5	290.4
	1975	27.5	19.9	46.4	106.8	88.7	21.6	2.4	24.0	5.0	22.8	15.9	44.3	425.3
	1976	41.9	13.6	6.2	41.7	54.0	31.9	8.5	1.9	11.3	44.4	17.1	20.1	292.6
	1977	12.9	13.3	38.6	63.8	61.4	40.1	4.1	**16.1**	14.6	38.6	14.7	49.8	368.0
	1978	59.9	36.4	22.5	72.8	23.3	11.4	6.2	1.3	29.6	33.1	1.8	32.1	330.4
	1979	70.4	23.9	15.7	23.4	76.8	67.2	24.1	19.3	29.1	20.1	45.9	23.6	439.5
	1980	56.1	31.9	37.4	53.5	102.6	16.2	9.8	8.2	15.6	28.2	51.5	29.2	440.2
	1981	41.8	23.8	66.6	21.2	61.1	71.5	28.2	6.1	13.6	20.2	31.2	31.2	416.5
	1982	15.6	9.7	37.2	53.4	43.9	61.7	17.6	3.6	0.4	13.6	8.4	27.2	292.3
	1983	30.5	47.5	16.8	54.3	42.7	32.5	35.7	17.8	8.6	44.7	100.6	38.6	470.3
	1984	32.8	18.8	24.0	98.6	37.7	15.8	7.8	12.8	1.2	1.9	6.2	11.4	269.0
	1985	26.4	48.5	23.5	48.6	66.8	2.2	10.6	9.2	**17.9**	82.2	55.8	36.2	427.9
	1986	42.6	23.2	7.0	28.1	83.2	76.7	0.4	**16.1**	8.5	3.3	23.5	56.7	369.3
	1987	63.1	39.1	41.1	38.3	46.8	61.5	33.1	51.3	**17.9**	12.1	53.3	75.7	533.3
	1988	33.0	40.1	33.4	23.9	38.7	70.2	38.1	2.7	2.9	95.1	56.2	40.2	474.5
	1989	18.9	19.4	12.5	24.1	56.7	23.4	4.4	2.6	2.9	45.6	96.2	29.8	336.5
	1990	35.8	7.5	20.2	73.8	92.7	18.4	6.6	4.8	28.5	8.3	19.1	57.1	372.8
	1991	13.9	39.8	24.7	101.2	89.7	36.5	**16.4**	1.8	0.6	38.8	22.7	44.3	430.4
	1992	5.9	19.3	28.5	24.9	27.4	64.4	17.6	2.4	15.5	21.2	56.5	41.9	325.5
	1993	34.2	40.6	18.6	41.8	116.0	33.0	1.6	3.8	8.6	1.0	**39.6**	**38.7**	377.5
	1994	**32.0**	15.6	36.3	31.7	30.4	2.6	2.2	3.6	2.2	27.0	66.4	30.4	280.4
	1997	11.4	**26.6**	12.4	58.8	**58.7**	**41.5**	13.4	16.6	11.2	48.0	24.0	83.1	405.7
	1998	26.8	15.7	36.6	41.7	152.0	131.6	7.0	**16.1**	4.8	23.3	30.6	43.5	529.7
	1999	20.7	29.0	75.6	48.8	13.1	25.1	55.0	79.5	29.7	24.2	21.4	8.5	430.6
	2000	79.4	59.9	23.7	87.4	61.5	64.4	**16.4**	65.5	11.2	18.7	**39.6**	44.1	571.8
	2001	8.0	37.3	38.3	23.4	83.8	13.3	6.3	7.8	**17.9**	4.6	48.4	76.7	365.8
	2002	65.2	18.6	57.0	64.3	4.9	39.7	71.8	21.1	47.2	32.6	**39.6**	11.6	473.6
	2003	46.3	28.9	25.6	69.3	29.4	**41.5**	**16.4**	**16.1**	65.0	32.5	29.9	84.0	484.9
	2004	44.4	14.7	30.3	34.2	41.2	77.1	6.4	22.5	2.7	3.7	82.3	18.0	377.5
	2005	8.5	27.9	73.2	59.6	62.3	26.9	5.2	10.0	12.9	33.6	79.1	15.5	414.7
	2006	32.0	50.5	60.9	17.0	32.5	31.2	**16.4**	**16.1**	63.4	36.4	34.8	4.4	395.6
	2007	26.2	29.6	56.0	36.5	20.3	98.3	**16.4**	32.2	7.1	22.1	75.6	33.3	453.6
Average		32.2	26.8	32.9	50.2	58.8	42.0	16.4	16.1	17.9	26.7	39.6	38.8	398.3

Hattusha is located almost at the center of these stations. Plan distances from Hattusha to these settlements are calculated as: 20 km to Yozgat, 24 km to Sungurlu and 25 km to Alaca. The drainage basin of Hattusha, however, that collects water for the city is totally located to the south of Hattusha and is closer to Yozgat. Therefore, instead of taking the averages of all these stations, it is decided to use Yozgat data alone (Figure 4.17).

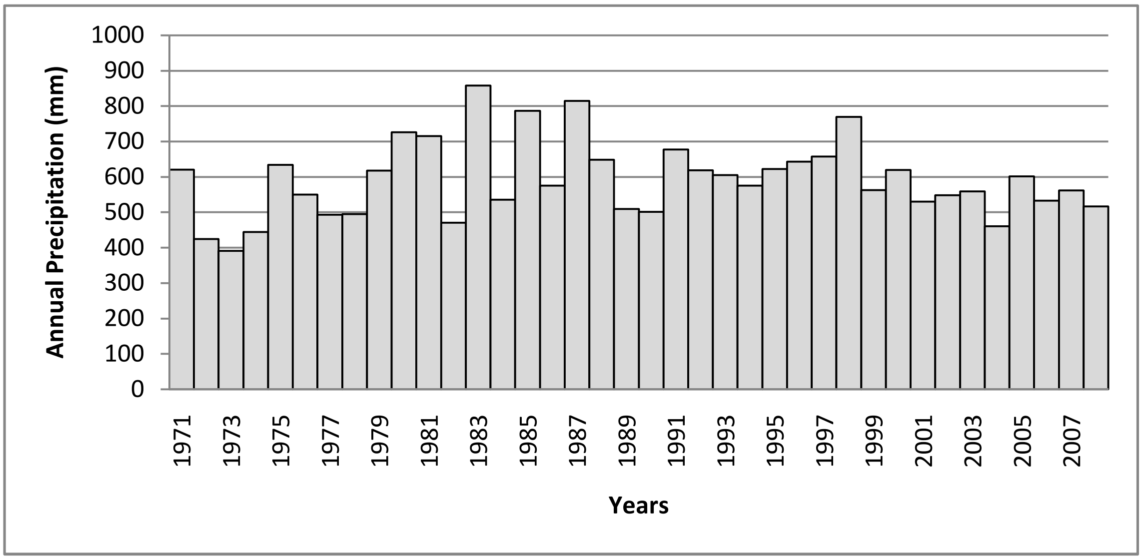


Figure 4.17 Annual precipitations for the period of 1971-2008 measured at Yozgat station. Data is provided from Turkish State Meteorological Service.

On the monthly basis, the lowest precipitation is observed in three months (July, August and September) which are almost one-third to one-fourth of other months (Table 4.1). This is an important evidence for the water management for summer period and may refer to the necessity of construction of some structures to collect water. Possible potential sites for this purpose will be mentioned in the next chapter.

Annual precipitation ranges from 391 mm (year 1973) to 858 mm (year 1983) for the interval 1971 to 2008. The average of all these 38 years is 591.4 mm. This is the thickness of the water collected in one m2. To find the volume of the water this thickness is simply multiplied by the area of the basin. Accordingly the water collected by Büyükkaya basin is 36826478 m^3 (62.27 km^2 * 591.4 mm) and by Yazır basin is 12715100 m3 (21.5 km^2 * 591.4 mm).

Total water, therefore, transferred to Budaközü stream just north of Hattusha is 49541578 m^3 assuming. Evaporation from the surface and seepage into next basin are not considered during this calculation.

Possible Dam Sites

Although there are streams and springs in the close vicinity of Hattusha, it is possible that a permanent water body is always needed for a continuous water supply. For this reason probable dam site is investigated around the city using 1/25000 scale topographic map.

There is a dam constructed about 600 m east of Alacahöyük which is also a Hittite city and close to Hattusha (Figure 4.18). According to the information provided for this dam, capacity of the dam is about 15000 m3. The dam is built almost over a flat area suggesting that deep and narrow valley is not necessary as in the case of recent dams. This dam is an example for the investigated one(s) as far its size and proximity to the settlement is considered.

Figure 4.18 Ancient Hittite dam constructed 600 m east of Alacahöyük to provide water for the city.

Following criteria are applied for the identification of the possible dam sites around Hattusha:

- There are two pond complexes in the city (as will be mentioned in the next section) located to the eastern and western drainage basins of the city. Considering the divide between these ponds, at least two sites for dam construction should exist.
- Elevation of the possible sites should be higher than the ponds to provide a natural flow from the site to the ponds. Considering the topography of the area, the possible sites should be located to the south of the city.
- The site can be located on a small gully or depression because a large construction dam across a major stream is not expected. Although, there are suitable places for the modern dam constructions across both Büyükkale and Yazır streams, these sites are considered for large dams
- There should be some indications at the surface such as spring or related features.
- It should not be far away from the pond.

Water related features are shown in Figure 4.19. There are several springs observed both within and out of the city. These springs are visible on 1/25000 scale topographic maps; however, there is no evidence that the springs were existing during historical times. There is not yet a clear evidence of a construction around these springs for collecting water.

Two streams (Büyükkale and Yazır) are flowing very close to the city. About 1 km of Büyükkale stream is included within the city at its NE corner. Considering the size of their drainage basins mentioned in previous section, one can claim that these streams might be permanent. The streams meet at the point approximately 500 m NW of the city. Therefore, the city is basically located between these two streams. Both streams have a basal elevation lower than the city wall between 20 to 90 m. There is no field data for the use of these streams to provide water for the city.

Two pond complexes (simplified in the figure as two circles) are located to the east and southern part of the city. Detailed characteristics of these ponds will be given in the next section. Here it should be emphasized that, size and location of these pond suggest the presence of larger water structures (dams) out of the city.

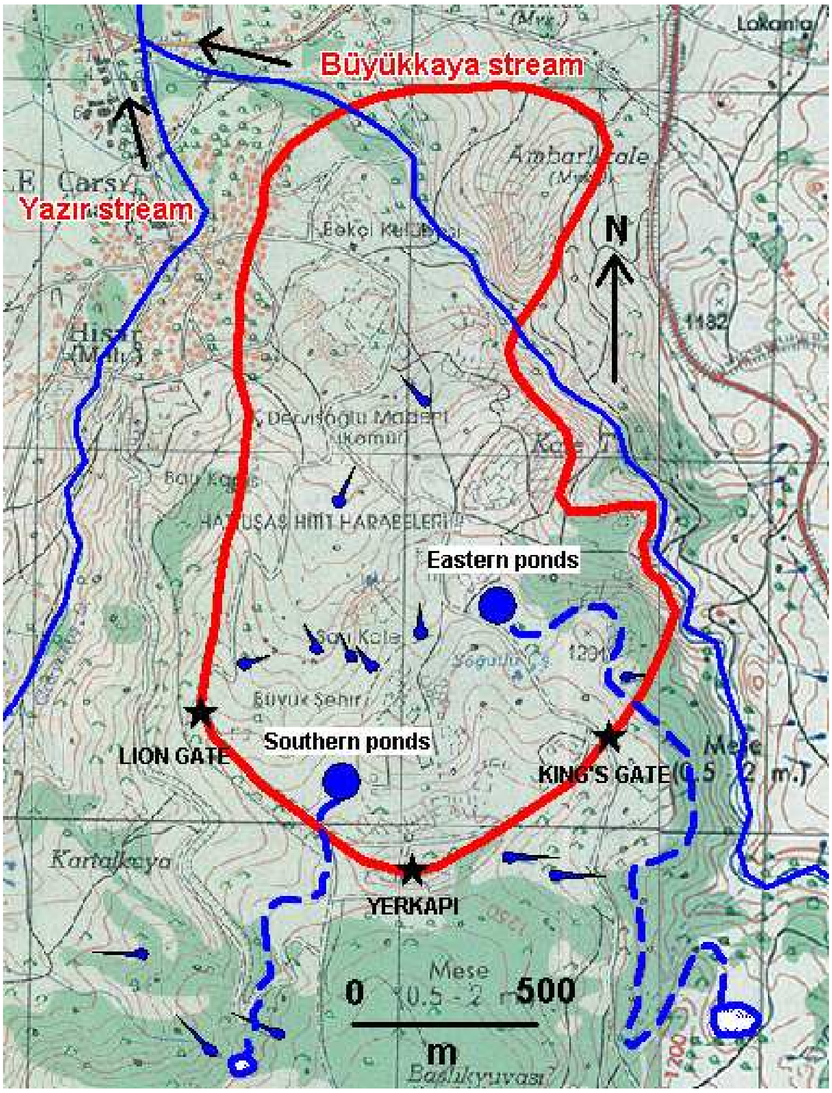


Figure 4.19 Topographic map of the regional area showing the water sources in the vicinity of Hattusha. Red line is the boundary of city, blue symbols are springs, solid blue circles are ponds; circular blue lines are possible water collection sites and dashed blue lines are possible lines of transportation.

Two sites that satisfy the conditions mentioned above are identified. These are located to the SE and SW parts of the city (Figure 4.19).

The first site is located about 1 km south of King's gate (Figure 4.20). Topographic map at 1/25000 scale shows this area as swamp. The swamp is located over a ridge between two creeks flowing northward (parallel to each other) and join Büyükkaya stream 500 m north of the swamp. Major characteristics of this site are as follows:

- The swamp is represented by a semi-circular depression in the middle of the ridge, which is not expected to form under normal erosional conditions.
- There is an elevation difference of 5 m between the swamp and the eastern pond.
- Surface area of the swamp is measured as 0.008 km^2 digitized from 1/25000 scale topographic map.
- The drainage basin of the swamp area is measured as 0.2123 km^2.

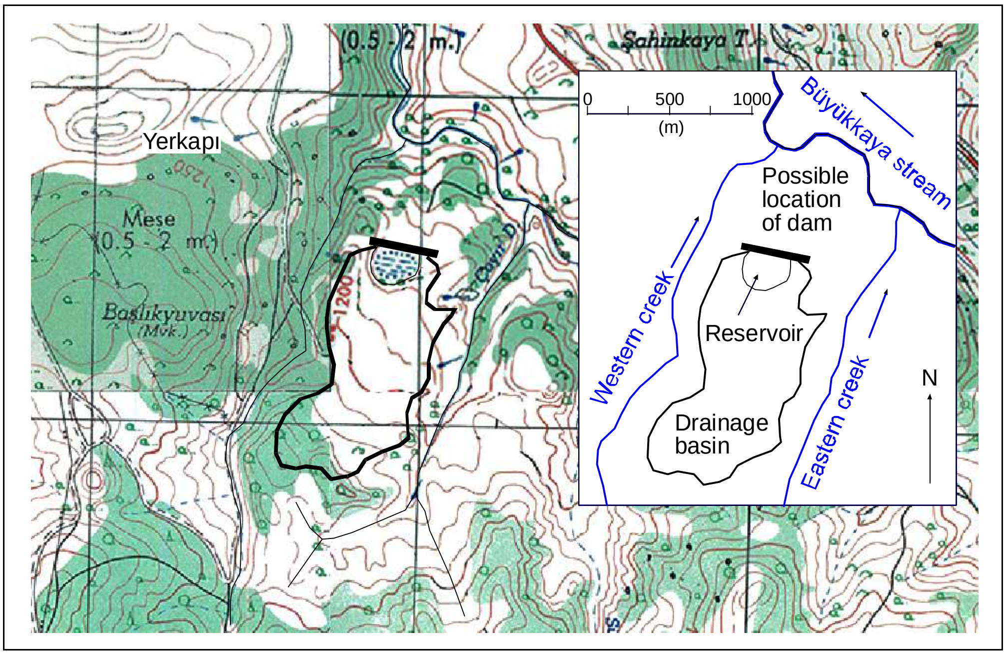


Figure 4.20 Details of the swamp located out of the city in the SW.

- Plan distance between the swamp and the eastern pond is 1207 m. However, considering the transportation in relation to the topography, a distance of 2285 m is estimated. This difference is mostly due the presence of the western creek along the route.
- Seeher (2005) mentioned a system of clay pipes installed to bring water from springs outside the city (Figure 4.21). A pipeline is reported to pass through the city walls below the King's Gate. This is consistent with the suggested path shown in Figure 4.19.

Figure 4.21 Clay pipeline found in Hattusha used to transport the water (Boğazkale museum)

The second place for a possible dam site is about 930 m south of Lion gate, out of the city (Figure 4.19). A close-up view of this site is shown in Figure 4.22. There are few springs in the site towards the upper parts of a gully which is connected to Yazır stream. There is not an obvious field data suggesting the exact location. Even the scale of the topographic map is not enough to locate a reservoir. However, minor undulations of contours, its elevation and distance to the city can be considered as evidences for this site.

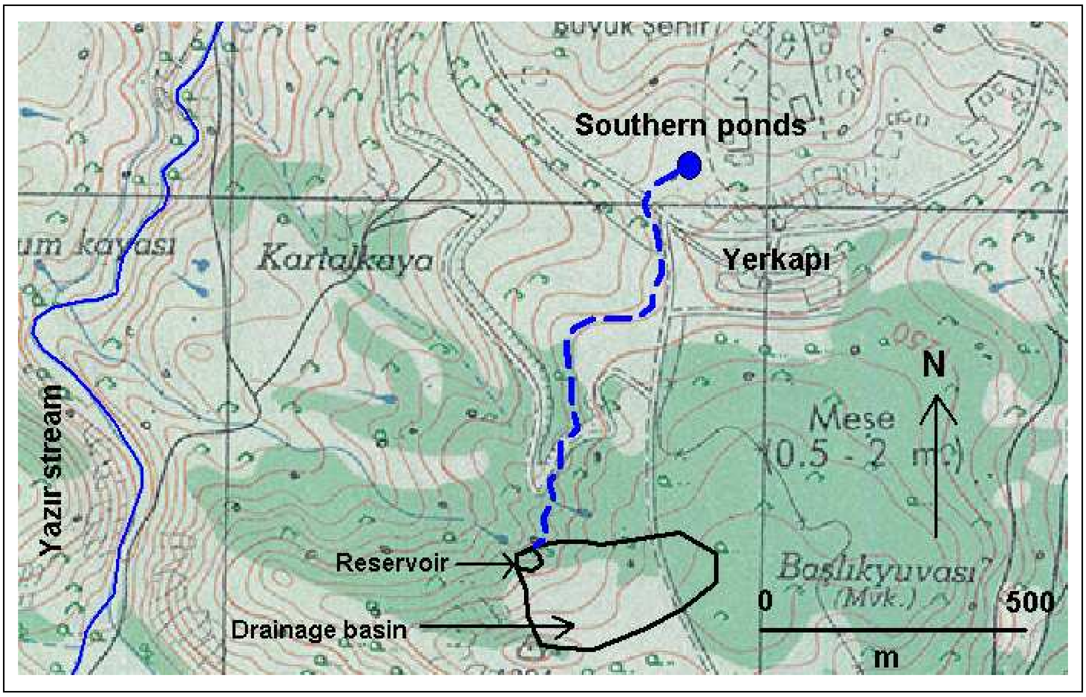


Figure 4.22 Location and general features of the second possible dam site.

Following information can be provided for this site from 1/25000 scale topographic map:

- The site is 5-10 m higher than the southern ponds in elevation.
- A reservoir can be suggested here that has an area of 0.002 km2. The drainage basin drawn according to this reservoir has an area of 0.059 km2.
- Plan distance from the site to the ponds is 747 m. The real distance, however, that follows topographic contours is 903 m.

4.2.2. Internal Water Resources

Two main streams, Büyükkaya and Yazır, are important water elements for Hattusha. As Figure 4.23 indicates, Yazır is flowing in the close vicinity of the ancient city wall, while Büyükkaya is flowing partly inside the city. In the previous section, it is already mentioned that the drainage divide of these streams is passing through the city. Therefore, together with the northern part of Büyükkaya stream, the city is divided into three regions shown as 1, 2 and

3 in the figure. The first and third regions belong to the western and eastern basins of Büyükkaya; the second region to the Yazır stream.

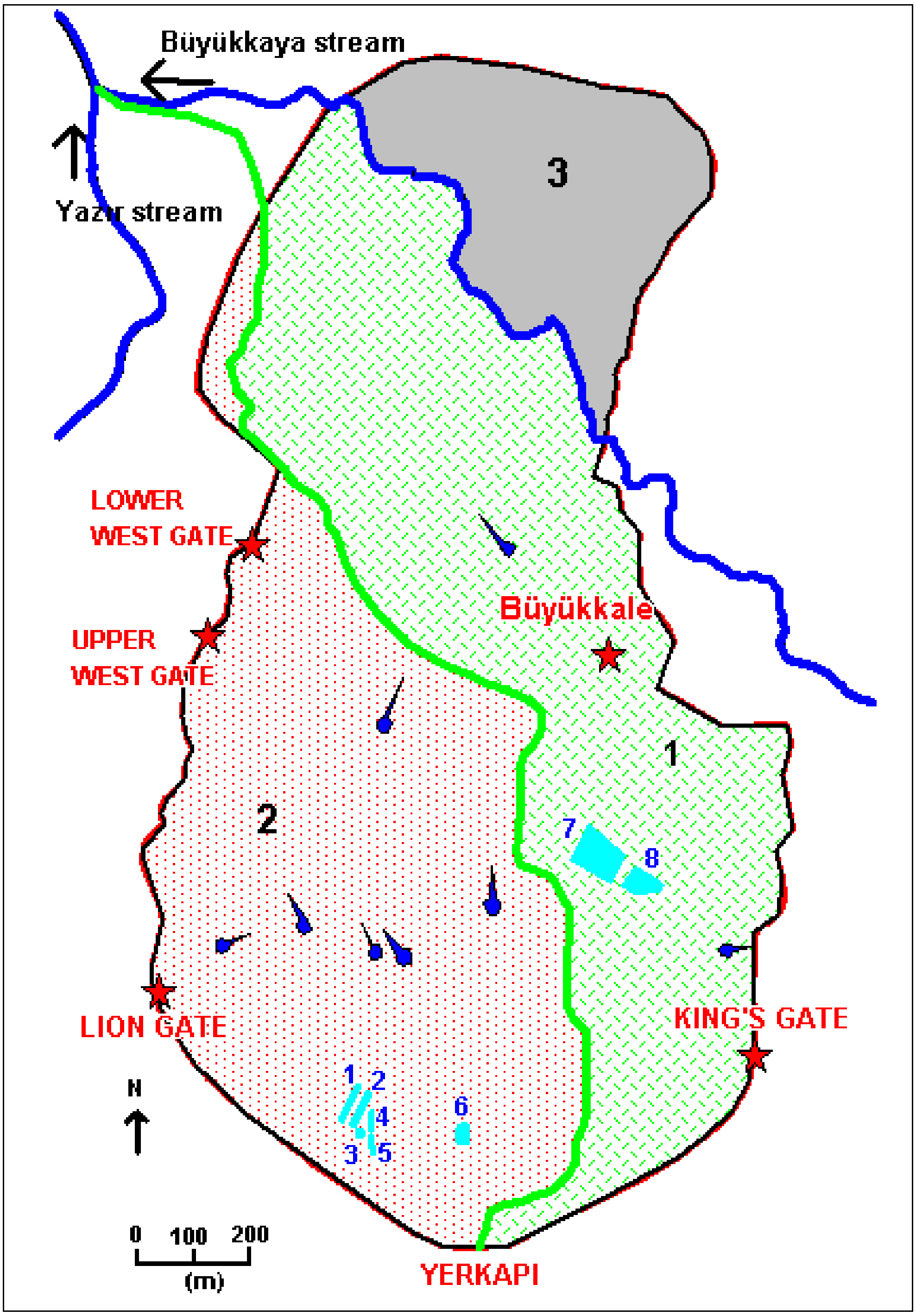


Figure 4.23 Southern and eastern ponds in the local area in relation to sub-basins of Büyükkaya and Yazır streams. Areas 1 and 3 are western and eastern sub-basins of Büyükkaya stream respectively. Area 2 is included in the sub-basin of Yazır stream. Green line shows the drainage divide; blue symbols indicate the springs in the city. Numbers from 1 to 8 represents the ponds.

There are eight ponds located in both southern and eastern parts of the city. These ponds are thought as water basins providing water for Hattusha. The southern ponds are consisting of six ponds that are located at the highest elevations within the city. Their basins are up to 8 m deep (Seeher, 2005). Their areas are calculated as 767 m^2, 788 m^2, 219 m^2, 316 m^2, 310 m^2 and 370 m^2, respectively. Therefore the total area of the southern ponds is 2770 m^2. Assuming that all the southern ponds are in 8 m depth, the total volume of the ponds is approximately 22160 m^3.

In the eastern part, there are two ponds, one of which has an area about 5500 m^2 (Figure 4.24) and the other one is about 2200 m^2 approximately based on the calculated polygonal areas. Their depths are expected to be not more than 2 meters so their total volume is approximately 15400 m^3.

Figure 4.24 General view of the first pond of the eastern ponds

According to the drainage divide within the city, it is obvious that the eastern and southern ponds are located in different regions of drainage basins. The eastern ponds provide water for the first; and southern ponds for the second region (Figure 4.23). The area that each group can supply water is calculated from the topographic map at 1/1000 scale. In order to do this, intervals are assigned for each group to represent the topography below and above the pond. The results are shown in Figures 4.25 and 4.26.

The southern ponds can supply water to the area shown in blue color in Figure 4.25. The red area is higher than the elevation of the ponds (1195 m) which corresponds to the Yerkapı rampart. Although, theoretically all blue areas are below the elevation of the ponds, considering the divide between first and second regions and the river between the first and the third regions it can be concluded that these ponds are used to provide only for the second region.

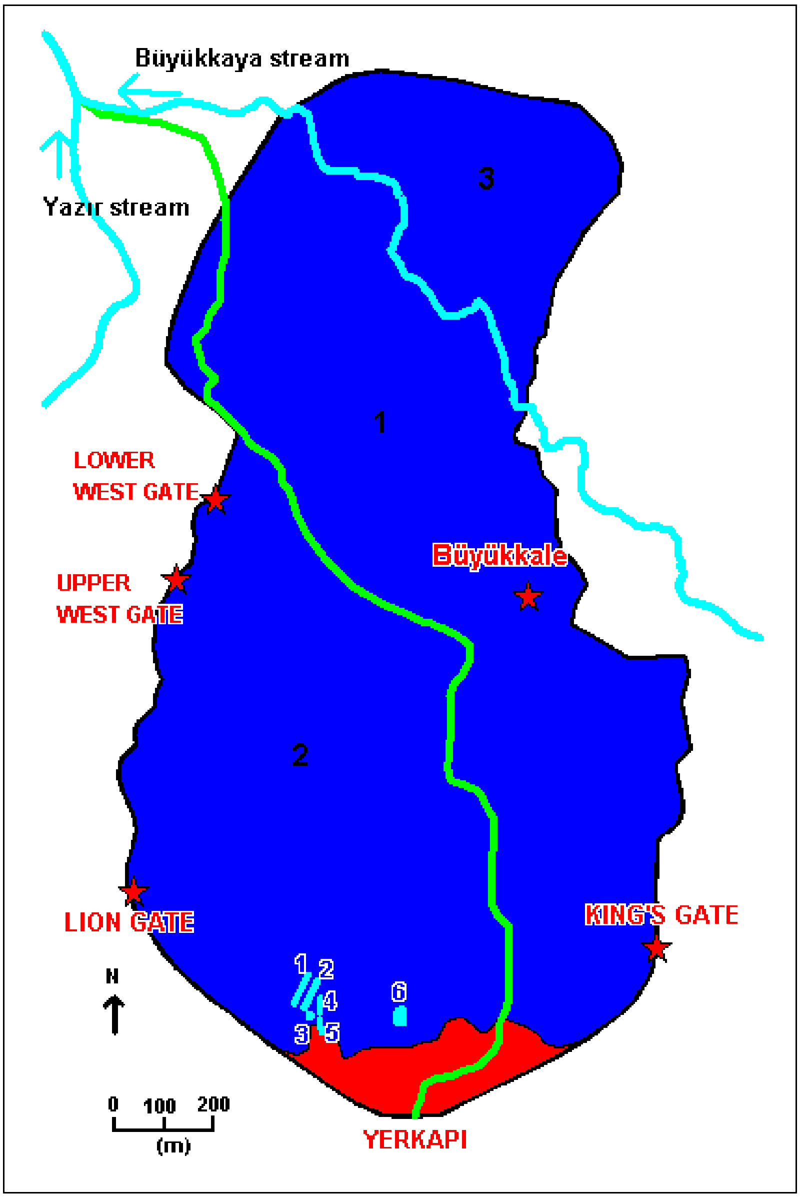


Figure 4.25 Area with elevation less than 1195 that southern ponds can provide water (shown in blue). Red areas are above the ponds. Green line shows the divide of two streams. (For numbers see Figure 4.23).

Elevation of the eastern ponds is 1139 and is 56 m lower than southern ones. The area that these ponds can provide water is shown in blue colour in Figure 4.26. Similar to the topographic characteristics mentioned for southern ponds (divide and river) these ponds can supply water to region 1, under normal conditions. The red area in the figure has an elevation higher than the pond and corresponds to the Yerkapı rampart.

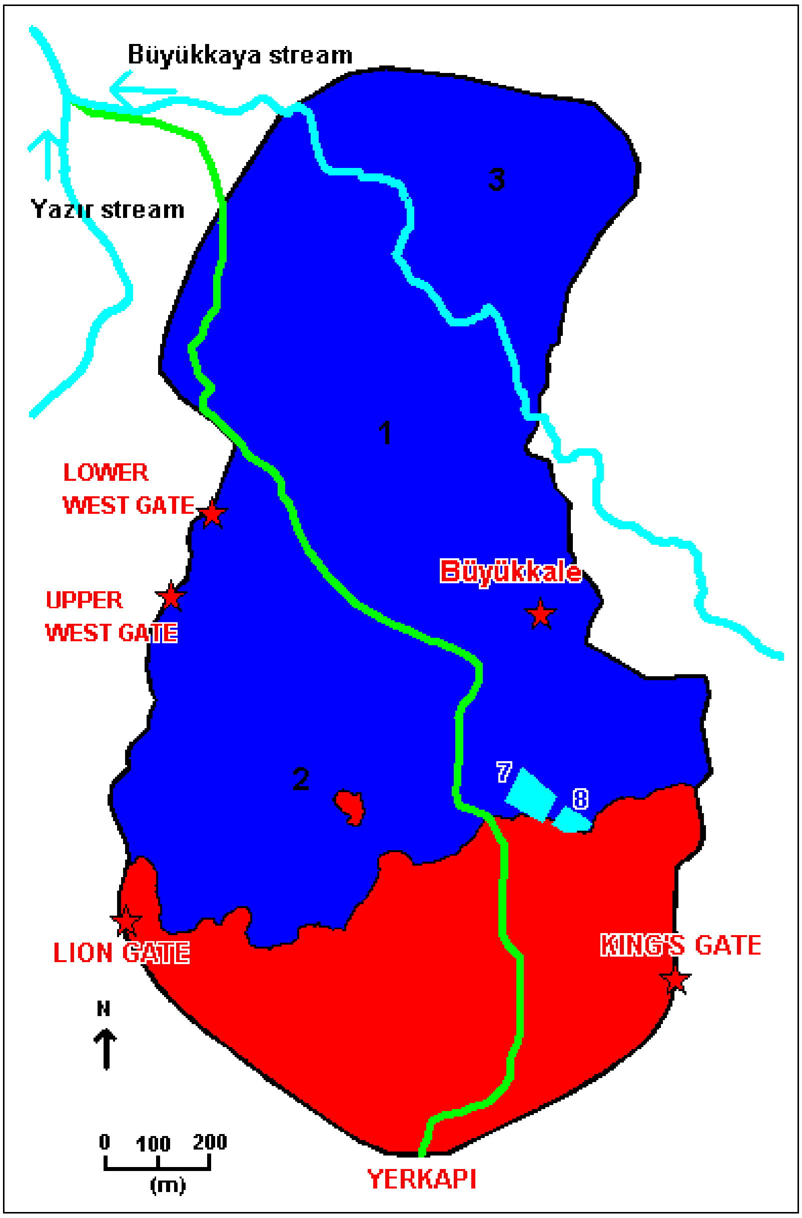


Figure 4.26 Area with elevation less than 1139 m that eastern ponds can provide water (shown in blue). Red areas are above the ponds. Green line shows the divide of two streams. (For numbers see Figure 4.23).

4.3. Visibility Analyses in Hattusha

The visibility analyses in this thesis are carried out using Viewshed Analysis tool in MapInfo Professional. Simple viewshed calculations are used to produce a classified grid that shows the grid cells that are visible and invisible from an observation point**.** The analyses are performed both for the local study area which is bounded by the city wall and the regional area that is composed of four 1/25000 scale maps. The parameters selected in visibility analyses are viewpoint height and viewing radius. By considering the height of an average person, viewpoint height is taken as 2 m. Three different analyses are carried out in this section:.

1. In the first analysis 18 points are selected along the city wall (except Büyükkale) assuming that the observers are standing above the city wall and looking towards the city. Viewpoint height is taken as 12 meters and so that the approximate height of the city wall which is assumed as 10 meters is added to viewpoint height.

2. In the second analysis, the aim is to show the areas that are visible to a person entering to the city from the 3 main gates (Yerkapı, Lion Gate and King's Gate) and also to the King standing at the highest point of Büyükkale. For the gates, it is assumed that a person is standing just in front of the wall and looking toward the city. The viewpoint height is taken as 2 m in this analysis.

3. The third analysis aims to determine the visible areas outside the city to the observers standing above the wall. This is the analysis performed by 1/25000 scale. Three main gates are selected for this analysis and the viewpoint height is also taken as 12 m.

Viewing radius is the radius of the distance where the visibility analysis will be carried out. The radius is taken as 30 km both for local and regional analyses considering the longest margin of the regional area which is approximately 28.5 km. The vegetation factor and weather conditions are not taken into account in this analysis.

Analysis 1:

Eighteen viewpoints where the local visibility analyses performed are selected on the city wall (Figure 4.27). The points are chosen randomly except for six points (points no: 1, 3, 6, 14, 15, 17) which are the locations of five gates and the royal citadel of Büyükkale. Other points are selected so that the wall is divided into almost equal segments.

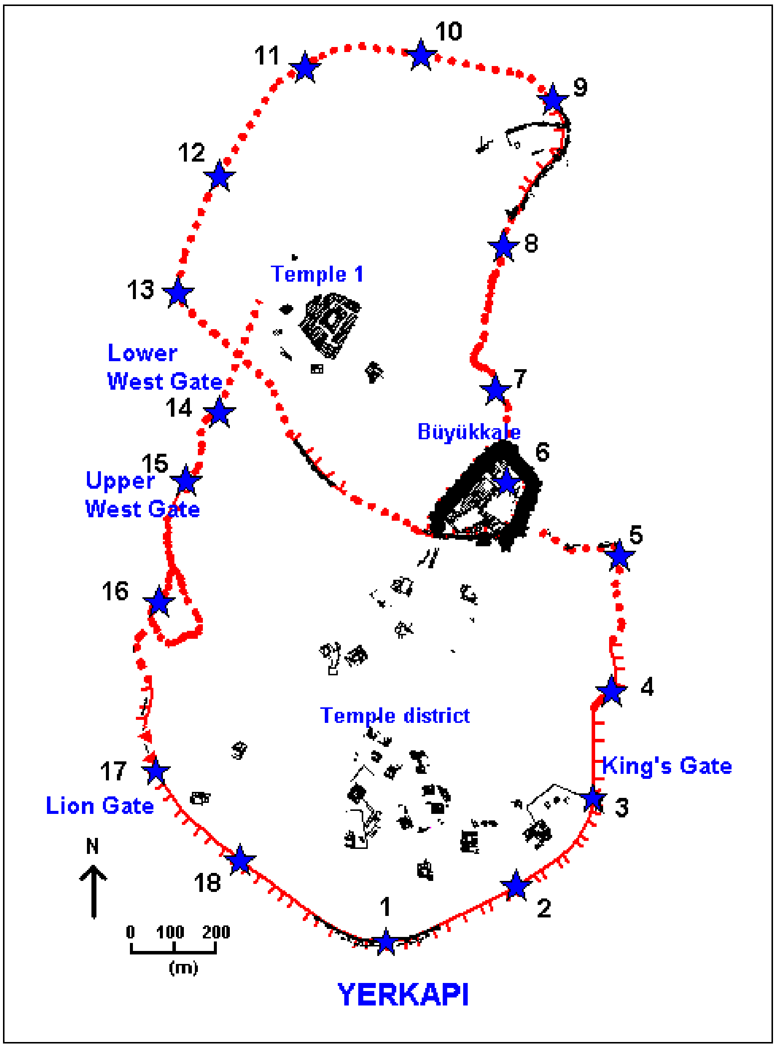


Figure 4.27 Location of eighteen points selected to prepare viewshed maps.

Eighteen maps are prepared for each point on the wall. These maps are illustrated in Appendix B and summarized in Table 4.4. Following observations are based on the results given in the table:

- Visibility of the points range from a minimum of 8.7 % to a maximum of 71 %.
- Overall average for the visibility is 36.0 % suggesting that a random point can see one-third of the whole city.
- Visibility of the points on the eastern segment of the wall is very sensitive to topography and can change dramatically as location shift for a short distance (particularly the points 4 to 9).

Table 4.4 Results of the viewshed analyses carried out for eighteen points located on the city wall (except Büyükkale).

Point No	Area visible (m2)	Percentage of visible area	Elevation of point (m)
1 (Yerkapı)	846916	46.4	1249.0
2	307174	17.4	1210.0
3 (King's gate)	285338	16.0	1186.0
4	240587	13.0	1159.0
5	158355	8.7	1079.5
6 (Büyükkale)	1253255	69.6	1138.5
7	211595	11.6	1048.5
8	1273825	71.0	1096.0
9	246826	13.0	1063.5
10	1049547	58.0	1006.5
11	815452	44.9	967.0
12	778074	43.5	983.0
13	386486	21.7	984.0
14 (L. West Gate)	717392	39.1	1039.5
15 (U. West Gate)	774597	42.0	1073.0
16	1140588	62.3	1137.0
17 (Lion gate)	621155	34.8	1164.0
18	620462	34.8	1193.5

- Visible areas of the points on the western segment of the wall are more or less consistent and compared to the eastern ones have larger values.
- In the last column of the table, elevations of the points are given. These elevations are plotted against visibility to seek a relationship between the two values. According to the result of this plot no one can claim that the visibility increases as the elevation increases (Figure 4.28).

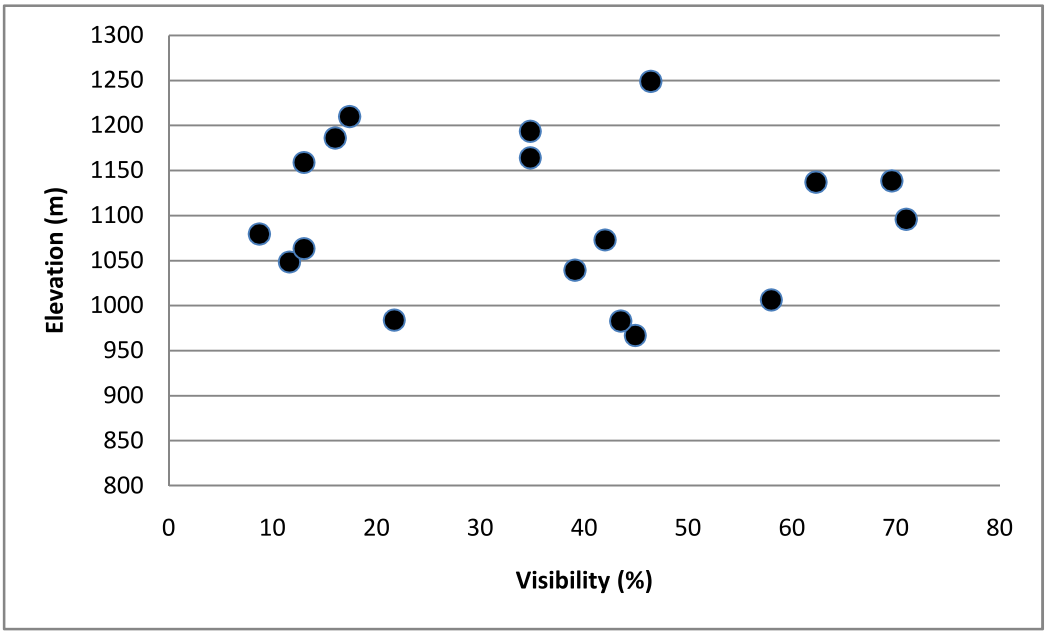


Figure 4.28 Elevation plotted against the visibility for eighteen points.

All these eighteen maps are combined to produce a single map that will indicate a composite viewshed of the city from the wall. This map is shown in Figure 4.29. The green areas (1.807.590 m^2 in total) are visible and the white areas (14.660 m^2 in total) are invisible parts of the city. As seen in the figure, only some minor areas between the Temple district and Büyükkale, and some places towards the NE margin of the city are not visible. Total area covered by these places is about 0.8 % of the whole city.

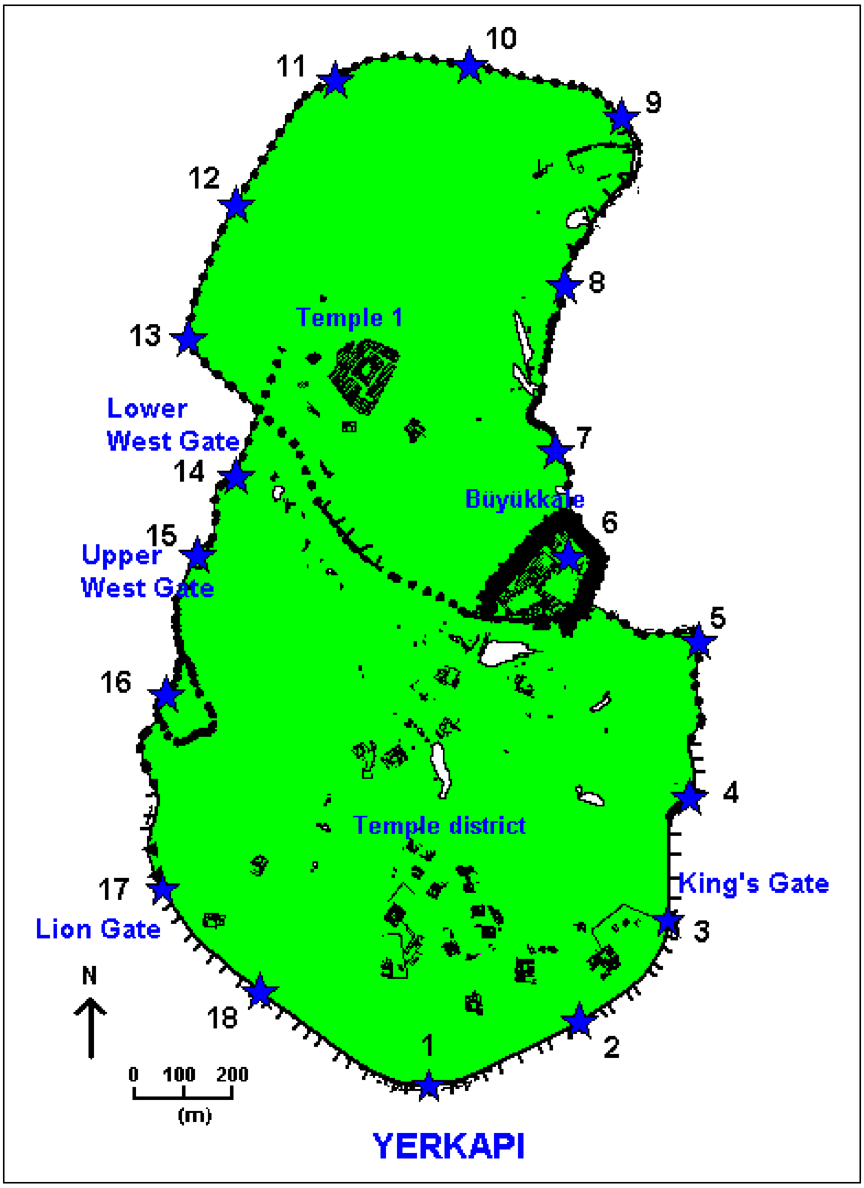


Figure 4.29 Total visible area from the selected 18 points. The green colour represents the visible area while the white colour shows invisible regions.

Analysis 2:

Second analysis is carried out for three main entrances of the city (namely Yerkapı, Lion Gate and King's Gate) and royal citadel of Büyükkale. It should be noted that these four points are used in the previous analysis. However, different maps are generated because in the previous analysis the viewpoint height was 12 m; but in this analysis this height is 2 m. Results of the analysis are shown in Figure 4.30 and summarized in Table 4.5.

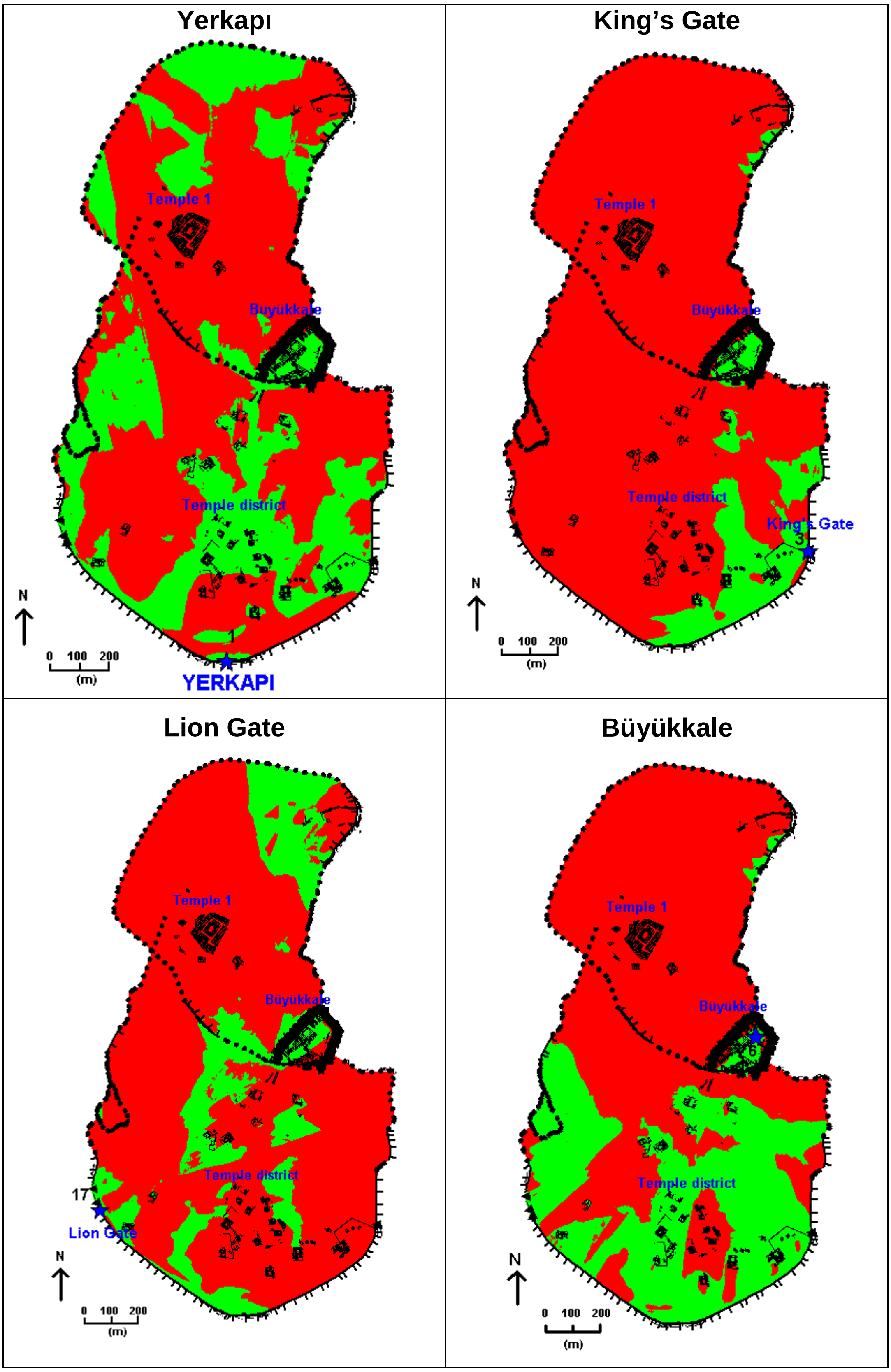


Figure 4.30 Viewshed maps showing the visible areas from the three main gates and Büyükkale. Green colour represents the visible area while the white and red colours show the invisible regions. Viewing height is 2 m.

The results suggest that visibility of the gates greatly varies and has in general low values. The biggest value belongs to Yerkapı with a visible area of 36.2 %. Temple 1, for example is not visible from any point. On the other hand, the great citadel of Büyükkale is visible from the gates. From Yerkapı, other two gates are visible, but these two gates cannot see each other. The main reason for this low values can be attributed to the presence of drainage divide within the city and the inner wall both of which behave as barrier. The analysis also suggests that Büyükkale has the second biggest value in terms of visible area. The selected point dominates the three gates and sees approximately half of the upper city.

Table 4.5 Summary of the results of viewshed analysis carried out for three gates and Büyükkale for the interior of the city.

	Area visible (m2)	Percentage of visible area	Elevation of point
Yerkapı	652879	36.2	1239
King's gate	192003	10.1	1176
Lion gate	363940	20.3	1154
Büyükkale	609337	33.3	1128.5
TOTAL	1094680	60.0	

Analysis 3:

The last viewshed analysis is carried out for three main gates (Yerkapı, King's gate and Lion gate) to observe the visible areas out of the city. It should be remembered that there is a difference in the elevation datum plane for 1/25000 and 1/1000 scale maps. Therefore elevations of the points in this analysis are different from the previous one. Resultant maps of this analysis are shown in Figure 4.31 and summarized in Table 4.6.

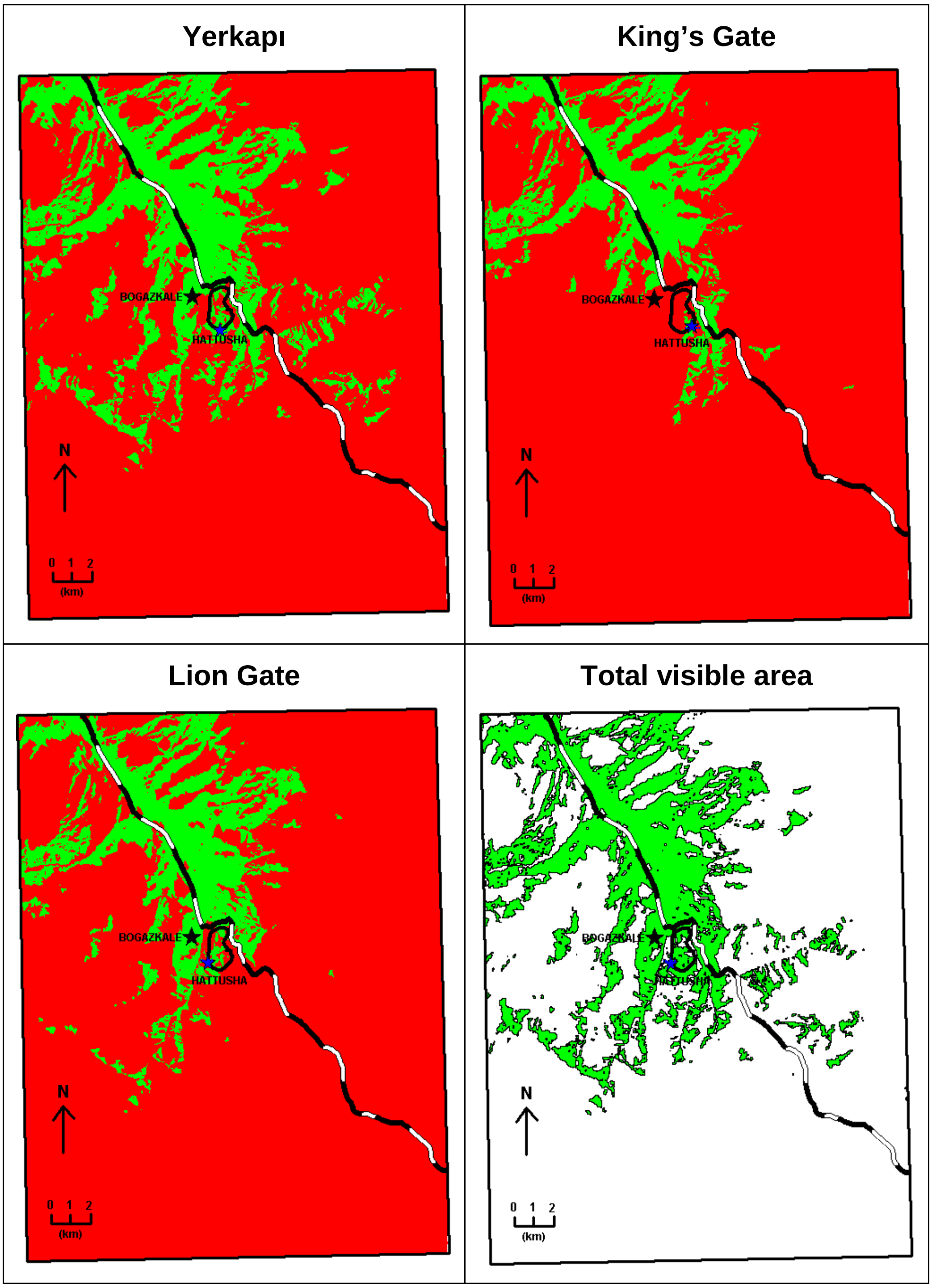


Figure 4.31 Viewshed maps and the total visible area from the three main gates. Green colour represents the visible area while the white and red colours show the invisible regions. Viewing height is 12 m.

Table 4.6 Summary of the results of viewshed analysis carried out for three gates for the exterior of the city.

	Area visible (km2)	Percentage of visible area	Elevation of point (m)
Yerkapı	104.6	16.7	1294
King's gate	65.5	10.5	1220
Lion gate	75.5	12.1	1207
TOTAL	108.7	17.5	

Following observation can be made based on the results of this analysis:

- The area visible by Yerkapı is almost equal to the total area observed by all points.
- The area observed in all points coincides with the low topographic region located to the NW of Hattusha. Present road from the site to Ankara-Çorum highway is located almost in the central part of this area.
- Most of the area along the road to Yozgat direction (SW of the city) is not visible.

CHAPTER 5

DISCUSSION

Hattusha ancient city is investigated with respect to its morphological properties. The main features considered in this study are elevation, slope and aspect parameters of local area and its main building complexes in relation to regional area and the local area, respectively. The city wall is examined in accordance with the topography and visibility analyses are performed for the points above the city wall. The city is also investigated in the context of water resources inside and possible sources outside.

5.1. Quality of Data

Topographic data: Four data sets are used in this study. These are topographic and cartographic data of both regional and local study areas obtained from General Command of Mapping (Turkey) and Hattusha excavation team, respectively. The digital data consist of topographic contours at 1/25000 scale for regional area and 1/1000 scale for local area. The cartographic data, on the other hand, include water related data and locations of the city components.

Cartographic data of the regional area covers four 1/25000 scaled topographic maps (H33-d1, d2 and I33-a1, a2) centering Hattusha. These four maps are all registered according to four ground control points using the Universal Transverse Mercator (UTM ED-50, Zone 36) coordinate system. Then, they are merged to get a continuous layer. During registration and merging process, maps can shift, so that the results may change in negligible amount. For the local area, most of the cartographic data also exist in digital format at 1/1000 scale.

Two important points exist about the raw data:

- Two digital data sets have different coordinate systems.
- Elevation values are different in the two sets.

The coordinate system in the local data has its own reference with an origin (0, 0) somewhere southwest of Hattusha. This system is not converted to the regional one because of difficulty to find suitable ground control points at two scales.

Elevation is changing from 999 to 1284 m based on the map prepared by clipping out the boundary of local area from the map of regional study area at 1/25000 scale. On the other hand, elevation of the local area ranges from 943 to 1237 m according to 1/1000 scale topographic map. Therefore, regional topographic elevations seem to be about 40 m higher than the local ones. However, this elevation difference is not continuous over the whole area. At some places, it can be more or less than this amount.

Considering these two differences; regional and local data sets are not overlapped in order to prevent some mistakes in the results. Therefore, they are investigated separately within their own original coordinate systems. On the other hand, the local boundary and some cartographic information such as the main gates are visually defined on the regional area. Therefore, they may not represent the exact locations and cause some changes in the results.

City components: The city components form an important part of this thesis. At the beginning of the thesis, an attempt is made to evaluate the elements of the city in relation to the topography. However, there is not yet detailed information on the distribution of the city elements such as “public buildings”, “private houses”, “water system” etc. Therefore, three areas with dense buildings (Temple District, Temple 1 and Büyükkale) are randomly selected for the analyses. There are, however, other structures that are not included here. A more detailed analysis can be carried out if there is a better classification of the city elements.

The polygons drawn to represent the areas of the city components are products of visual interpretation. Thus, minor changes in the borders of the polygons are possible. In addition, because the topographic contours inside these components were missing in the local digital data, they are drawn approximately.

City wall is another structure used in the analysis. The whole path of this wall did not exist digitally in 1/1000 scale map, particularly in the northern half of the city. The missing parts are drawn based on the analogue map of the city.

5.2. Analyses and Results

Analyses in this study are conducted under four titles; morphological analyses, investigation of city wall, investigation of water resources and visibility analyses.

5.2.1. Morphological analyses

Morphological analyses are carried out based on Digital Elevation Model and its derivatives, namely, elevation, slope and aspect. Each of these parameters are discussed below for both regional (1/25000 scale) and local (1/25000 scale) features.

Elevation: At regional scale, the selection of the city in relation to elevation is shown in Figure 3.6. Although the region in the vicinity of Hattusha provides an elevation in the range of 850 to 1550, the interval of 1000-1250 m is preferred for the settlement. The elevations between 850-1000 m and 1250-1550 m are avoided as indicated by negative values in the histogram. The interval, for example at 1300-1350 m, has a value of minus 13 suggesting that although the region provides considerable amount of area at this interval, they did not prefer to settle here.

Topography of the local area ranges from 943 to 1237 m and the percentages of the intervals are close to each other. In other words, the area is distributed over the whole region homogeneously (Figure 3.5). However, it can be seen that the three main regions are located on specific elevation intervals within the local area (Figure 3.28). Temple 1 covers only the interval of 980-1019 m, Büyükkale, where the royal citadel is built; falls in the interval of 1100-1139 m. Temple district exist at the highest elevation interval (1140-1219 m) relative to the other features.

Slope: Slope values of the whole area and the local area are shown in the histograms in Figures 3.8 and 3.10, respectively. Subtracted histograms (Figure 3.11) indicate that the values within a range of 0 to 5 degrees in regional area are much greater than the local one. In contrast, slope values between 6 and 15 degrees is more abundant in the local area. These values suggest that the low degree slopes especially from 6 to 15 degrees are mostly preferred to settle. On the other hand, lower slopes within a range of 0 to 5 degrees, which can be considered nearly flat areas, are avoided. For the values greater than 15 degree, difference is not as significant as these two intervals.

The local area has a wide range of slope value from 0 to 65 degrees. It has the greatest percentage value of 6 degrees with 7%. Almost 75% of the pixels fall into the range of 4 to 21 degrees (Figure 3.10).

For Büyükkale, slope values change from 0 to 38 degree according to the histogram (Figure 3.30). Approximately, 64% of Büyükkale polygon is between 3 and 15 degrees with the greatest value of 9 % at 4 degrees.

The slope values in the region of Temple 1 are confined to a narrow interval relative to the other regions. The values change from 2 to 10 degrees where the maximum percentage occurs at 4 degrees with 25 % (Figure 3.30).

Within the temple district region, the pixels having slope value from 4 to 14 degrees cover almost 80 % of the area. Pixels with slope of 6 degree have the greatest percentage with 15 %.

According to slope values, it can be claimed that the slope values are changing from 2 to 15 degrees for all main building complexes and that low sloping areas are preferred for the construction of major buildings. There are, however, other buildings not included in this study. A better understanding of the slope will be possible after all these buildings are processed.

Aspect: For all aspect analyses, the slope amount less than 2 degrees are assumed to be flat. Another interval may be proposed by somebody else, and that may produce a different output. Although, the resultant aspects maps (Figures 3.12, 3.14 for regional and 3.20, 3.31 for local areas) are based on 1-degree interval, the histograms prepared from these maps have 10-degree intervals. Therefore, the aspects values in histograms are classified into 37 groups one of which corresponds to flat areas.

On the regional scale, there is not a well defined direction of the slope for the area as indicated by the histogram in Figure 3.13. There is however, a minor increase in the directions of east and west. This is due to the fact that the rivers are dominantly flowing towards the north and the south, therefore producing ridges in the same direction. The dominant direction of slope in Hattusha city, on the other hand, is north, northeast and northwest (Figure 3.15). Subtracted histogram (Figure 3.16) clearly indicates that:

- Flat areas are avoided as indicated by minus. It should be noted that the flat areas have maximum negative values in the histogram.
- The directions in 300 to 070 that correspond to northwest, north and northeast, have positive values. Therefore this interval is preferred in the area for the selection of the site.

For the local area, the comparison of the aspect values is shown in Figure 3.32. Areas of Temple 1 and Temple district show similar patterns with the slope directions of the pixels mostly towards the north. Within the region of Temple 1, there is almost no pixel considered to be flat. Interval of 0-20 has a value about 63% and 350-359 has about 16%. For Temple district; maximum percentages occur at interval of 0-9 degrees and 350-359 degrees with 10% and 13%, respectively. Büyükkale shows a heterogeneous distribution in slope directions and the values change from flat to 360 degrees. The greatest percentages occur in northwest, west and south, while there are variations between these directions. Interval of 310-319 has the maximum value of 8 %. The main reason for this variation is that Büyükkale is built over a hill both at the hilltop with almost flat pixels and on the flanks with gentle slopes.

5.2.2. City Wall Analyses

Two analyses are carried out for the city wall. The first is to investigate the relationship between the path of the wall and topography. In the second analysis an attempt is made to estimate the volume of the city wall approximately between the Lion gate and the King's gate.

Path of the wall: The relationship between the path of the wall and topography is investigated in six selected regions (Figure 4.1). Results of the analysis indicate that the first region including Yerkapı rampart represents the best section that totally follows the topographic divide. Other five regions, however, show a different tendency that does not fit to topography. Figure 5.1 shows the major deviations of the city wall from the divide. Following observation can be made based on this figure:

- The southernmost part of the wall around Yerkapı rampart is the only obvious wall segment that fits the topography. The wall in this section is totally over the divide. However, the flat surfaces north, northeast and northwest of the rampart suggest that the area was levelled before the construction of the wall.

- Certain deviations of the wall from the divide are observed to the north of Lion gate, King's gate, in the NE corner of the city and around Kesikkaya locality. The common characteristics all these segments are the shift of the wall so that the area of city is enlarged and a hill is included within the city. Therefore a total of 49136 m^2 (5 hectares) is added to the city.

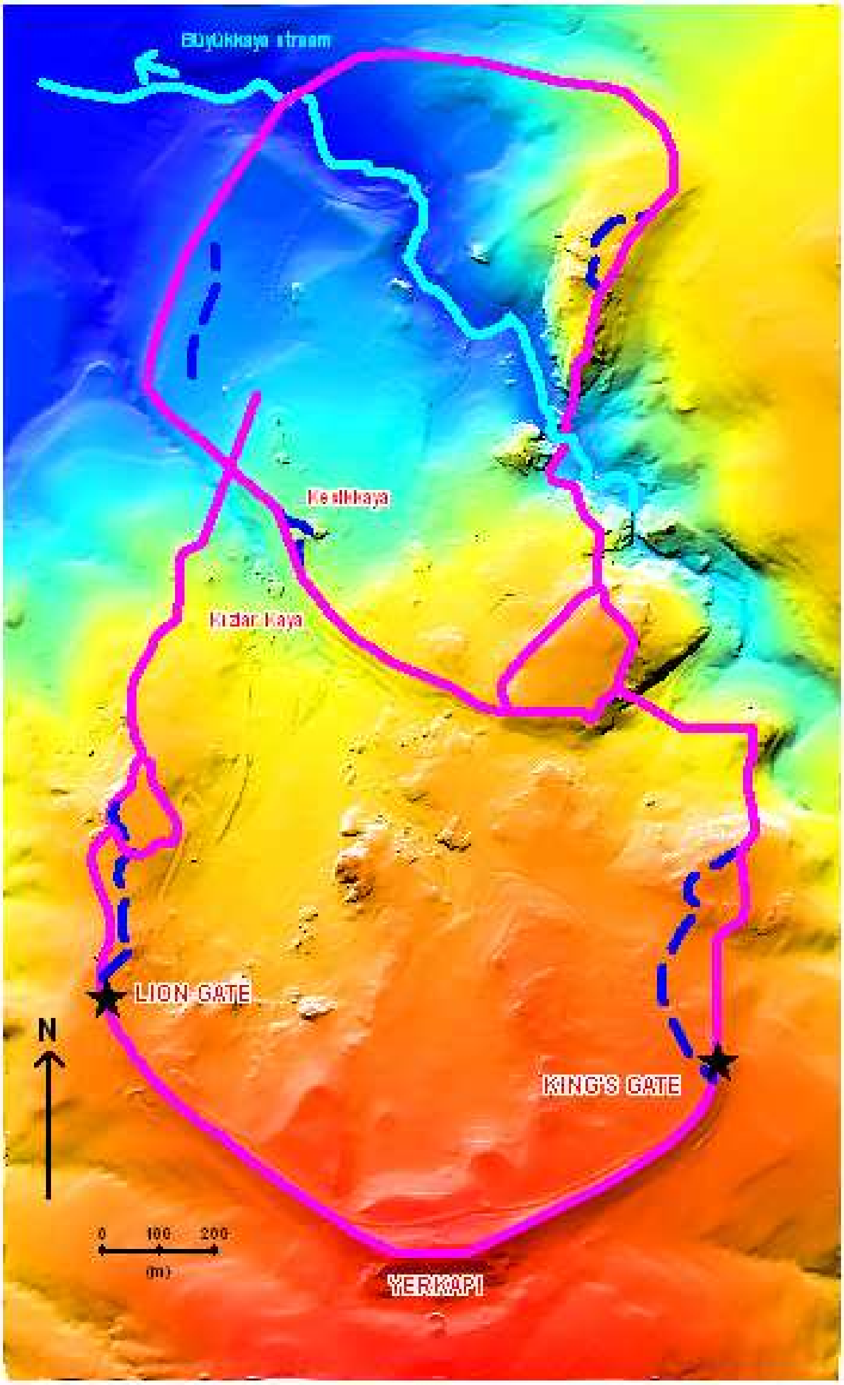


Figure 5.1 Present city wall (purple) and sections of the wall deviated from the divide (dashed blue).

- Since the new paths for the deviated segments are lower than the divide, an artificial depression is expected to form between the wall and the divide. Such depressions are very obvious north of King's gate (Figure 4.3), north of Lion gate (Figure 4.4), and in the NE corner of the area (Figure 4.7). The walls in these segments behaved like a barrier and blocked the natural flow of water. Therefore, certain structures are supposed to exist to drain the water beneath the wall at the lowest elevation of these depressions.
- The wall is built 170 m shorter by deviating it from the divide at three localities (91 m north of King's gate; 28 m north of Lion gate; and 51 m NE corner of the area). This value corresponds only for the segments analyzed in three regions for the outer wall. The inner wall, on the other hand, is 41 m shorter than the ideal one due to its deviation near the Kesikkaya locality.
- In the NW part of the city the wall deviates considerably from the divide (Figure 4.8). The whole area is modified in this part and an artificial divide is created by the construction of the wall. A large depression is formed with dimension of 199 by 131 m and a present depth of 3.5 m.
- Along two segments no analysis is made due to the lack of data. These are located to the north of the city and to the north of Büyükkale. In both segments the wall is expected to cross the Büyükkaya stream.

Volume of the wall: The volume of the city wall approximately between Lion and King's gates is estimated in this study. Reason for the selection of this segment is simply because the wall is best preserved along this segment. During the calculation of the volume two surfaces are used that belong to present and ancient topography. Ancient topography is estimated by removing the wall and smoothing the contours (Figure 4.11).

Calculations indicate the area modified by the construction of the wall is 130682 m2 (13 hectares). Volume of the body in this area is 613966 m^3. Considering the collapse of the original structure and the erosion acting in the area for more than three millenniums it can be concluded that the original volume was much more than this.

5.2.3. Water Resources

Being the capital city of an empire a sophisticated water system is expected to exist within Hattusha. Presence of large ponds in the city might be considered as an evidence for this system. Capacity of eastern ponds is estimated at 15400 m^3 based on surface area (total of 7700 m^2) and a depth of 2 m. The southern ponds, on the other hand, have a capacity of 22160 m^3 (surface area: 2770 m^2; depth: 8 m). Both pond systems alone have a capacity greater than the dam constructed for Alacahöyük (Figure 4.18).

These ponds should not be expected to be filled with rainfall because they have very small drainage basins. Therefore, other external structures should be expected to feed these ponds.

Two possible locations are suggested in this study one for the eastern and the other for the southern ponds (Figure 4.19). Their total drainage basin is 0.2713 km^2. These sites, however, are not tested in the field and need to be supported by other evidences.

Another interesting feature of the ponds is their locations within the city. The ponds are located at the elevated parts of the city so that they can supply water to most of the city. The eastern and southern ponds belong to two sub-basins separated by a divide that passes through the city almost in N-S direction. Therefore, it can be concluded that these ponds were serving to different parts of the city. Details of their function can be better understood by additional information provided by excavations such as the locations and routes of the pipes within the city (Figure 4.21).

5.2.4. Visibility analyses

Visibility analyses are performed for both inside and outside the city. The aim is of this analysis is to emphasize the importance of such analysis for the archaeological sites.

In all viewshed maps, viewing radius is taken as 30 km considering the longest margin of the regional area which is approximately 28.5 km. The vegetation condition, limitations related to human factor and weather conditions are not taken into account in this analysis. In addition, elevations of common points which are used in visibility analyses inside and outside the city are different because of the elevation difference in 1/25000 and 1/1000 scale maps.

In the first set of visibility analyses, 18 points are selected and viewshed maps are created by taking viewpoint height as 12 m. Six of these points are selected on purpose because of being archaeologically important locations. These points are Yerkapı, King’s Gate, Lion Gate, Lower West Gate, Upper West Gate, and Büyükkale. However, other 12 points are selected so that all the points cover the whole city wall and exist at visually equal distance from each other. The resultant viewshed map (Figure 4.29.) shows that; 1.807.590 m^2 (1.8 km^2) can be seen by all points in total. However, regions that cannot be seen from any points cover 14.660 m^2 (0.014 km^2) in total. The invisible areas which are indicated as white in Figure 4.29 are mostly within the upper city.

The second set of visibility analyses are carried out to show the areas that are visible to a man entering to the city from the 3 main gates (Yerkapı, Lion Gate and King’s Gate) and also to the King standing at the highest point of Büyükkale. The viewpoint height is taken as 2m. Accordingly a man standing at:

- Yerkapı, 36.2 % of the city with an area of 652879 m^2 is visible.
- King’s Gate, 10.1 % of the city with an area of 192003 m^2 is visible.
- Lion Gate, 20.3 % of the city with an area of 363940 m^2 is visible.

- Büyükkale, 33.3% of the city with an area of 609337 m^2 is visible.

For the last set of visibility analyses, three main gates (Yerkapı, Lion Gate and King's Gate) are selected to determine the visible areas to an observer standing in front of the gates and looking out of the city. Because there is a difference in the elevation datum plane for 1/25000 and 1/1000 scale maps, elevations of the points in this analysis are different from the first one. The resultant viewshed maps show that, the area visible by Yerkapı is almost equal to the total area observed by all points. The area observed from all points is located to the NW of Hattusha and the present road from the site to Ankara-Çorum highway is located almost in the central part of this area.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The data obtained as a result of this study will be discussed in four sections which are; morphological analyses, city wall analyses, water resources and visibility analyses. In the fifth section, recommendations will be given.

6.1. Morphological Analyses

Morphological analyses are conducted for both regional and local area based on elevation, slope and aspect parameters.

For regional analyses;

- According to the subtracted histograms for elevation values; interval of 1000-1250 m is preferred to settle. On the other hand, elevations between 850-1000 m and 1250-1550 m are mostly avoided.
- Low degree slopes especially from 6 to 15 degrees are mostly preferred to settle. On the other hand, lower slopes within a range of 0 to 5 degrees, which can be considered nearly flat areas, are avoided. For the values greater than 15 degrees, difference is not as significant as these two intervals.
- The dominant direction of slope in Hattusha city is North, Northeast and Northwest. Elevation map of the local area is also supporting this result as it shows a decreasing attribute in elevation values from North to South. However, percentages of aspect values for East, South and West directions are greater in regional area relative to the local one. In addition, ratio of the flat areas in regional area is much greater than the local area. As a result, north, northeast and northwest facing slopes are preferred for Hattusha city to settle. On the other hand, the other directions and flat landforms are avoided.

For local analyses;

- The three main regions (Temple 1, Temple district and Büyükkale) are located on specific elevation intervals within the local area. Temple 1 covers only the interval of 980-1019 m, Büyükkale, where the royal citadel is built; falls in the interval of 1100-1139 m. Temple district exist at the highest elevation interval (1140-1219 m) relative to the other features.
- As the slope values are changing from 2 to 15 degrees for all main building complexes, low sloping areas are preferred for the construction of major buildings.
- Slope directions for the areas Temple 1 and Temple district are mostly toward north and it is convenient with the local area. However, Büyükkale shows a heterogeneous distribution in slope directions and the values change from flat to 360 degrees.

6.2. City Wall Analyses

- Five regions are detected where the city wall deviates from the topographic divide resulting in a shorter path and addition of certain areas to the city. As a result of these shifting, a total of 49136 m^2 (5 hectares) is added to the city. The wall is built 211 m shorter by deviating it from the divide at four localities (91 m north of King's gate; 28 m north of Lion gate, 51 m NE corner of the area and 41 m near the Kesikkaya locality.
- The volume of the city wall approximately between Lion and King's gates is 613966 m^3 and covers an area of 130682 m^2.

6.3. Water Resources

- Capacity of eastern ponds is estimated as 15400 m3 based on surface area (total of 7700 m2) and a depth of 2 m. The southern ponds, on the other hand, have a capacity of 22160 m3 (surface area: 2770 m2; depth: 8 m).
- There exists two potential dam sites are suggested outside the city with a total drainage basin of 0.2713 km^2.
- Southern ponds can provide water for elevations less than 1195, while the eastern ponds can provide water for elevations less than 1139 m.
- According to the average annual precipitation measured at Yozgat station, total water transferred to Budaközü stream just north of Hattusha is 49541578 m^3.

6.4. Visibility Analyses

- For the first analysis conducted for 18 points with a viewpoint height of 12 m; total visible area is 1.807.590 m^2 (1.8 km^2), while the invisible part is 14.660 m^2 (0.014 km^2). There is no relation between the visibility and elevation of points.
- For the second analysis conducted for 3 gates and Büyükkale from 2m; the biggest value belongs to Yerkapı with a visible area of 36.2 %. Temple 1 is not visible from any point. However, the great citadel of Büyükkale is visible from all points. From Yerkapı, other two gates are visible, but these two gates cannot see each other. Büyükkale has the second biggest value in terms of visible area. The selected point dominates the three gates and sees approximately half of the upper city.

- For the third analysis conducted for 3 gates looking at outside the city from 12 m; the area visible by Yerkapı is almost equal to the total area observed by all points. The area observed in all points coincides with the low topographic region located to the NW of Hattusha. Present road from the site to Ankara-Çorum highway is located almost in the central part of this area. Most of the area along the road to Yozgat direction (SE of the city) is not visible.

6.5. Recommendations

- Geology (lithology and structural features) which is left out of this study should be integrated to the analyses.

- A detailed field survey should be conducted to investigate other possible water resources. Geophysical techniques can also be used for underground water exploration.

- Types of settlements and estimated population of them can be taken into account in the morphological analyses, so that a detailed classification of settlements based on the morphological parameters (elevations, slope and aspect) is obtained.

- Change detection analysis especially for the close vicinity of the city wall, might also give an idea for the erosional changes during ancient times. Aerial photographic survey can be used for this purpose.

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APPENDIX-A

Table A.1 Precipitation data from Yozgat station (Source: Turkish State Meteorological Service).

METEOROLOJİ

T.C.
ÇEVRE ve ORMAN BAKANLIĞI
DEVLET METEOROLOJİ İŞLERİ GENEL MÜDÜRLÜĞÜ

Aylık Toplam Yağış (mm)

İSTASYON ADI/NO: YOZGAT / 17140

YIL/AY	1	2	3	4	5	6	7	8	9	10	11	12
1971	13.7	39.5	99.8	95.0	39.1	45.2	7.2	44.1	33.5	31.8	75.6	95.9
1972	23.5	57.1	12.8	55.1	54.2	60.9	52.9	0.9	14.6	56.3	25.0	11.2
1973	17.2	24.2	59.7	80.6	72.2	42.4	3.6	4.1	0.8	10.9	26.0	49.3
1974	57.3	23.0	45.3	45.2	62.2	4.4	6.7	7.8	52.5	18.0	16.9	104.7
1975	34.3	41.4	73.4	136.6	134.7	60.6	2.7	18.9	3.9	22.0	30.4	74.8
1976	96.8	59.5	25.4	81.2	46.5	18.7	4.2	1.1	11.8	71.1	80.6	53.2
1977	34.7	26.5	80.8	87.3	53.4	32.9	2.7		22.4	57.0	32.4	51.1
1978	104.5	93.2	57.3	83.0	8.2	5.6	6.4		23.1	35.6	4.6	60.6
1979	145.5	73.9	29.6	36.0	82.6	28.0	17.9	1.0	34.4	41.3	70.9	56.7
1980	107.8	43.1	76.5	83.2	127.1	24.0	2.5	0.6	9.5	37.9	122.4	91.3
1981	97.7	58.1	107.6	39.2	50.6	87.7	66.1	1.0	9.4	22.4	42.1	133.4
1982	83.6	22.3	61.5	85.5	57.2	47.9	22.1	13.0	4.2	14.2	15.5	43.2
1983	66.5	192.3	62.9	54.1	72.6	42.8	47.4	9.8	9.2	87.9	164.9	47.8
1984	59.8	37.2	66.2	133.8	37.1	21.3	6.9	12.1		0.0	33.9	63.1
1985	106.0	112.2	47.1	54.5	111.4	6.5	8.1	6.1		109.4	123.7	80.0
1986	79.1	56.3	11.5	53.0	72.7	103.9	7.9		28.1	7.1	64.2	78.5
1987	120.8	70.7	104.7	79.4	39.2	73.9	29.1	12.8		35.5	67.0	159.3
1988	27.3	86.3	74.4	30.4	36.3	97.9	34.6		9.0	73.0	108.4	57.8
1989	35.5	25.2	28.4	45.7	55.6	27.7	2.8	1.0	8.8	52.5	171.8	54.1
1990	52.6	37.7	25.9	93.8	83.5	27.5	13.7	2.6	22.0	13.6	27.6	101.3
1991	24.3	82.9	29.0	136.8	92.6	38.0	2.2		8.1	109.9	48.3	92.1
1992	13.9	59.8	61.6	44.3	47.9	103.3	13.2	11.9	21.0	24.2	109.0	108.4
1993	81.6	91.2	55.1	51.3	98.0	63.5		7.8	0.2	0.4	49.1	90.2
1994	71.1	83.6	62.6	57.1	42.3	1.7	6.3	3.9		43.4	96.6	85.0
1995	51.9	12.0	109.5	89.9	47.7	52.3	12.5	19.4	18.0	38.4	127.8	42.9
1996	27.4	81.1	135.9	84.0	51.4	31.7	8.0	19.1	58.3	55.3	2.8	88.6
1997	35.8	54.0	35.0	106.3	49.2	54.0	0.0	13.8	6.5	110.4	36.5	140.0
1998	33.0	52.6	91.9	81.8	157.3	48.4	5.0		6.3	49.3	86.5	144.3
1999	32.8	81.8	91.0	31.2	47.7	45.1	79.2	56.1	6.2	29.4	29.1	33.2
2000	126.9	90.6	64.2	87.7	82.1	42.4		37.4	6.9	28.5	2.5	33.7
2001	1.5	65.1	42.1	32.3	80.0	9.9	5.3	7.4	8.2	4.2	106.2	168.0
2002	94.3	31.9	45.5	133.1	33.3	17.0	32.2	31.6	31.6	15.3	40.4	42.1
2003	81.2	77.8	36.8	78.7	32.0	8.6	0.9	1.3	77.8	58.0	31.4	74.6
2004	95.7	26.3	38.1	47.0	37.7	45.8	16.9	25.8	1.4	13.3	89.2	23.3
2005	42.2	48.4	106.1	73.6	89.1	12.6	17.9	23.0	25.5	41.7	102.8	18.4
2006	49.6	47.5	72.0	48.9	30.3	44.5			107.7	53.1	46.1	3.6
2007	38.3	42.9	64.5	53.4	20.7	42.6		14.5	7.1	38.5	146.9	75.7
2008	50.6	45.3	61.4	54.8	35.6	23.2	0.4	1.2	65.0	31.3	66.8	80.7
2009	146.5	90.2	75.6	42.7	99.0							

APPENDIX-A

Table A.2 Precipitation data from Sungurlu station (Source: Turkish State Meteorological Service).

T.C.
ÇEVRE ve ORMAN BAKANLIĞI
DEVLET METEOROLOJİ İŞLERİ GENEL MÜDÜRLÜĞÜ

Aylık Toplam Yağış (mm)

İSTASYON ADI/NO: SUNGURLU / 2746

YIL/AY	1	2	3	4	5	6	7	8	9	10	11	12
1986										10.1	21.2	83.9
1987	62.1	35.0	65.7	78.3	37.5	91.8	43.1	7.7	0.3	29.7	41.8	83.8
1988	19.9	78.2	45.5	32.9	42.1	97.6	11.3	0.0	7.4	116.3	56.9	57.7
1989	24.2	16.8	24.7	20.9	66.7	37.2	4.2	0.8	2.5	43.5	117.3	45.1
1990	29.1	9.3	37.5	87.1	117.6	22.5	15.7	3.0	37.1	15.8	12.0	83.1
1991	20.7	51.5	25.0	79.4	69.4	22.6	2.9	3.5	9.8	50.7	23.1	46.9
1992	3.1	14.3	36.7	35.9	18.6	59.8	12.2	12.6	15.8	31.2	62.2	60.8
1993	36.7	58.4	20.2	38.6	101.7	29.9	0.0	19.5	2.1	1.7	35.5	45.2
1994	49.3	28.3	25.3	19.3	44.3	1.6	3.4	4.7	6.9	24.5	61.7	36.8
1995	31.3	12.8	77.9	57.7	50.0	61.9	19.1	6.4	31.6	27.1	78.0	9.1

Şube Müdürü

APPENDIX-A

Table A.3 Precipitation data from Alaca station (Source: Turkish State Meteorological Service).

METEOROLOJİ

T.C.
ÇEVRE ve ORMAN BAKANLIĞI
DEVLET METEOROLOJİ İŞLERİ GENEL MÜDÜRLÜĞÜ

Aylık Toplam Yağış (mm)

İSTASYON ADI/NO: ALACA / 2750

YIL/AY	1	2	3	4	5	6	7	8	9	10	11	12
1971	9.9	15.5	24.9	69.6	85.3	39.4	14.3	19.3	50.9	18.3	31.8	37.7
1973	11.8	15.2	25.5	56.5	53.9	35.6		2.3	2.1	6.5	7.6	25.1
1974	7.6	10.6	20.7	13.4	58.1	4.8	21.0	12.2	48.0	0.8	19.7	73.5
1975	27.5	19.9	46.4	106.8	88.7	21.6	2.4	24.0	5.0	22.8	15.9	44.3
1976	41.9	13.6	6.2	41.7	54.0	31.9	8.5	1.9	11.3	44.4	17.1	20.1
1977	12.9	13.3	38.6	63.8	61.4	40.1	4.1		14.6	38.6	14.7	49.8
1978	59.9	36.4	22.5	72.8	23.3	11.4	6.2	1.3	29.6	33.1	1.8	32.1
1979	70.4	23.9	15.7	23.4	76.8	67.2	24.1	19.3	29.1	20.1	45.9	23.6
1980	56.1	31.9	37.4	53.5	102.6	16.2	9.8	8.2	15.6	28.2	51.5	29.2
1981	41.8	23.8	66.6	21.2	61.1	71.5	28.2	6.1	13.6	20.2	31.2	31.2
1982	15.6	9.7	37.2	53.4	43.9	61.7	17.6	3.6	0.4	13.6	8.4	27.2
1983	30.5	47.5	16.8	54.3	47.2	32.5	35.7	17.8	8.6	44.7	100.6	38.6
1984	32.8	18.8	24.0	98.6	37.7	15.8	7.8	12.8	1.2	1.9	6.2	11.4
1985	26.4	48.5	23.5	48.6	66.8	2.2	10.6	9.2		82.2	55.8	36.2
1986	42.6	23.2	7.0	28.1	83.2	76.7	0.4		8.5	3.3	23.5	56.7
1987	63.1	39.1	41.1	38.3	46.8	61.5	33.1	51.3		12.1	53.3	75.7
1988	33.0	40.1	33.4	23.9	38.7	70.2	38.1	2.7	2.9	95.1	56.2	40.2
1989	18.9	19.4	12.5	24.1	56.7	23.4	4.4	2.6	2.9	45.6	96.2	29.8
1990	35.8	7.5	20.2	73.8	92.7	18.4	6.6	4.8	28.5	8.3	19.1	57.1
1991	13.9	39.8	24.7	101.2	89.7	36.5		1.8	0.6	38.8	22.7	44.3
1992	5.9	19.3	28.5	24.9	27.4	64.4	17.6	2.4	15.5	21.2	56.5	41.9
1993	34.2	40.6	18.6	41.8	116.0	33.0	1.6	3.8	8.6	1.0		
1994		15.6	36.3	31.7	30.4	2.6	2.2	3.6	2.2	27.0	66.4	30.4
1997	11.4		12.4	58.8			13.4	16.6	11.2	48.0	24.0	83.1
1998	26.8	15.7	36.6	41.7	152.0	131.6	7.0		4.8	23.3	30.6	43.5
1999	20.7	29.0	75.6	48.8	13.1	25.1	55.0	79.5	29.7	24.2	21.4	8.5
2000	79.4	59.9	23.7	87.4	61.5	64.4		65.5	11.2	18.7		44.1
2001	8.0	37.3	38.3	23.4	83.8	13.3	6.3	7.8		4.6	48.4	76.7
2002	65.2	18.6	57.0	64.3	4.9	39.7	71.8	21.1	47.2	32.6		11.6
2003	46.3	28.9	25.6	69.3	29.4				65.0	32.5	29.9	84.0
2004	44.4	14.7	30.3	34.2	41.2	77.1	6.4	22.5	2.7	3.7	82.3	18.0
2005	8.5	27.9	73.2	59.6	62.3	26.9	5.2	10.0	12.9	33.6	79.1	15.5
2006	32.0	50.5	60.9	17.0	32.5	31.2			63.4	36.4	34.8	4.4
2007	26.2	29.6	56.0	36.5	20.3	98.3		32.2	7.1	22.1	75.6	33.4
2008	27.1	21.2	31.1	25.3	58.2	24.1						

KAYITLARINA UYGUNDUR
İstatistik ve Yayın
Şube Müdürü

APPENDIX-B

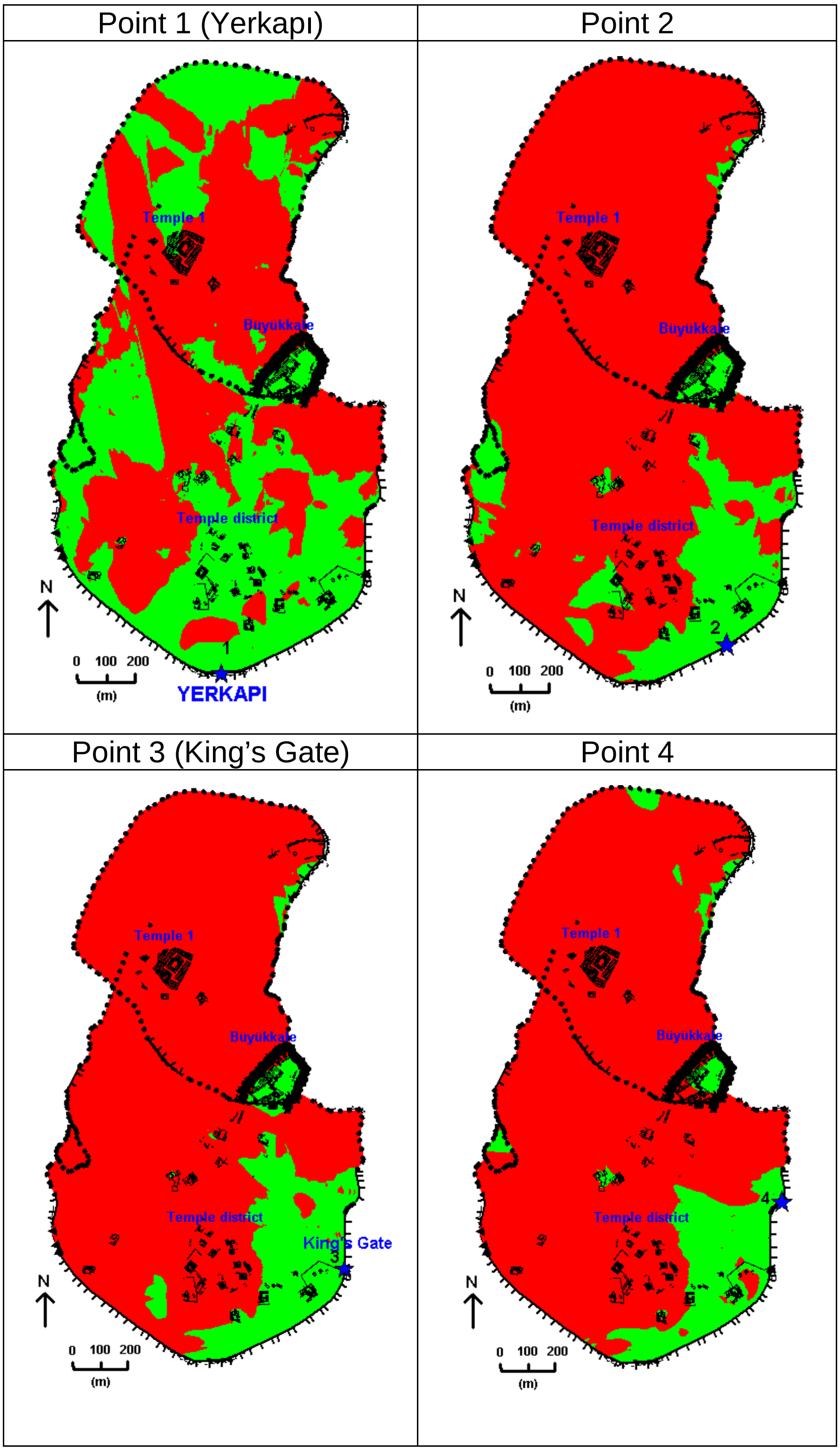
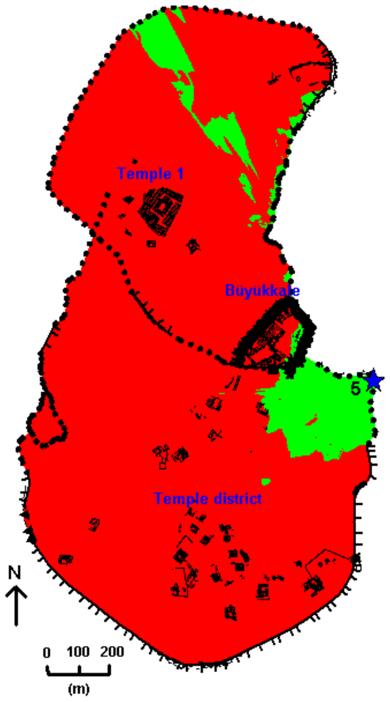
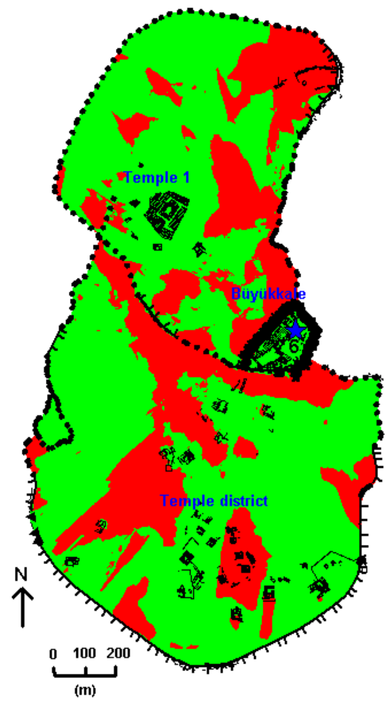


Figure B. Viewshed maps prepared for 18 points.

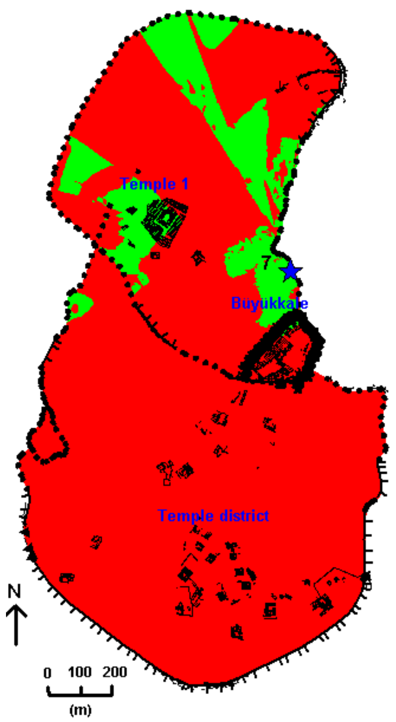
APPENDIX-B

Point 5	Point 6 (The Royal citadel of Büyükkale)





Point 7	Point 8



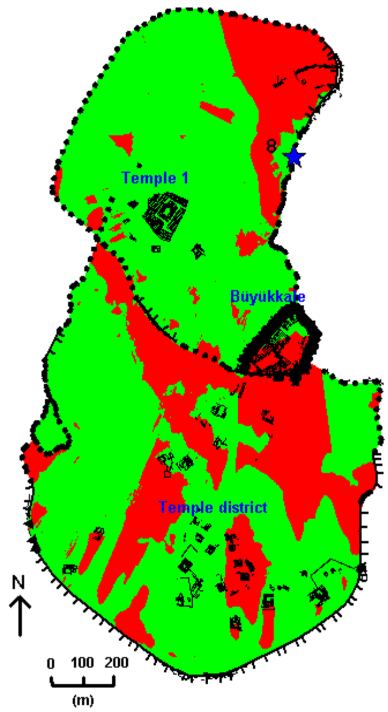


Figure B. continued

APPENDIX-B

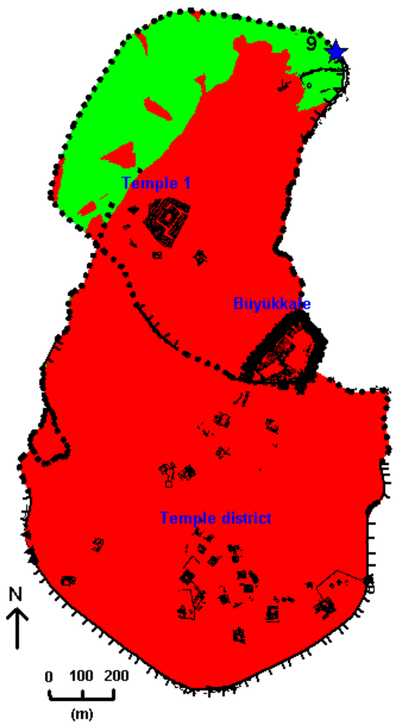
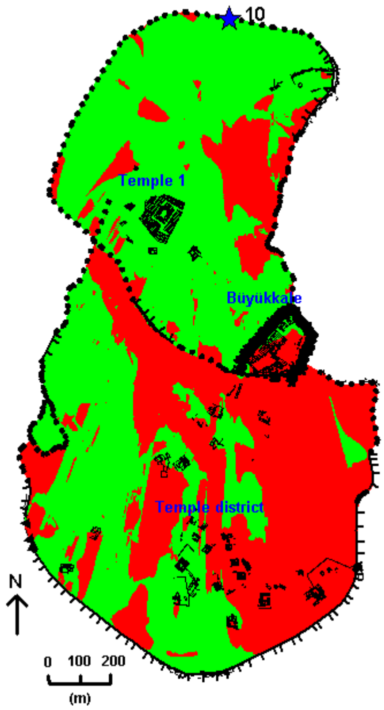
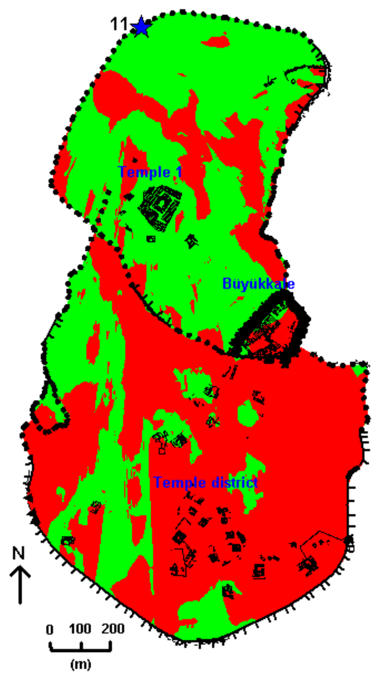
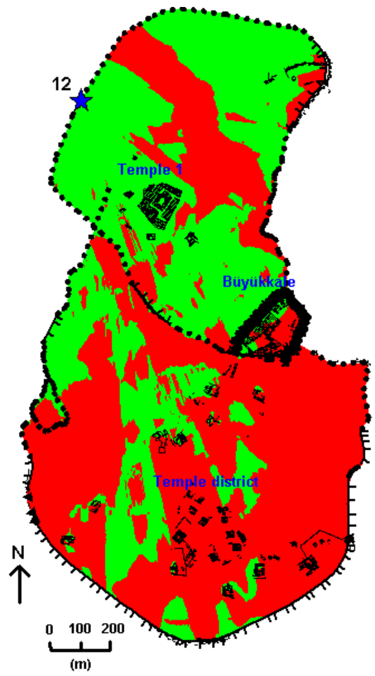
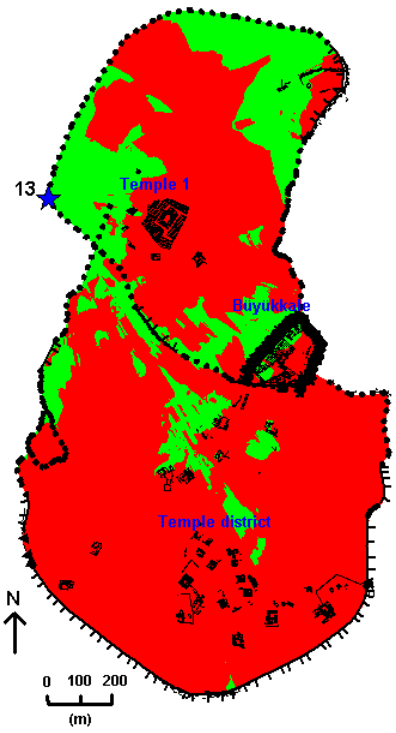
Point 9	Point 10
	
Point 11	**Point 12**
	

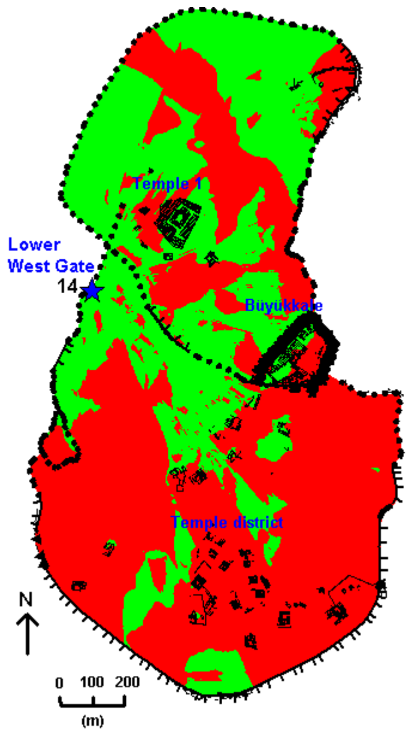
Figure B. continued

APPENDIX-B

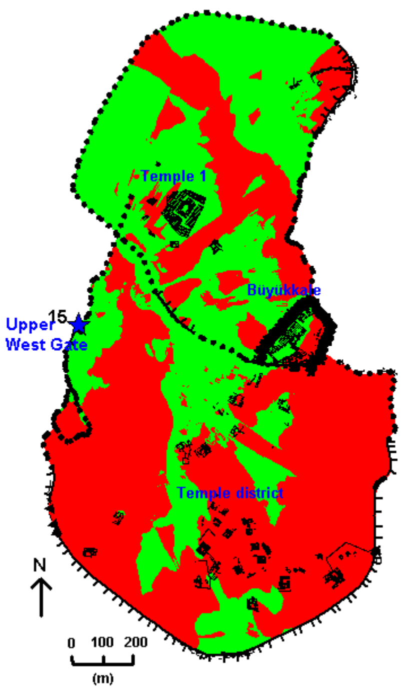
Point 13



Point 14 (Lower West Gate)



Point 15 (Upper West Gate)



Point 16

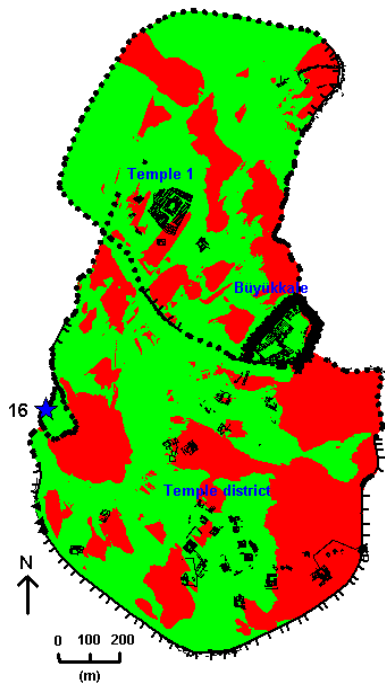


Figure B. continued

APPENDIX-B

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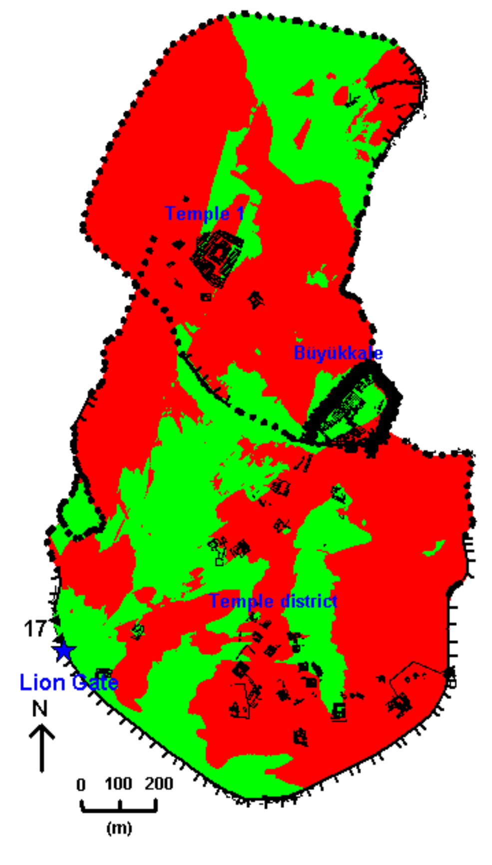

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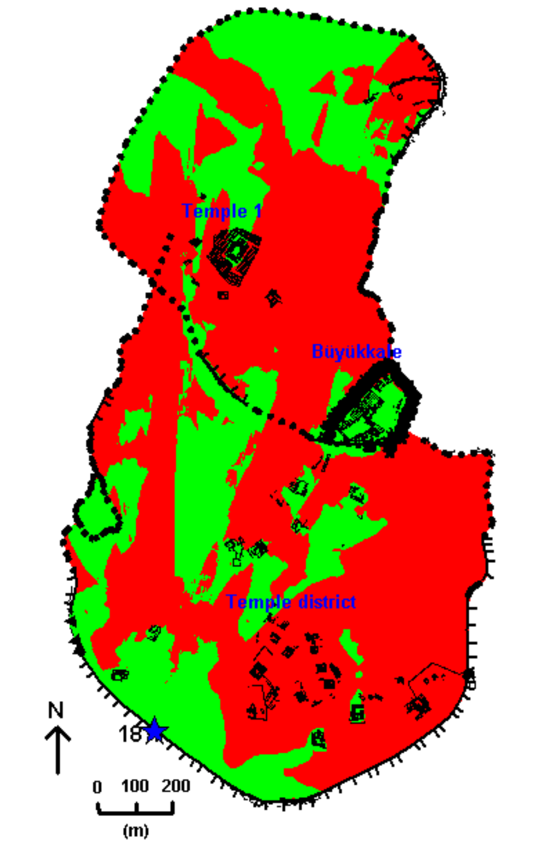

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Figure B. continued