ARCHEOLOGICAL PARK DESIGN IN THE VICINITY OF ZEUGMA AND APPLICABLE REMOTE SENSING AND PHOTOGRAMMETRY METHODS

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ABSTRACT:

It is considered that Zeugma, which is known as the magnificent city of the ancient Mesopotamia, will continue to enrich the cultural heritage of the world as an open-air museum. Due to the fact that the considerable segment of the Zeugma will be inundated by the impounding of the reservoir of Birecik dam, which has been constructed in the region, emergency rescue and excavation work had been carried on during 1999-2000 with the cooperation of Turkish governmental organizations and international foundations. During this activity, besides archeological work, mapping methods had also been applied for surveying and registration purposes. In this paper, not only the importance of the Zeugma among the world's cultural heritage has been emphasized, but also remote sensing and photogrammetric methods applicable for designing purposes of an open-air museum and an archeological park which surrounds the museum and has an area of 600 km^2, and establishing a geo-based archeological information system that will serve for the planning of the long term future archeological works to be conducted at this site has been discussed.

1. INFORMATION ABOUT ZEUGMA

1.1 Location

The ancient city of Zeugma has been situated on the river Euphrates, which determines the border of Mesopotamia. It is near to the village Belkis that is 10 km east of town Nizip in Gaziantep province (Figure 1). Location that has uninterruptedly been settled since ancient era owes its importance to being on the one of the two points that provide best crossing opportunity on Euphrates. Since the word Zeugma meant 'bridgehead' or 'crossing point', probably the name of the city reflects the strategic position of its own.

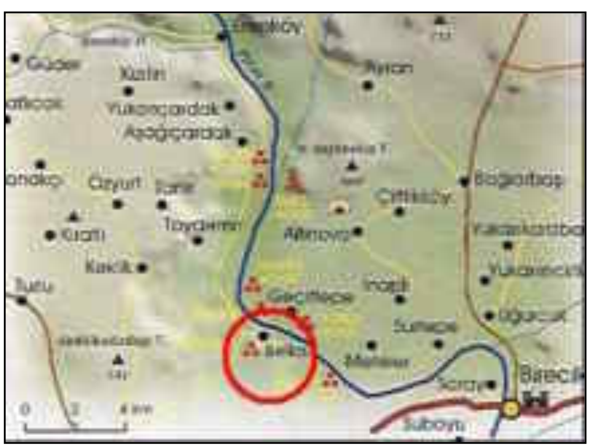

Figure 1: Location of the Zeugma ancient city.

Today, the area is covered with 3 to 4-m soil on which pistachio trees have been planted. Approximately 1/3 of the 2 thousand hectare area on which the ancient city Zeugma has been settled is inundated by the Birecik dam reservoir by October 2000.

1.2 History

The city of Zeugma used to be the most important trade center of the Hellenistic era and was founded in 300 BC by Seleucus I Nicator, one of Alexander's generals, as two cities on each side of the river, Seleuceia and Apamea. Major concern of the general was to control the critical crossing point of the river Euphrates. Famous historian Strabon had noted the city as one of the four major cities of Commagene Kingdom.

The region was conquered by the Roman Empire in 64 BC and the name Seleuceia was changed as Zeugma. During the Roman rule, a military legion called Legion IV was seated at the city and, thus by, importance of the city had been increased. As the trade develops at Zeugma, considerable art works had been started up. Nearly for two centuries, the city hosted high-ranking officials and officers of the Roman Empire. Zeugma experienced its golden ages during 1^{st} and 2^{nd} centuries AD as a big commercial center and a vital military base.

The art works and the villas that are constructed in terraced manner to view the Euphrates reflect the reach culture of the city. 65000 seal imprints that had been found in an archive room are not only evidently expressing that the city had customs and was experiencing border trading but also reveals the existence of a strong communication network and the advanced trade.

In 256 AD Zeugma was captured by Sassanid king Shahpur I and almost fully destroyed. A subsequent earthquake completed the unfinished job by Shahpur I and buried the city. From then on, city never reached to its Roman-ruled age magnificence.
In 4^{th} century AD, Zeugma settlement became a Late Roman territory. During the 5^{th} and 6^{th} centuries, the city was ruled over by the Early Byzantine domination. As a result of the ongoing Arab raids the city was abandoned once again. Later on, in the 10^{th} and 12^{th} centuries, a small Abbassid residence settled in Zeugma. Finally, a village called "Belkis" was founded in the 17^{th} century.

2. ARCHEOLOGICAL WORKS

2.1 Excavations and Rescue

First excavations were executed by the Gaziantep Museum in 1987 at the south of the Belkis Hill. During this work that took place in a grave chamber that was carved into main rock, many small statues were found which the smugglers left behind and all of them were moved to Gaziantep Museum.

During the excavations carried out by both Turkish and foreign scientists between 1992 and 1999, considerable amount of remains has been unearthed. Construction works of the Birecik dam accelerated the excavation and rescue works.

To develop a strategy for the Zeugma urgent excavation and rescue work launched under the coordination of the GAP Administration, examinations and observations were conducted at the site in May 2000 with the participation of staff from the GAP Administration, Turkish and foreign scientists, experts from Gaziantep Museum, Director of Cultural Affairs in Gaziantep and representatives of Birecik A.S. The antic city was divided into three zones as A, B and C as a result of these examinations and observations.

Zone A: This area is under water since June 2000. The Ministry of Culture had conducted archeological excavations and documentation work in the area for the last 9 years. In this region, which now remains under 372 meters as the altitude of the dam lake, rescue work continued until inundation.

Zone B: This zone covers the area under 385 meters as the highest level for the dam lake where urgent excavation and rescue work was materialized in October 2000.

Zone C: This is the area that is not affected by the dam lake but covers the main part of the antic city (about 70 percent of the city). The target is to carry out long term and full coverage work in this zone under the light of earlier work conducted in Zone B.

First observations in the area yielded some natural topographic zones. Consequently, the Zone B, which extends for about 1 km was divided into different topographical parts and archaeological works were given start in 19 excavation points expected to yield important data about the structure of the city.

In another part of the evaluation phase, a geophysical surveying was conducted by using ground penetrating radar (GPR) techniques. This surveying, not exerting any harm on possible remains under the ground, helped excavation work in directing it to some special points and locations.

Following these earlier evaluations at the excavation site, there was an urgent excavation and rescue work of international character racing against time to be completed in 4 October 2000. There were 250 manual workers and over 100 archeologists and conservation experts taking part in this work.

Urgent excavation and rescue work unearthed many properties including houses, shops, workshops, religious quarters dating back to the early years of Christianity, remains of a temple, paths and waste water discharge canals. Other items found include decorative window cases, figurines, glass objects, bronze statues, innumerable coin, helmets, iron spears and knives, golden rings, leaves made of gold, golden fibula, bulla, a relief stele describing Antioch, King of the Commagene shaking hands with Helios, God of Sun, column base with cross relief, oil lamps and many other smaller objects of glass, metal, ceramic and earth, all transferred to the storage in Zeugma excavation center.

2.2 Conservation and Documentation

Under the Conservation Program prepared by the "Centro di Conzervazione Archaeologia" (CCA), having a high level of expertise in conservation work, frescoes, mosaics and remains that could not be moved were made subject to in-situ conservation. This work includes the cleaning of frescoes and mosaics at their original locations and then their covering with "limestone mortar" so as to minimize the effect of water.

Since mosaics "Flight of Europa", "Eros and Psyche" and "Three Women" were of great importance they were moved to the laboratory. Conservation and restoration work on finds and mosaics continued after 4 October 2000, the date for the completion of the impoundment program.

All findings obtained in excavations were documented in line with the rules of modern archeology without missing any detail. Documentation works are based upon three methods as written records and drawings, digital camera and conventional photography. Documentation work including all details from the smallest architectural object to larger buildings, from small finds to earth samples was conducted in computers.

As a result of this work in Zeugma, there is now a large pile of archeological records including hundreds of drawings, thousands of written documents, over 500 photographs and 2,376 digital visions. Over 1,000 of small finds thus far recorded consist of coins. The number of bulla found can be considered a world record in this field.

3. PROTECTION OF CULTURAL PROPERTIES

3.1 GAP Regional Development Administration

The Southeastern Anatolia Project (GAP) had originally been planned as a set of 13 projects envisaging the construction of dams on the Euphrates and the Tigris for irrigation and energy production purposes. Altogether there would be 22 dams and 19 hydraulic power plants on these rivers. The case, however, has changed since then. Now GAP has turned into a full-fledged regional development project focusing on human resources. As such, other than hydraulic plants and irrigation facilities, it covers a whole range of activities in the fields of urban/rural infrastructure, transportation, industry, education, health, housing, tourism and many others.

GAP is presently one of the largest regional development projects in the world both for its coverage and its objectives and targets. The human centered approach of the project and its status of constituting a unique model in terms of its human development goals are the facts both of which find their reflection in ever increasing willingness for international cooperation and participation.

3.2 Coordination and Documentation

In order continue with post-excavation works in a systematic and scientific manner and to launch new projects for the future of Zeugma, the GAP Administration is maintaining its coordination function with regard to the Packard Humanities Institute (PHI), relevant organizations and agencies, teams engaged in excavations and local governments.

Upon the completion of excavation work on October 4th 2000, evaluation, documentation, computer entry and storage arrangement works were started at the excavation center. Five experts from the Turkish team taking part in excavation work continued with the classification, drawing, photographing, documenting and reporting on hundreds of thousands of clay bulla and coins. This team was also engaged in the follow up of new finds emerging as a result of changes in the level of water and waves and in ensuring the coordination with other teams. Turkish teams in the urgent excavation and rescue also conducted their work in a very tidy manner.

3.3 Open-air Museum

In order to minimize the adverse effects of dam constructions on people, their economic means as well as on cultural properties, studies and surveys to this end had been started in 1992. Later, the findings of these studies and surveys were gathered in action plans and implementation.

Projects relative to the protection of cultural properties in the region are addressed under the "Project Package for the Protection of Cultural Properties" and they are given priority in the annual programs of the Administration. Within this scope, it is planned to establish an open-air museum in order to exhibit all finds of Zeugma in-situ. Since the excavations at Zone C will continue, this plan could be implemented step by step at the areas that the excavations are completed.

4. REMOTE SENSING AND PHOTOGRAMMETRIC ISSUES

Location is an important issue for the management of archeological sites. It has vital importance during both planning and operational phases. If the location of a site is unknown, it is naturally impossible to take any action to manage, preserve or protect the site and its belongings. Determination and presentation of information related to location is accomplished via mapping of the site

Taking into consideration that the up-to-date small scale topographic maps (1:25K to 1:250K) of the area are available both in printed and raster forms, new map production should cover the large scale maps 1:500 or 1:1000 and 1:5000 for archeological excavations that will be carried on and detailed planning purposes respectively.

4.1 Ground Survey

Ground surveys that should be conducted will be mainly GPS observations on pre-selected ground control points (GCP) in order to determine the exterior orientation parameters of airborne sensors. Proper marking of the points that are observed is necessary so that they can be clearly identified on the image. Conducting a leveling work to determine the orthometric heights of the GCPs is optional since the geoid heights that are needed to derive the orthometric heights from GPS observations is known to +/- 10 cm accuracy. Nevertheless, by conducting first order leveling to 1 or 2 GCP will upgrade the height accuracy to +/- 5 cm.

In order to determine the coordinates of the GCPs with cm accuracy, at least one of the two points of Turkish National Fundamental GPS Network (TUTGA) points, which are very near to the area, should be used during the GPS observation campaigns, where TUTGA is established by General Command of Mapping and comprised of 594 points (Figure 2).

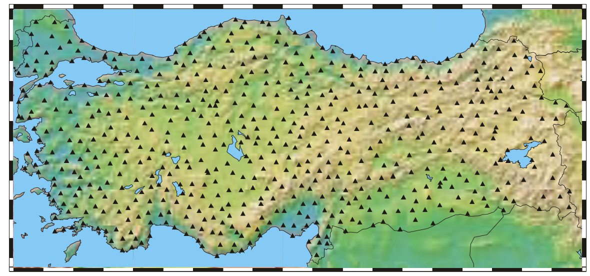

Figure 2. Turkish National Fundamental GPS Network.

Kinematic GPS supported aerial photography, by which projection center coordinates of each photo is obtained, reduces the number of ground control points at a considerable amount. Technique mainly depends on simultaneous operation of at least two GPS receivers, one on board in connection with the camera recording the time tag of the camera exposure instance, and the other(s) on the ground, preferably on a well-defined geodetic network point(s). At the end of the flight, GPS data, collected both on the flight and the ground, are processed to determine the projection center coordinates of the photograph at the moment of imaging. For a combined bundle block adjustment with projection center coordinates determined by relative kinematic GPS-positioning, control points are required only in the block corners if the flight lines do not exceed 30 base length (Jacobsen 1996).

On the other hand, in case the direct georeferencing of the airborne sensor could be made possible by operating a GPS/IMU, then theoretically there would be no need to conduct a ground survey. IMU is the acronym for Inertial Measurement Unit, which is derivative of Inertial Navigation System (INS). Within the last years numerous tests were conducted in order to determine the accuracy of integrated GPS/IMU for direct georeferencing, which was shown to be a serious alternative to indirect image orientation using classical or GPS-supported aerial triangulation. Since direct georeferencing without ground control relies on an extrapolation process only, remaining errors in the system calibration will significantly decrease the quality of object point determination (Cramer et al 2002).

4.2 Image Acquisition

Image of the area can be acquired either from airborne or spaceborne sensors. In case of airborne imaging, flight should be conducted at two different altitudes to obtain 1:4000 and 1:16000 scale aerial photography for 1:500 or 1:1000 and 1:5000 scale map production respectively.

At the moment Quickbird and Ikonos are the satellites to collect the highest resolution of imagery commercially available. It is stated that Quickbird panchromatic or natural color imagery of 60 to 70 cm resolution depending on the off-nadir angle is capable of supporting mapping in the 1:2500 to 1:5000 scale range (Nale 2002). On the other hand, accuracy assessments of the 1 m resolution Ikonos panchromatic imagery have been revealed that mapping accuracy achieved is about 2 m and it could be upgraded towards 1 m by improving the accuracy of the GCP (Fraser et al 2001, Grodecki et al 2001, Toutin 2001). As a matter of fact, the information contents of the Ikonos panchromatic images correspond to 1:10000 scale topographic maps (Jacobsen 2002b).

It is clear that imagery needed for large-scale mapping (1:500 or 1:1000) should be supplied by aerial photography, where satellite imagery stands by as an alternative for 1:5000 mapping. Since the imagery should be in digital form as satellite imagery, aerial photos taken by analogue cameras would be digitized at photogrammetric scanners or could directly be acquired by digital metric cameras such as ADS40 of Leica Geosystems and DMC of Z/I Imaging.

When deciding to use either aerial photos or satellite imagery, cost, time and accuracy issues dominate the selection. While aerial photo flight costs vary dramatically as country or company basis, satellite prices are rather stable. Since, both airborne and spaceborne sensors are optical devices and require clear skies, image availability time mostly depends on meteorological conditions. From the point of the accuracy view, aerial photography is still one step ahead when speaking of large-scale mapping.

Since both image types are both daylight and good weather dependent, distinctive fact for the choice is their cost and accuracy. Cost is limited with the project budget, while accuracy is determined by the expected exactness of the final product. Providing that the requested satellite images of the area are present in the archives of satellite image distributor, it is possible to get them at very low costs comparing to the programmed imagery upon request. This is an important note that should be kept in mind because the area is not experiencing any significant change since October 2000.

4.3 Photogrammetric Work

Photogrammetry has experienced an evolution parallel to the technological development, starting with analogue, continuing with analytic and reaching to digital technique. Taking into account that the main objective of the photogrammetric work mentioned herein is to supply sufficient geographical infrastructure for the proposed geo-based archeological information system of Zeugma site, all of the photogrammetric outputs are desired to be in digital form. For this reason, final products of the photogrammetric labor, such as orthoimages, topographic maps and Digital Elevation Model (DEM) of the area, should be in digital form.

First step of the photogrammetric process will be digitizing the aerial photography if it is not obtained directly in digital form. During this process, 12 mm scanning resolution is considered to suffice. Subsequently, combined block adjustment will take place for aerial triangulation

Third phase covers the compilation process during which the operator will collect every natural and men made details. Though most of the commercial photogrammetric software allow DEM generation by automatic image matching and determination of contour lines by using the DEM, it must be reminded that elevation model created will be not a DEM but digital surface model (DSM) including natural and artificial features on the terrain. This is due to the fact that if the automatically selected points are features such as a building or a tree, floating mark will be on top of the object whereby the operator will set it down to the ground. Therefore DSM created by either automatic image matching or LIDAR should be reduced to DEM using appropriate software. Final phase of the photogrammetric work is obtaining the orthoimages by using the DEM of the area.

Another way of generating DEM is utilizing Light Detection and Radar (LIDAR) technology, which is also called as airborne laser scanning or mapping. Over the last years, LIDAR technology has become the accurate, timely and economical way to capture elevation data by means of DSM (Hill et al 2000). LIDAR system basically consists of a laser scanner and a GPS/INS. Fundamental principle of the system is based on measuring the direction and distance between the feature and the sensor by the mirror angle and accurate laser beam travel time computation while GPS/INS system is determining the coordinates of the sensor at the moment of recording. The accuracy of the system mostly depends on the positional information acquired by GPS/INS. Various accuracy validation studies have shown that LIDAR technology has reached to a vertical accuracy of 10-20 cm and horizontal accuracy of 1 m, which can be enhanced by additional ground survey observations (Murakami et al 1999, Hill et al 2000).

4.4 Proposed Work Summary

In order to produce 1:500 or 1:1000 and 1:5000 scale digital maps of the region, including the area on which establishment of an open-air museum is planned, whole area has to be photographed at a scale of 1:4000 and 1:16000 either with analogue or digital airborne cameras. Film type could be either panchromatic or color, however considering the ease of interpretation and feature classification color photography is preferred. In order conduct a less ground survey, flight should be conducted with kinematic GPS support and GCP coordinates should be determined accurately according to TUTGA. For our case, if the flight is conducted by kinematic GPS technique, instead of 12 GCP, only four will be enough but two additional cross flight strips are required to avoid possible cycle slips.

As it is depicted in Figure 3, for 1:4000 photography, in addition to five north-east flight strips, two cross strips have to be flown while only one flight line is will be enough for 1:16000 flight.

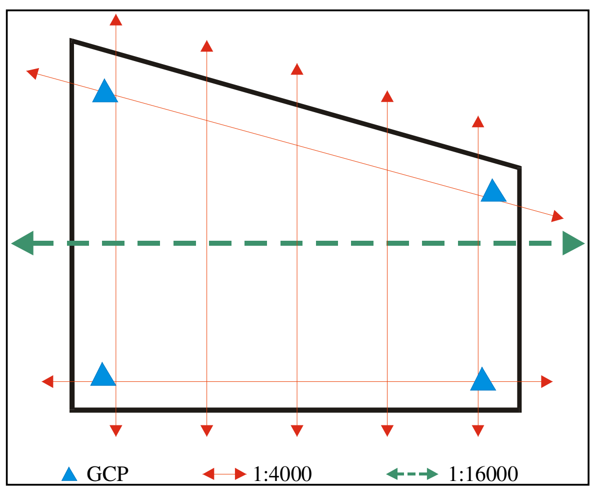

Figure 3. Sketch of the GCPs and flight strips.

As an alternative panchromatic or natural color 0.6 m resolution Quickbird imagery could be used for 1:5000 map production. For aerial triangulation, combined bundle block adjustment should be applied with proper software and digital compilation process should be carried on.

If possible, it is recommended that DEM of the area generated by LIDAR technology. In case of the lack of the LIDAR, instead of automatic image matching, points selected by the operator will avoid discrepancies due to relief and plant cover of the area.

5. ARCHEOLOGICAL INFORMATION SYSTEM

Geographical Information System (GIS) can simply be defined as a digital environment, which is capable of data storage, analysis, interpretation and presentation and comprises of software, hardware and data components. Since the software and hardware could be supplied at reasonable costs including the training, main difficulty at establishing a GIS comes out to be the data acquisition, which is the most time consuming and costly component of the system.

Data component of a GIS includes the aerial and/or satellite images, digitized maps, digitally compiled photogrammetric maps, digital or digitized ground photos and drawings, field survey data collected by GPS and all means of digital data. Since government agencies and other organizations make use of computer-based mapping and analytical tools in a variety of management, planning, and research activities, in order to keep in pace with the widely used GIS, photogrammetric mapping today has become a data acquisition for GIS (Jacobsen 2002a).

Preservation of cultural sites has traditionally been oriented toward the protection and restoration of built structures, but there is now a trend toward the protection of larger sites and a monument's surrounds. This trend calls for new tools and methods for site documentation and management, such as GIS (Hardy 1997). The benefits of GIS has been discussed in vast number of publications so it will not be again emphasized but there is no doubt that it is a powerful tool for cultural resource managing, procurement planning and documentation of the heritage within the archeological site.

There are numerous GIS that have been generated for different historical and archeological sites. The one developed for Mycenae (Ionnidis et al 2003) has been overviewed and it has been resolved that a similar geo-based archeological information system could be applied for Zeugma. Since all documentation is computerized, in order to complete the data component of the system all it has be done is obtaining the products that are described in section 4.3.

6. CONCLUSION

The benefits of a GIS include more accurate and accessible documentation of sites, and improved monitoring, maintenance and planning of sites. By developing an archeological GIS that displays the locations and boundaries of the remains of the Zeugma, both state and local authorities will be capable of monitoring the archeological work that are being conducted in the areas of their proposed projects. At the same time, by adding the project locations to the GIS system, meaningful predictive models of archeological site location can be developed using existing information pertaining to the environmental and cultural characteristics associated with the presence or absence of sites in previously surveyed areas.

The Southeastern Anatolia Project assigns specific importance to the protection and promotion of the cultural heritage of the region, which has its roots in the early civilizations of the world. The concept of sustainable development also covers "cultural continuity" whereby this heritage is transferred to future generations.

Until now, extraordinary efforts have been exposed in order to rescue the remains of Zeugma and, from now on, intensive labor shall be carried on with the help of both domestic and international volunteer organizations. However, it should be noted that it is a matter of considerable time and money to undertake an archeological project on such large area.

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