Photogrammetry, GIS and Geophysics Integration for Archaeological Documentation of the Baptism area

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Abstract. The archaeological heritage constitutes the basic record of past human activities. Its protection and proper management is therefore essential for studying and interpretation of present and future generations. The protection of archaeological heritage must be based upon effective collaboration between professionals from many disciplines. In this study, knowledge from different sources and research areas has to be integrated and established for complete documentations of one of the most important archeological discovers of recent time (Baptism area, Jordan). Photogrammetry will be used for planning, recording, reconstruction, and revitalization of heritage site. Geophysical methods, such as ground penetrating radar (GPR) will be used to explore the underlying structure of the study area.

For realistic representation of the study area, a three dimensional Geographic Information will be prepared for the baptism place in Jordan, where efficient generation, management and visualization of such special data can be achieved.

1. Introduction:

The archaeological heritage constitutes the basic record of past human activities. Its protection and proper management is therefore essential to enable archaeologists and other scholars to study and interpret it for the benefit of present and future generations. The protection of archaeological heritage must be based upon effective collaboration between professionals from many disciplines. In this research, knowledge from different sources and research areas has to be integrated and established for complete documentations of historical and archeological area (Baptism area, Jordan, Figure 1). *Photogrammetry* has been applied to the planning, recording, reconstruction, and revitalization of world heritage sites. *Geophysical* methods have gained favor in portions of the archaeological community as a way to determine the nature and location of buried features. Three *dimensional Geographic Information* (3D GIS) play an important rule in archaeology and the preservation of cultural heritage. In this study, a 3D GIS will be prepared for efficient generation, management and visualization of large 3D landscape, Maps, Monuments, Digital elevation models, Orthophoto, satellite images and various models that have been developed using photogrammetry or geophysical methods for one of the most important archeological discovers of recent time (Al-Maghtas, baptism place in Jordan) .

2. Historical and Religious Importance of the Study Area

It is one of the most important archeological discovers of recent time. It is an important site of early Christianity, rich with spiritual associations from the old and new Testaments. It is the settlement of the Bethany in Jordan, where John the Baptist lived and Baptised during the time of Christ, (Khouri , 2000).

The biblical text of John 1:28 mentions '…Bethany beyond Jordan, where John was Baptising' John 10:40 mentions when Jesus escaped from hostile crowds in Jerusalem and 'went back across Jordan to the place where john had been Baptising …'. John the Baptist's settlement of Bethany in Jordan is associated with several biblical incidents: the Baptism of Jesus which took place in Bethany, Joshua's crossing of the Jordan river, the late days of Moses, and the Prophet Elijah's crossing the Jordan and ascent to haven in a whirlwind on a chariot and horses of fire: "and it came to pass, as they still went on, and talked, that, behold, were appeared a chariot of fire, and horses of fire, which parted them asunder; and Elijah went up by a whirlwind into heaven". (II Kings 2: 11-13).

Figure 1: General Overview of Al-Maghtas Location in Jordan

For nearly 2000 years, local church tradition and pilgrims have all identified the small hill at the center of Bethany as the place from which Elijah ascended to heaven, and the site have been known for centuries as Elijah's hill (or Tell Mar Elias or Jabal Mar Elias, in Arabic). The settlement of Bethany and the region surrounding it , in Jordan were also known in different ancient periods as Ainon, Saphasphas, Bethania and Bethabara (from Arabic Beit el-qbour or house of the crossing) .Arabic Language bibles call it Beit'Anya, and today the entire region between Bethany and the Jordan river is called ***El-Maghtas*** Figure 2, (Khouri, 2000).

Figure 2: Al-Maghtas Area

3. Site Structures and Description of the Study Area

The previous work in the Bethany area has identified numerous structures, monastic complexes, churches, caves, a spring water systems and other facilities from the Roman and Byzantine periods, all of which are mentioned in ancient pilgrim text as early as the 4^{th} to 8^{th} centuries AD. The Bethany setting and surrounding region are magical in their beauty, and mystical in their spiritual associations. The settlement of Bethany, on and around Elijah's Hill, stands on the south bank of a perennial stream called Wadi Al-Kharrar, Figure 3 (Wadi is the Arabic word for riverbed , usually means a seasonal stream that dries up in the summer). Wadi Al-Kharrar starts here amidst a fertile agricultural landscape that is hot and dusty for much of the year, (Waheeb, 2000).

Several historical and archeological sites has been discovered along Wadi Al-Kharrar (Elijah Hill, Pilgrims Station, Main Baptist pool, Main Baptist pool, John the Baptist Spring, Cave cell, Laura of St Mary the Egyption and the Chapels of the Jordan river). In this paper focus will be on two main sites: the south – eastern end of Wadi Al-Kharrar ,a hill known as St.Elijah Hill-Jabal Mar Elias in Arabic, where the Prophet Elijah ascended into Heaven Figure 4(a) and Church of St .John the Baptist on the east bank of the Jordan river where the baptism of Jesus is said to have taken place, Figure 4(b).

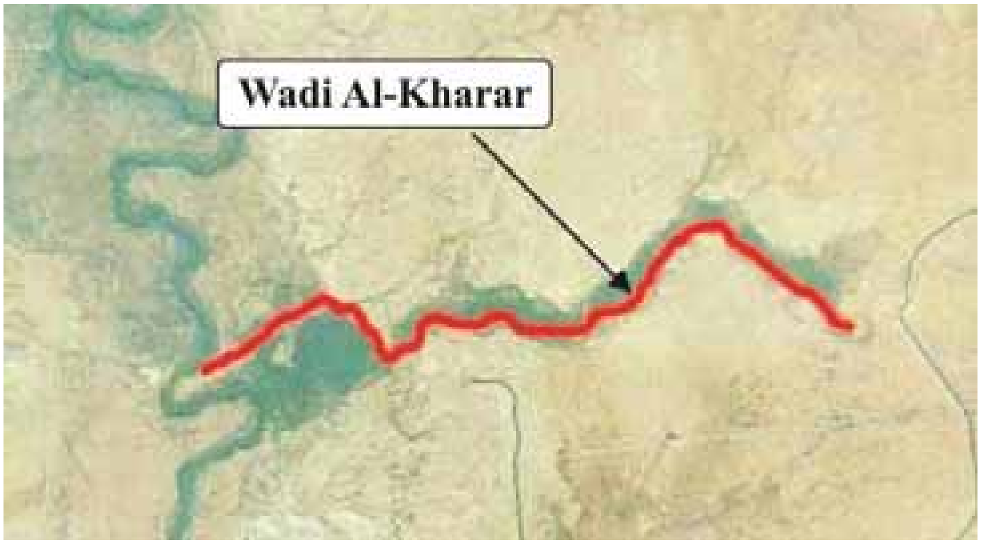


Figure 3: Wadi Al-Kharrar Area.

(a)

(b)

Figure 4: (a) Jabal Mar Elias, (b) Church of St .John the Baptist.

As mentioned before the main objective of this study is to integrate photogrammetry, geophysics and GIS for archeological documentation of baptism site, therefore the next three sections will describe the different tasks that have been accomplished for such purpose.

3. Photogrammetric Processing

Photogrammetry is concerned with deriving measurements of the size, shape and position of objects from measurements made to photographs. With the advent of digital photogrammetry and image processing technology, photogrammetric recording of world heritage sites has rapidly increased. Working in a digital environment allows flexibility in the choice of computer hardware and software and enables non-photogrammetrist to produce accurate data for recording purposes. Digital object enhancement and 3D modelling techniques are also possible and usually give clear presentation of heritage sites. They considerably enhance recognition of construction material, shape and area, and their spatial distribution, which is considered as one of the most difficult and time-consuming tasks for architects (Lerma et al., 2000). In summary, photogrammetry offers a rapid and accurate method of acquiring three-dimensional information regarding cultural monuments. Combining the measurements obtained from the photogrammetric record and 3D CAD models offer the means to recreate historic environments. This facilitates the generation of accurate digital records of historical and archaeological objects, while reducing the overall costs.

Figure 5 shows a LANDSAT satellite image with 15m resolution taken at 2002, where the location of Al-Mahgtas Area with respect to other major cites (Jerusalem, Jericho, Bethlehem and Madaba) are illustrated. In this paper photogrammetric processing used for three main productions; digital terrain Model (DTM), orthophoto and 3D modeling of existing archeological structure were established.

Figure 5: LANDSAT Imagery for Dead Sea and Al-Maghtas Area

For DTM generation, image correlation strategy was used for automatic extraction of the conjugate points. Moreover, adaptive method was used to generate a DTM with grid format, where the nature terrain (hilly, flat) was considered; Firstly a DTM file was created with 100 m post spacing to provide the whole project area with initial elevations of the terrain model where each post was edited to ground and saved. Then another DTM was built with 10 m post spacing, where improved representation of real terrain for 1:10000 photo-scales can be obtained. Finally, consistency test between the generated

DTM and collected GPS checkpoints was carried out in order to insure of the quality of the produced DTM. Figure 6 shows the DTM along Wadi Al-Kharar where elevation varies from -399 to -342 meter below the mean sea level.

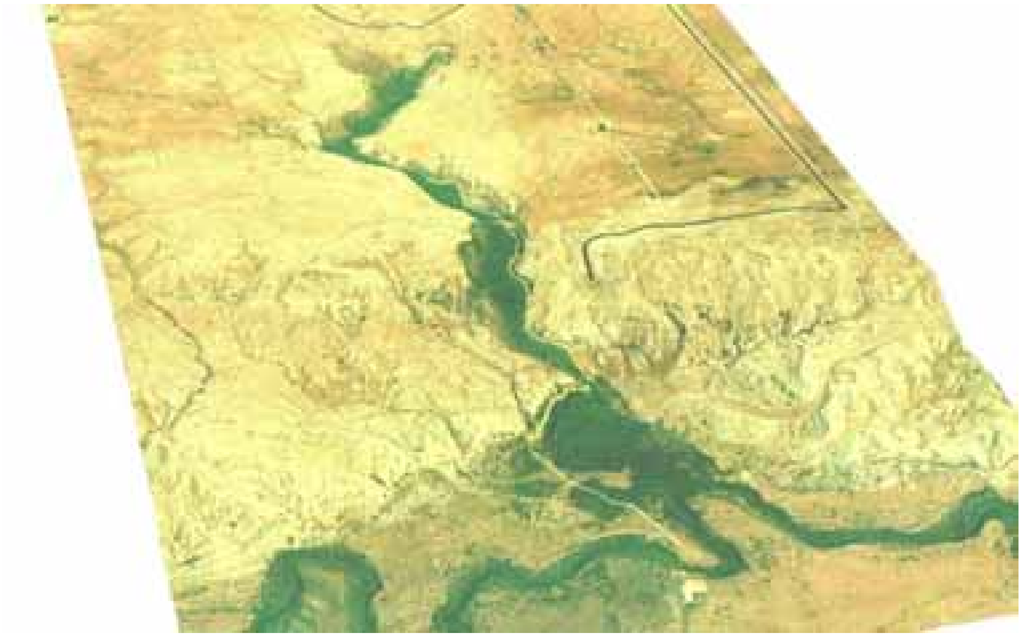


Figure 6: Ortho-Photo over Digital Terrain Model Extracted From Stereo-Model

Next stage in the processing is to generate Ortho-photo, Figure 6. Basically the Ortho-photo is photograph, transformed from perspective to orthogonal projection, or otherwise said, corrected for tilts and relief displacements. The produced DTM was used for orthophoto generation. Regions that are not edited correctly in the DTM file appear on the orthophoto as breaks and cuts in the region. These errors were removed by manual editing of the DTM based on visual inspections.

The last part in photogrammetric processing is 3D modeling that deal with real representation of the features, shapes, and texture. The principle of the 3D modeling is to give the features the same dimension and texture as it in the reality. As mentioned before, photogrammetry offers a rapid and accurate method of acquiring three-dimensional information regarding cultural monuments. Combining the measurements obtained from the photogrammetric record and 3D CAD models offer the means to recreate historic environments. This facilitates the generation of accurate digital records of historical and archaeological objects, while reducing the overall costs.

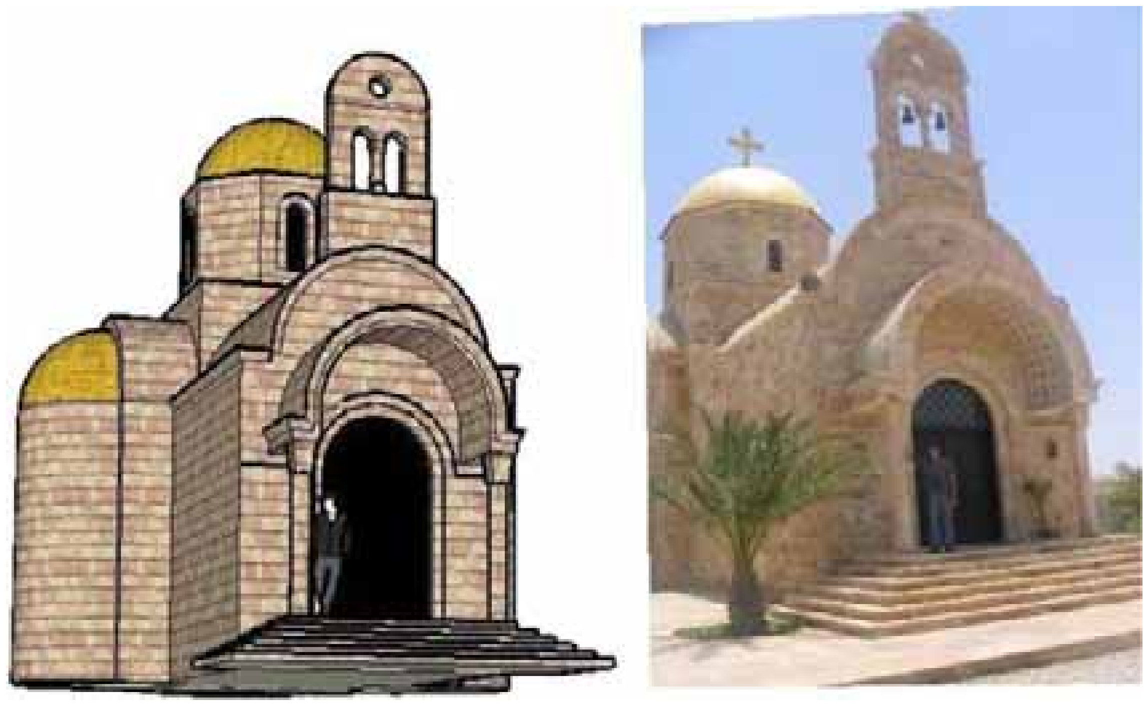
It has to be mentioned that using photogrammetric techniques for the recording and documentation of cultural heritage, factors that have an impact on recording accuracy and archiving efficiency have to be considered: namely, metric characteristics of the camera, imaging resolution, and requirements of the bundle adjustment procedure (Chong et al.,2002). The mathematical model that incorporates self-calibration and bundle adjustment procedure for accurate estimation of the interior orientation parameters has been adopted (Habib et al., 2004). This is a necessary prerequisite for accurate and reliable 3D-reconstruction.

After estimating the interior orientation parameters of the camera, experiments are conducted based on real data to build a three dimensional model for Church of St .John the Baptist and on the east bank of the Jordan river, Figure 4. For this purpose, the calibrated SONY P90 digital camera is used to capture convergent images at three different locations with 90^o rotation around the Z-axis at each exposure station. An arbitrary datum is chosen as reference for the object space. Conjugate points are selected and introduced into the bundle adjustment in order to estimate their ground coordinates. Selection of the points was performed while considering the following issues (Habib et al., 2004):

- Distribution of points. The measured points have to be well distributed and cover the whole object under study.
- Visibility of each point in two or more images. If the same points appear in larger number of images, the geometrical strength as well as the accuracy of three-dimensional coordinates will be improved.
- Adequacy of selected points for the reconstruction of different shapes from an architectural point of view. For example, to draw a circle, at least three points on the circumference have to be located.

As shown in Figure 7 (a, b), the three dimensional coordinates resulting from the adjustment procedure are used to reconstruct 3D model for structure that appear in Figure 4 as well as a new church that has been recently constructed along the Jordan River Figure 7 (c).

	
(a)	(b)



(c)

Figure 7: 3D Model with Surface Rendering

Surface rendering, which involves the generation of a 3D model with real world surface texture, is constructed, Figure 7 (a). That is, surface textures are added to the 3D model surfaces to give a real world appearance to the displayed model. The 3D surface rendering is very important for the presentation of ruined heritage sites where architects and renovation experts must have a realist view of the ruin for further inspiration (Ogleby 1999). Moreover, the 3D model can be digitally rotated to give a whole range of perspective views (El-Hakim, 2002).

4. Geophysical Processing

Ground penetrating radar (GPR) is an electronic system that transmits electromagnetic (EM) waves and detects the location of reflected energy. GPR has become a popular tool for different fields include geological, archaeological, environmental, engineering and construction, glaciological and forensic science. As a high-resolution technique for imaging soil and structures, GPR uses EM waves in the frequency band of 10-1000 MHz.

The advantage of using EM waves with signals of relatively short wavelength is the capability to resolved small objects at shallow depths. The GPR is used for geological strata mapping, stratigraphic studies, geological faces, and detection subsurface geological features like shallow subsurface faults, cracks and folds. GPR is used also to map shallow ground water, (Abueladas, 2005).

Archaeological excavations are usually along and labor-intensive process. The exploration of digging is the only way to know the artifact presence which consume time and expense. Geophysical methods especially GPR is effective tools to direct the excavations to locate buried structures and artifacts.

Figure 8 shows interpreted 400 MHz radargram along part of a GPR profile. The GPR data shows two targets along this profile at offsets 13 and 15 m, which present represent buried boulders.

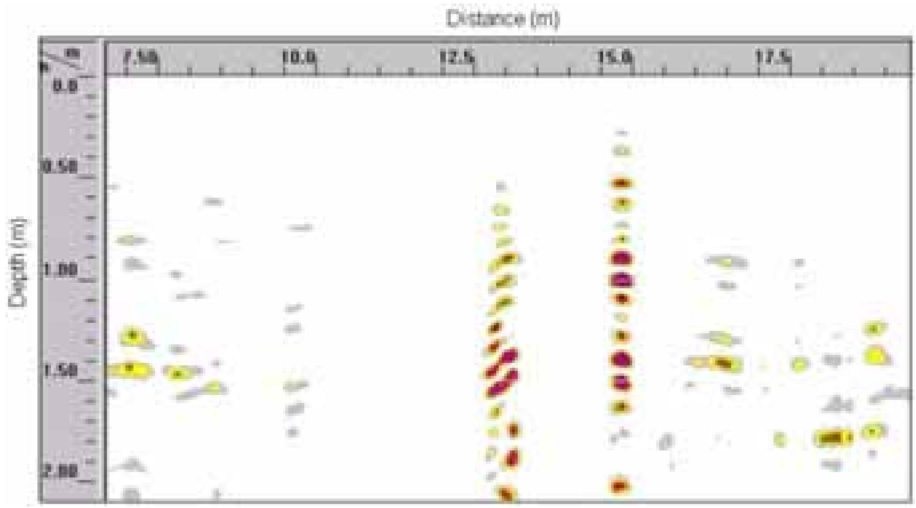


Figure 8: 400 MHz Radar-Gram along Part of GPR Profile.

Figure 9 shows a radargram along GPR scouting profile (40 MHz antenna), Anomaly at horizontal distance between 15.5 and 17.5 m indicate the location of the buried wall.

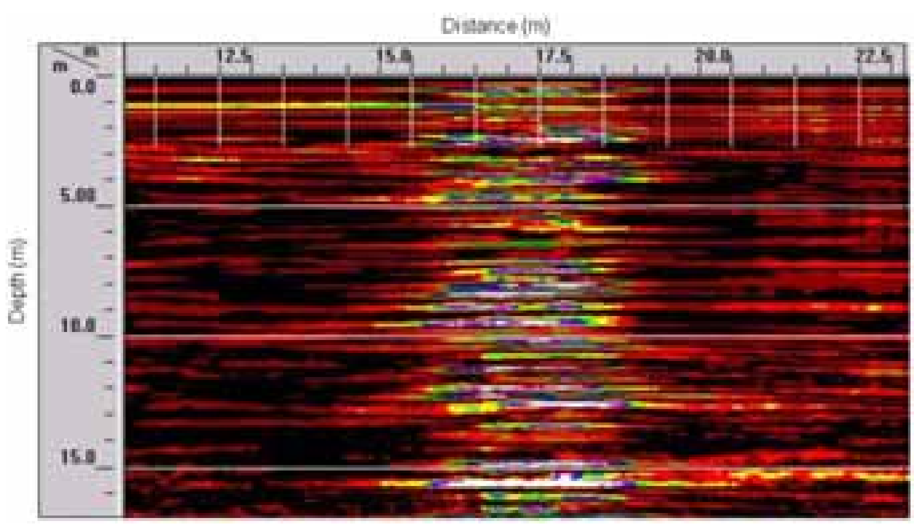


Figure 9: Radar-Gram along GPR Profile (40 MHz Antenna).

5. GIS Role in Archeological Documentation

A Geographic information System is a collection of information technology, data, and procedures for collecting , storing, manipulating, analyzing, and presenting maps and descriptive information about features that can be represented on maps (William et al., 1995). Cultural heritage objects often have a very irregular complex geometry. Thus, a good digital reconstruction requires a very detailed 3D model with a lot of geometry elements. So there are two main requirements to a 3D GIS. The first one is a support for the acquisition and handling of large amounts of complex and non-planar 3D geometry. The second one is the visualization of these objects which consists of a lot of geometry elements (Wüst et al., 2004).

This study highlights the representation and integration of photogrammetric products as well as geophysical profiles, which has been illustrated in section 3 and 4, in geo-referenced maps and images, where huge database can be manipulated, managed, and visualized. The obvious and accurate geometric overlaying of these different data will be helpful and great support for interpretation and analysis of the results.

the diversity of superimpose data that can be represented in the GIS system include (Boundary maps, point location of archeological sites, transportation layer, hydrological maps, digital elevation model, Aerial Images (Ortho-rectified) , Satellite images, land classification image , aquifer profiles and geology of the area), Figure 10. All these layers are associated with database and descriptive attributes. The system is designed in away that to allow easy and flexible updating for new coming database.

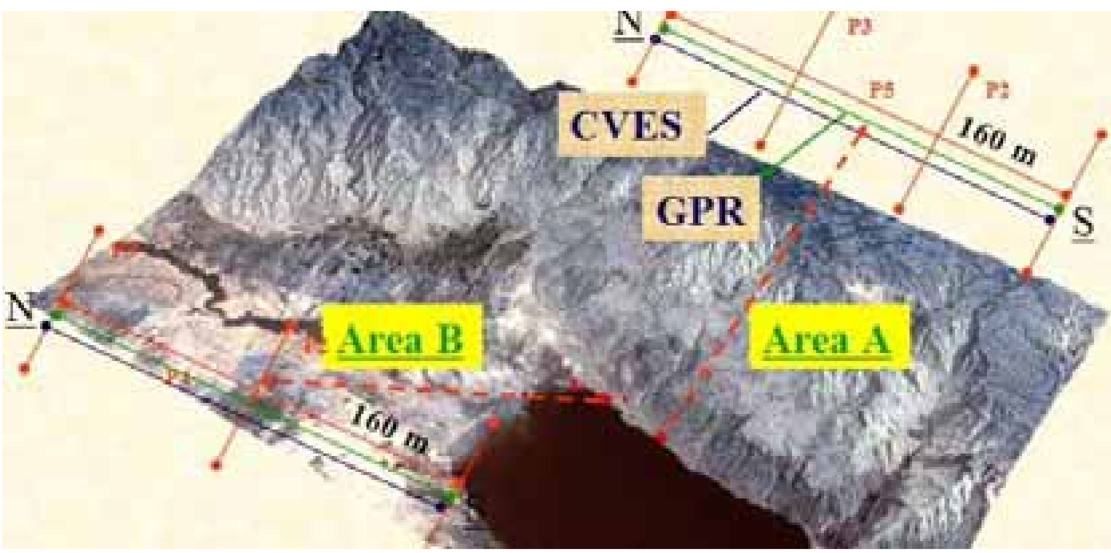


Figure 10: GIS system that includes registered layers from diverse disciplines (phtogrammetry, geophysics, remote sensing).

6. Conclusion and future work

In this study, we have presented different steps that can be used for atchylogical documentation of Al-Maghtas (Baptism site) along Jordan river. The feasibility of integration between different sciences has been explored.

Photogrammetric Techniques were used to emphasis on the identification of existing archeological sites in addition to generate map for tourism purposes where complete listing of all historical sites can be conducted. Also, Aerial photographs Processing (stereo pair) in the study area was conducted where high resolution Orthophoto image produced in order to be used for measurement in GIS systems. Moreover, High resolution Digital Elevation Model was generated to grant details about the topography of the study area. Finally, 3D models of historical archeological structures in Al-Mgatas area (Al-Magtas, Chuch, pools…) was performed. During the generation of these models, requirements such as high geometric accuracy, availability of all details, and efficiency in the model size and photo realism have been considered.

On other hand geophysical methods such as ground penetration radar was conducted for mapping buried walls, graves, buried ruins, cavities or chamber, crypts, marble plates, and other buried antiquities to direct forward excavations. Geophysical methods will also conducted for constructing hydro-geological map for the shallow aquifer in the study area, prepare map for active faults describe their depths and extensions, and estimate the hydrodynamics characteristics for the groundwater aquifers (Allen, 1975). All the geophysical results will be mapped on the orthophoto generated using photogrammetry. It has to be mentioned also, that digital elevation model is extremely necessary for reliable and precise analysis of geophysical output.

Finally, photogrammetric as well as geophysical results has to be geometrically registered and presented in a system that enable better viewing, analyses and interpretation. consequently , 3D GIS Model or al-Mahgtas area that include (Boundary maps, point location of archeological sites, transportation layer, hydrological maps, digital elevation model, Aerial Images (Ortho-rectified) , Satellite images, land classification image , aquifer profiles , geology of the area and GPR cross sections) was established. The provided 3D models will serve as basis for preservations or for interactive presentations of the historic site.

7. References

Abueladas, A., 2005. Ground penetrating radar investigations of active faults and antiquities along the Dead Sea Transform in Aqaba and Taba Sabkha, Jordan University of Missouri-Kansas City, master's thesis, p. 37, 61.

Allen, C. R., 1975. Geological criteria for evaluating seismicity. Geological Society of America Bulletin, v. 86, Issue 8, p.1041-1057.

Chong. A., B. McFadgen, Z. Majid, H. McKinlay, S. Luther, N. McHutchon, C.Khaw, S. Wamg, and A. Ahmad, 2002. Digital architectural photogrammetric recording of historical building and monuments, New Zeland Surveyor, 293: pp. 25-30.

Dallas, R., W., J. Kerr, S. Lunnon, and P. Bryan, 1995. Windsor Castle: Photogrammetric and archaeological recording after the fire, Photogrammetric Record 15(86):

El-Hakim, S., A. Beraldin and M. Picard (2002): Detailed 3D Reconstruction of Monuments using Multiple Techniques. In: ISPRS/CIPA International Workshop on Scanning for Cultural Heritage Recording, Corfu, Greece, pp.58-64.

Garfunkel, Z., 1981. Internal structure of the Dead Sea leaky transform (rift) in relation

Habib, A., Mwafag G R. Al-Ruzouq, and E. M. Kim 2004. 3-D Modelling of Historical Sites using Low-Cost Digital Cameras. XXth Congress of ISPRS, 12-23 July, 2004.

Khouri, R. , 2000. In the foot steps of John the Baptist. Royal wings, pp.62-66.

Lerma, J. Luis, Ruiz, L. Angel and F. Buchon, 2000. Application of spectral and textural classifications to recognise materials and damages on historical building façades. International Archives of Photogrammetry and Remote Sensing, 33(B5): 480-484.

to plate kinematics. Tectonophysics, v.80, p. 81-108.

Waheeb, 2000 M. “ New Discoveries Near the Baptism Site (Jordan River)” Newsletter of the German Protestant Institute of Archaeology in Amman, Department of Antiquities, Amman (Jordan), “MyProjects\Baptism\Baptism\baptism\Baptism Site - Bethany.htm”

William E., and G. Allan, 1995.”Manging Geographic Information System Projects”. Oxford University Press, New York Oxford.

Wüst T., S. Nebiker and R. Landolt, 2004. “Applying the 3d GIS DILAS to Archaeology and Cultural Heritage Projects – Requirements and First Results”. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 34, Part .