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IMPLEMENTATION OF GROUND PENETRATING RADAR (GPR) TO EVALUATE THE GEOTECHNICAL SITUATION OF THE SUBMERGED SIPHON AT MAHMOUDIA CHANNEL, DAMANHUR CITY, EGYPT

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عمل مسح جيوراداري لتقييم الحالة الجيوتقنية لسحارة ترعة المحمودية،مدينة دمنهور،مصر

الخلاصة: تم عمل مسح راداري علي السحارة القديمة أسفل ترعة المحمودية في مدينة دمنهور، مصر. مثل هذه السحارات يتم تشييدها لتسمح بمرور الماء أسفل ترع وقنوات الري. السحارة لها مدخل لمرور الماء من خلاله وأيضاً لها مخرج . يوجد كوبريين أعلي مدخل ومخرج السحارة، الأحمال الزائدة نتيجة مرور السيارات وشاحنات النقل تغير بالطبع من الحالة الجيوتقنية للسحارة. وتؤدى إلى وجود بعض التشققات التى ينتج عنها تسرب للمياه في الدراسة الحالية، وقد تم عمل قطاعات رادارية باستخدام جهاز SIR –system-10A موصل بهوائي ٢٠٠ ميجا هرتز والغرض من هذه الدراسة هي تحديد التشوهات والكسور في جسم السحارة الناجم عن الأحمال الزائدة، لذا تم عمل ثماني قطاعات رادارية يتراوح طولها ما بين ٢٠–٢٨م، خمسة أعلي مدخل السحارة، وثلاثة علي مخرج السحارة. تم معالجة بيانات المسح الراداري باستخدام برنامج المعالجة (Reflex W2d/3d) باستخدام مرشحات مختلفة بغرض الوصول لاعلي دقة في القطاعات الرادارية.

بعد عمل توصيف دقيق للقطاعات الرادارية بعد معالجة البيانات أمكن التوصل لتحديد أماكن وجود التشوهات والكسور والتي ظهرت علي أعماق تتراوح ما بين ٤–٦ م.

ABSTRACT: *Ground penetrating radar (GPR) investigation has been conducted on the old submerged siphon beneath El mahmodia channel of Edko at Damanhur city, Egypt. This siphon is a submerged water construction allowing the water drains to pass underneath irrigation water channels and canals. The siphon has a mouth where the drain's water enters and an exit where the drain's water goes out. It is a normal situation to find two bridges; one passing over the mouth and the other passing over the exit. The loads over the siphon might be affecting its geotechnical situation.*

The GPR profiles have been conducted using the GPR SIR system -10A connected to 200 MHz antenna. The survey is oriented to allocate the cracks, fractures, deformities and the distortion places in the siphon's body. Eight GPR profiles were conducted, five profiles were carried out in the northeastern side (the mouth) and three profiles were in the southwestern side (the exit). The measured GPR data are processed and visualized using Reflex software program (Reflex W2d/3d) in different ways to show the infra-structural content of the submerged Siphon body. Interpretations of the processed data show some deformities and the distortion places in the body of the submerged Siphon at different location with different depths. The horizontal distances range from 20m to 28m and the subsurface depth ranges from 4m to 6m in both sides of the submerged siphon. Detection of the deformities is the target of the present study.

INTRODUCTION

The study area is located at Damanhur city near Ashur Bridge, which is an old submerged Siphon of Edku beneath the Mahmoudia channel (Fig. 1). The present study is an anatomical measurement of the submerged Siphon body using the geo-radar survey. The GPR profiles are taken to the extension of the submerged Siphon to reveal the stress on its body (Fig.2). The purpose of the surveying was to know if there are deformations in the body of the submerged Siphon, so that it can be treated by engineering solutions. There are some distortions and destroyed parts in the northeastern and the side of the submerged Siphon (Figs 3). In the southwestern parts, there are erosion for the mud layers which bearing the road under the asphaltic layer, as well as a partial fall of the asphaltic road over the body of the submerged Siphon as shown in figure (4). Surveying the study area using ground penetrating radar will help accurately to identify the locations of the damaged parts and the places of deformations in the body of the submerged Siphon, then to determine the ways to deal with these defects to protect the Siphon from collapse and complete damage.

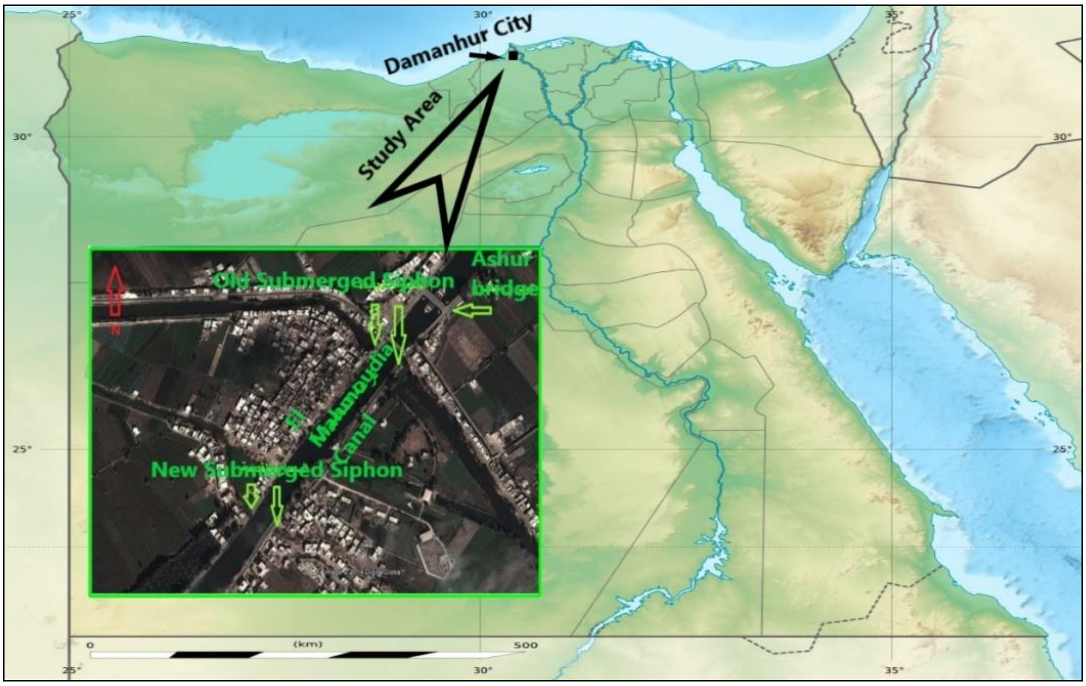

Fig. (1): The location map of the study area.

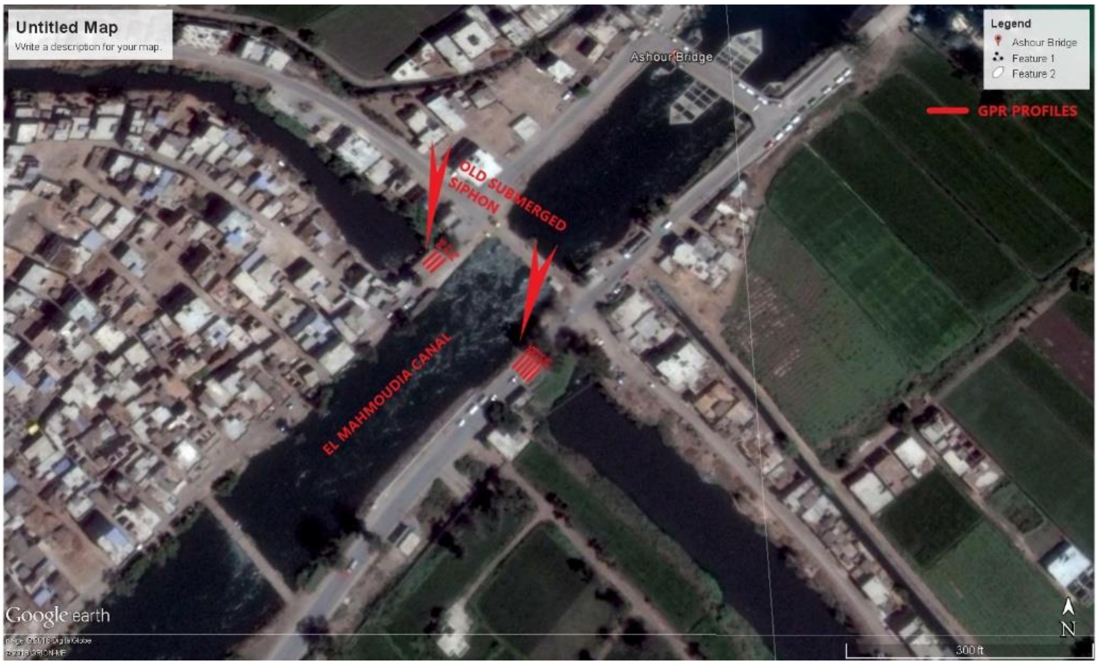

Fig. (2): Eye bird view showing the study area with the selected GPR profiles.

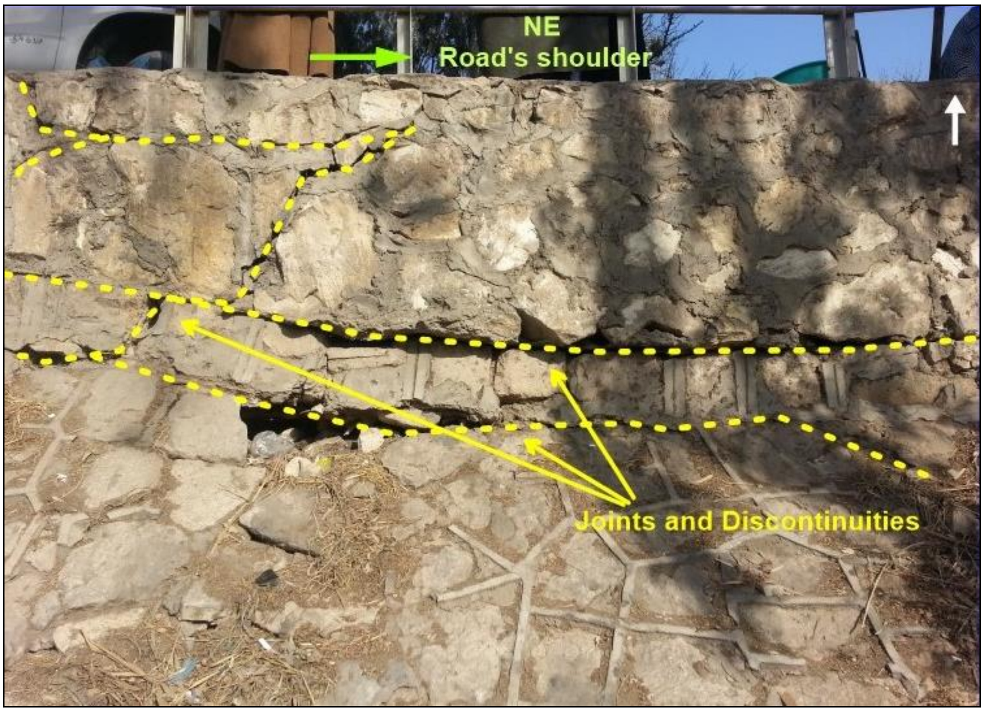

Fig. (3): The northeastern shoulder of the submerged Siphon body.

Fig. (4): The southwestern shoulder of the submerged Siphon body.

GPR method concept

A ground penetrating radar unit includes a transmitter, a receiver and a data collection device (Fig.5). A radar transmitter sends a radio signal from an antenna into surrounding space. A receiver picks up reflections received from this radio signal, the strength and direction of the reflected signal give the size and distance to reflecting object (Daniels,1996).

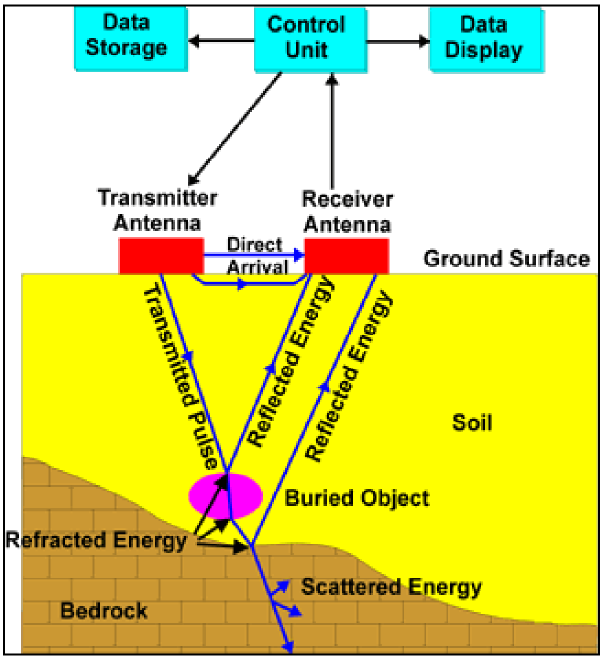

Fig. (5): GPR schematic, from EPA (Environmental Protection Agency, web site).

A major advantage of GPR is that it records detail vertical soil profiles rather than just generating a horizontal plan maps. It must be remembers that GPR doesn't only image targets in the subsurface, it provides 2D record of the 3D waves bouncing of object in the ground (Davis et al.,1989). Linear features which are aligned with the GPR's electrical field will not produce high reflectance values. However, this means that GPR is good at distinguishing linear features only if they run perpendicular to the path of the antenna (Sharma Prem, 1997).

The GPR instrument used in present study

In the present study, subsurface interface radar (SIR system-10A) was used; this GPR instrument is usually used for civil engineering, construction, geology, hydrogeology, archaeology and environmental protection (Fig.6). The SIR system-10A provides a detailed look at what's beneath the surface. Designed to interface with geophysical survey system 1nc.entire line of state-of-the-art antennas, it is the first system to offer leading-edge, GPR technology with full digital control of all setup parameters and multi-channel color display (GSSI, 2006).

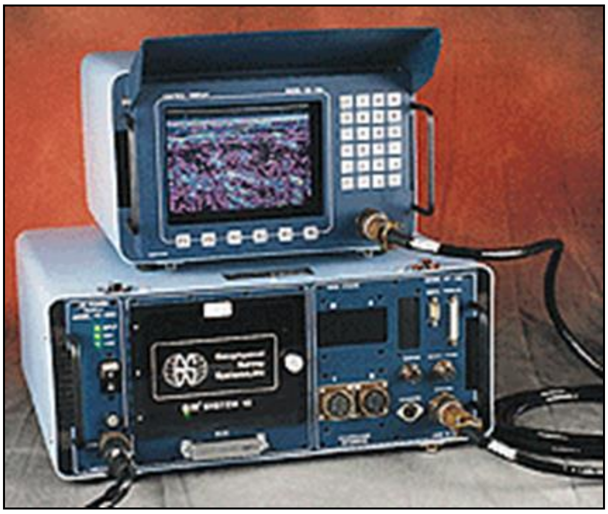

Fig (6): GPR instrument model SIR system-10A used in the study area.

GPR data acquisition

GPR data acquisitions are very similar to the methods used in seismic reflection. However, GPR has more resolution and it is good tool to pick up the changes in electromagnetic better than sounding properties. The GPR reflections which caused by electromagnetic waves penetrating media that have variations in the electrical properties of the boundaries of different dielectric constant contrasts. Reflection is almost proportional to the variation of the dielectric constants at the boundary (Davis and Annan, 1989). Before starting the measurement, the antenna 200 MHz was tested with the different settings of the device. It showed its compatibility with the monostatic system. The device was fed to detect the depth with the target position by radar recording. We also reduced the electromagnetic emission by removing its various sources as well as the exclusion of any external influence. The GPR data measured a lined in both sides (entrance and exit) of the submerged Siphon as in Figure (7).

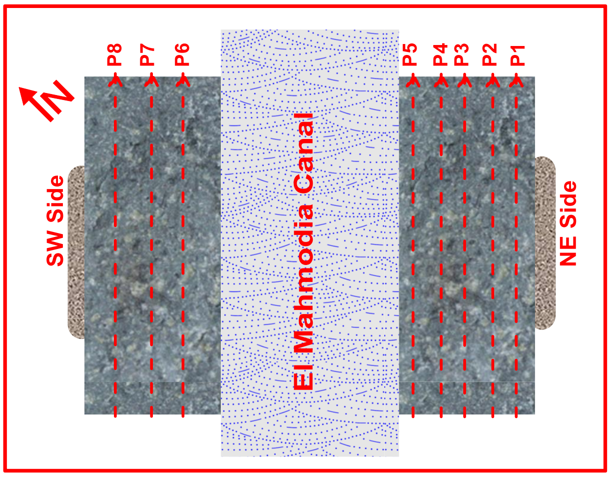

Fig. (7): The GPR profiles directions over the submerged Siphon body.

Eight profiles were carried out on both sides of the submerged Siphon (Sahara). Five of them were conducted in the northeastern (the entrance), and three other profiles in the southwestern part (the exit) of the submerged Siphon (Fig.7). The length of the profiles range from 20m to 28m with a 2m space. The study area in total profiles covered perfectly.

GPR data processing

GPR raw data have all the information and we have to extract requested information in it. The total of the information cannot be enhanced by signal processing, but the quality of the information can greatly be improved by different processing parameters. To get good processing, it must understand the meaning of each processing, to produce serious artifact. These artifacts help to do perfect interpretation of GPR data. This article is applied to explain fundamental physics and mathematics, which are used for GPR data processing (Motoyuki Sato, 2001).

The collected data are processed using the software program (Reflex W, 2D/3D), in which this program is designed for the steps of processing and interpretation of 2D and 3D electromagnetic and seismic reflections data. The program supports the most formats of the GPR data. A part of the standard filter algorithms a wide range of special methods is available. The obtained GPR raw data were processed by applying different parameters and filters to get clear and high resolution 2D GPR profiles. The data was processed in a way to fulfill the objectives of the survey that is to visualize the geotechnical elements inside and around the siphon's body.

RESULTS AND DISCUSSION

For the most part, determining subsurface geology and buried man-made objects is an art more than a since. In other words, it takes lots of practice before you get it right. In many GPR surveys performed by Beres and Haeni (1991), they outline the procedure for determining shallow subsurface features from GPR data. The depth to an anomaly source is based on the signal velocity through the soil (or other matrix). The velocity of the signal is not uniform for different materials, but in most instances the vertical error is not likely to be great (Benson 1995).

If the subsurface was perfectly homogenous, the GPR unit would not record any reflections. Thus, the fact that the earth is heterogeneous gives us radar reflection data to interpret (Hempen and Hatheway, 1992; Daniels, 1989; and Daniels, 1996).

GPR is a non-destructive geophysical method that produces vertical cross-sectional images of the shallow subsurface, the resulting image (radar-gram) being very similar in style to seismic reflection profiles. GPR acquisition is based on the penetration, reflection and scattering of high frequency electromagnetic waves within the subsurface (Gutierrez et al. 2009 and Mustasaar et al.2012).

The Ground Penetrating Radar (GPR) survey data can be analyzed and presented in many ways. Due to the data being displayed in real time, it may be interpreted qualitatively, on site provided it is of an adequate quality. This is a very rapid and cost effective means. The raw data obtained from the study area after the processing, can be described and analyzed as the following;

Profiles P1 and P2

The interpretation of the processed GPR raw data of profile P1 (Fig. 8) represents an anatomical case of the submerged Siphon body and their hard loads. The asphalt layer, the Siphon body and its sides are clear and visible. By the visual inspection to the variations in the reflections, it is clear that there are some distortions in the left side of the submerged Siphon and it is being mixed with water. The slope reflections in the two sides are referring to the Siphon shoulder.

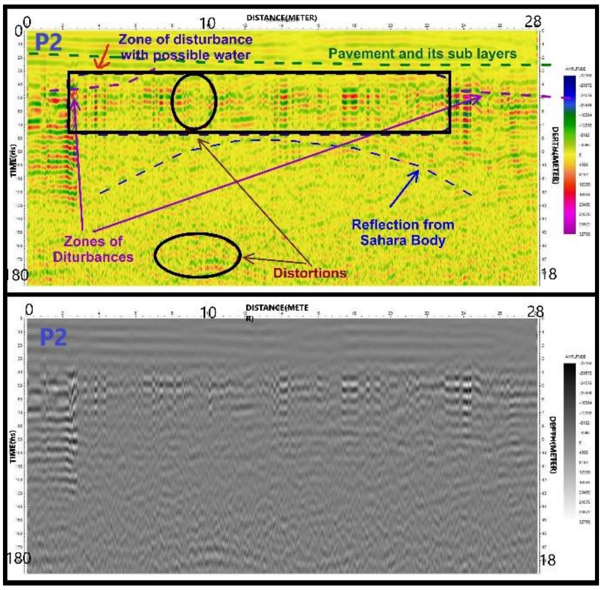

Fig. (8): The GPR profile P1.

The interpretation of GPR profile P2 (Fig.9) shows almost all of the features that have been observed in profile P1, with note that the probability of water availability is more apparent

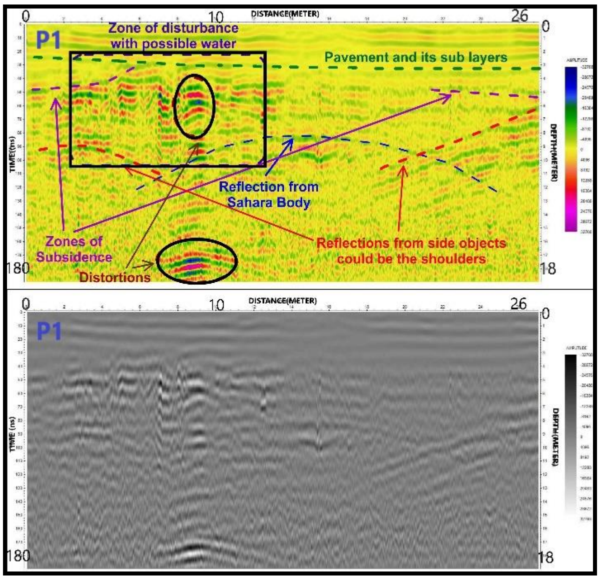

Fig. (9): The GPR profile P2.

Profiles P3 and 4

The GPR profile P3 Shows a relatively different view from the previous profiles, but it was possible to limit some of the places that were previously observed and were confined by circles as shown in Figure 10. The GPR profile 4 (Fig. 11) shows conformation the presence of water saturated in the marked red zones.

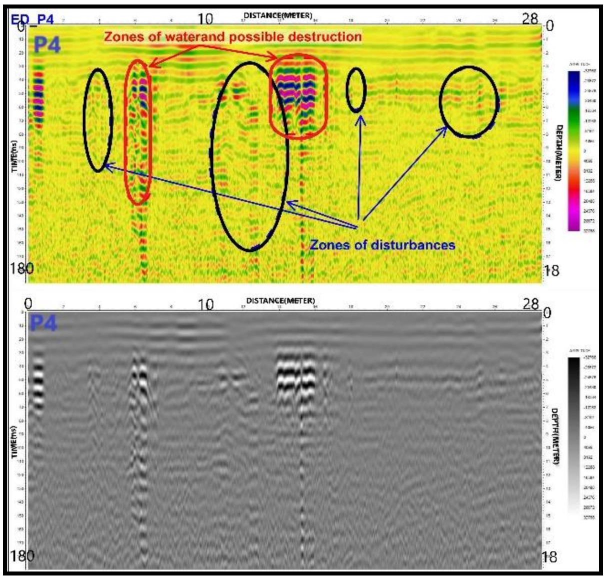

Fig. (10): The GPR profile P3.

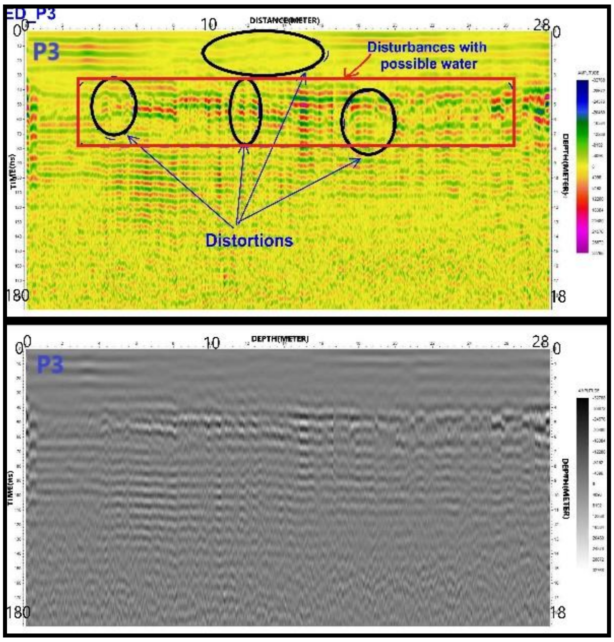

Fig. (11): The GPR profile P4.

Profile P5

The GPR profile 5 located in the northern side of the study area. Visual inspection of the variation in the reflected signals shows a significant difference from the previous profiles, where the presence of water is very abundant and also increasing the chances of the Siphon body falling in the places referred in the profile (Fig.12).

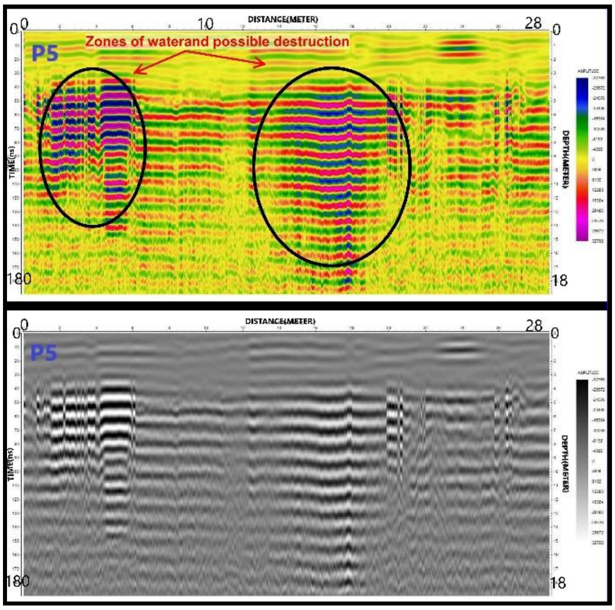

Fig. (12): The GPR profile P5.

Profiles P6, P7 and P8

The same observations that were recorded in the interpretation of the previous profiles in the northeastern side of the submerged Siphon can be observed in the profiles P6, P7, and P8, where the fractures and distortions appear with the possibility of the presence of water in those places, that will increase the chance of landing and collapse of the submerged Siphon body in the direction of Mahmoudia channel (Fig.13).In profile P6 ,the fractures and the distortions places appear at depth of 5m ,and at distances from 8 to 18 m from the profile starting. In profile P7, there is clear distortion place locate at depth of 5m and at distance of 14 m. The third profile P8 shows fractures and distortions place appear at depth of about 6m, and at distance of 19 m.

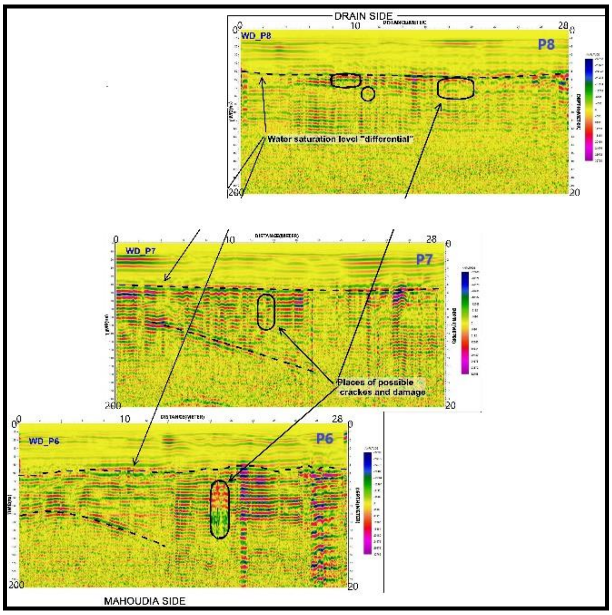

Fig. (13): The GPR profiles P6, P7 and P8.

CONCLUSION

The study area is located at Damanhur city near Ashur Bridge, which is an old submerged Siphon of Edku with the channel of Mahmoudia. The study is an anatomical measurement of the submerged Siphon body using the geo-radar survey. Surveying the study area using ground penetrating radar will help to accurately identify the locations of the damaged parts and identify the places of deformations in the body of the covering drainage. At the present study, subsurface interface radar (SIR system-10A) was used. Eight profiles were carried out on the two sides of the covered drainage (Sahara). Five profiles were carried out in the northeastern, and three profiles in the southwestern of the submerged Siphon.

The GPR profiles are processed using the software program (Reflex W, 2D/3D), in which this program is especially designed for the complete processing and interpretation of 2 and 3 dimensional electromagnetic and seismic reflections.

From the interpretation and analysis of the GPR profiles (P1-P5), we can observe that the entrance of the submerged Siphon in the northeastern side is relatively good, although there is a dislocation at the shoulders and cracks in the asphalt opposite to the channel, but the situation worsens in the direction of the exit close to the channel, also there are many fractures and deformities, but does not extend to the body of the Sahara. Near the channel, there is increasing in the indicators of the decline and the presence of water, which warns the risk of collapse. The first third of the Sahara in the southeastern side shows an object whose repeated in the first three profiles may be related to the Sahara body.

From the analysis of the GPR profiles (P6-P8) in the southwestern side of the submerged Siphon, the exit of the covered drainage is relatively good, even though it is worse than the entrance. The profile P6 close to the channel shows increasing of water presence, although the probability of collapse increases toward the channel and decrease toward the submerged Siphon.

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