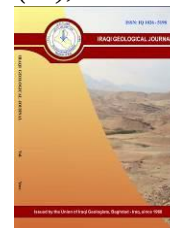




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Using GPR Technique to Investigate Buried Engineering Objects at a Site Located East of Baghdad University Campus, Iraq

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Abstract

A ground-penetrating radar survey was conducted at the eastern part of the University of Baghdad Campus to detect buried engineering objects and evaluate the lateral soil heterogeneity in the site. Malå Geoscience RAMAC system equipped with a 250 MHz antenna was used to perform the survey. Four profiles with a length ranging from 30 to 46 m were acquired across the site. Two parallel profiles were oriented in the N- S direction, while other two profiles were oriented E-W, to provide adequate spatial coverage. The collected data were processed and interpreted using Reflex-Win software following standard processing procedures. In profiles A and B, a prominent hyperbolic anomaly was identified at approximately 14 m along them at a depth of 1.0 m. Another hyperbolic shape is detected in profile A at distance 24m, depth of 1.6 m. Having profile C, two hyperbolic reflections were observed, the first was located at a distance of 2 m, depth of 1.4 m, whereas the second one located at approximately 22m with a depth of about 0.8m. The radargram of profile D exhibited three distinct hyperbolic anomalies located at distances of 1m, 12m, and 32m, with corresponding depths of approximately 1.4m, 1m, and 1.4m, respectively. In addition, shallow subsurface variations were observed at depths ranging from 0.5 to 0.8 m, which may indicate variations in soil compaction or the presence of fill material across the surveyed section. Some surface noise was also detected, extended into the deeper part of the radar sections, particularly beneath the concrete slab which identified in profiles A and D. These findings were validated by comparing them with the engineering layouts of the University of Baghdad Campus, which confirmed that the detected anomalies correspond to the locations of underground high-voltage electrical cables and water pipes. Overall, the results demonstrate that ground penetrating radar is an effective non-destructive geophysical method for detecting buried engineering and characterizing of shallow subsurface conditions in the urban environments.

Keywords: Ground Penetrating Radar; Buried objects; Soil compaction; University of Baghdad; Iraq

1. Introduction

Ground penetrating radar (GPR) is one of the most important near-surface geophysical survey methods and has experienced significant development over the past three decades in shallow and high-resolution investigation (Leong and Zhu, 2021). This method is widely used in urban environments because it is a non-destructive technique which capable of detecting buried objects and characterizing

subsurface conditions (Annan et al. 1991; Jol, 2009; Wei and Hashim, 2011). GPR technique operates by transmitting high-frequency electromagnetic waves into the ground and recording the reflected signals generated by contrasts in the electrical properties of subsurface materials. Several studies have demonstrated the effectiveness of GPR in archaeological, and environmental and engineering applications (Ghozzi et al., 2018; Abdulrazzaq et al. 2021; Al-Rawi and Al-Banna, 2023; El-Khteeb et al., 2025). In archaeological studies, GPR has been successfully used to detect buried walls, foundation and other structural remains. For example, in the ancient city of Babylon, GPR survey integrated with electrical resistivity tomography were employed to map subsurface archaeological and buried walls (Al-Hameedawi et al., 2022). In engineering applications, GPR has become an essential tool for a wide range of investigations, including utility detection, geotechnical characterization, pavement evaluation, buried pipes, identification of subsurface voids, and infrastructures (Karim et al., 2016; Metwaly, 2015; Tabarro et al., 2018; Al-Khalidy et al., 2018; Al-Yasi et al., 2019; Chlaib, 2020; Haron et al., 2023). Electrical methods have been used in several studies to support or supplement GPR findings. Within the University of Baghdad Campus, there are numerous underground facilities whose actual locations deviate from those depicted on the engineering plans, therefore, this study aims for attempting to detect the location of some engineering objects using the GPR technique, as well as to investigate the soil compaction variations at the study sites.

2. Materials and Methods

2.1. Location and Geology of the Study Area

The study area is located within the University of Baghdad campus, south of Baghdad Governorate, on the eastern bank of the Tigris River. According to the Universal Transverse Mercator (UTM) coordinate system, zone 38 North, the center of the site coordinates is Northing = 36°81'72.5" m, and Easting = 44°24'14" m (Fig. 1). Baghdad lies within the Mesopotamian Basin, which is characterized by thick sedimentary layers covered by recent alluvial sediments at the top surface, resulting from continuous river deposits (Jassim and Goff, 2006). The surface layer, known as the fill layer, consists of clay, silt and construction debris such as gravel and concrete, with a thickness ranging from 1 to 15 m (NCCL, 2002). The groundwater conditions may influence the penetration depth of electromagnetic waves. The groundwater depth at the study site is found to be ranged between 5 and 6 m below the surface (Thabit et al., 2016).

2.2. Fieldwork and Processing

2.2.1. The fieldwork

The fieldwork was conducted at the considered site of the University of Baghdad (Fig. 2). Malå Geoscience RAMAC ground penetrating radar (GPR) instrument, which ownership is to Iraqi Geological Survey, was used for the survey, equipped with a 250 MHz antenna to ensure adequate soil penetration depth. Field data were collected by scanning two profiles (A and B) are in N-S direction with distance between them about 20 m. The lengths of these two profiles are 30 m and 36 m, respectively. Another two profiles (C and D) are conducting and trending in E-W direction with 30 m distance between them. Their lengths are 46 m and 41 m, respectively, as shown in Fig. 2. The survey was conducted using a continuous profiling mode with a survey wheel to control trace spacing. The operating parameters of the survey, which are chosen to get good results are:

- Antenna frequency: 250 MHz; (The antenna frequency of 250 MHz was selected as a compromise between penetration depth and resolution)
- Velocity: 0.027 m/ns.

- Point Interval: 0.03 m.
- Depth: 2 m.
- Sampling Frequency: 4274.6 MHz.
- Time Window: 100 ns.

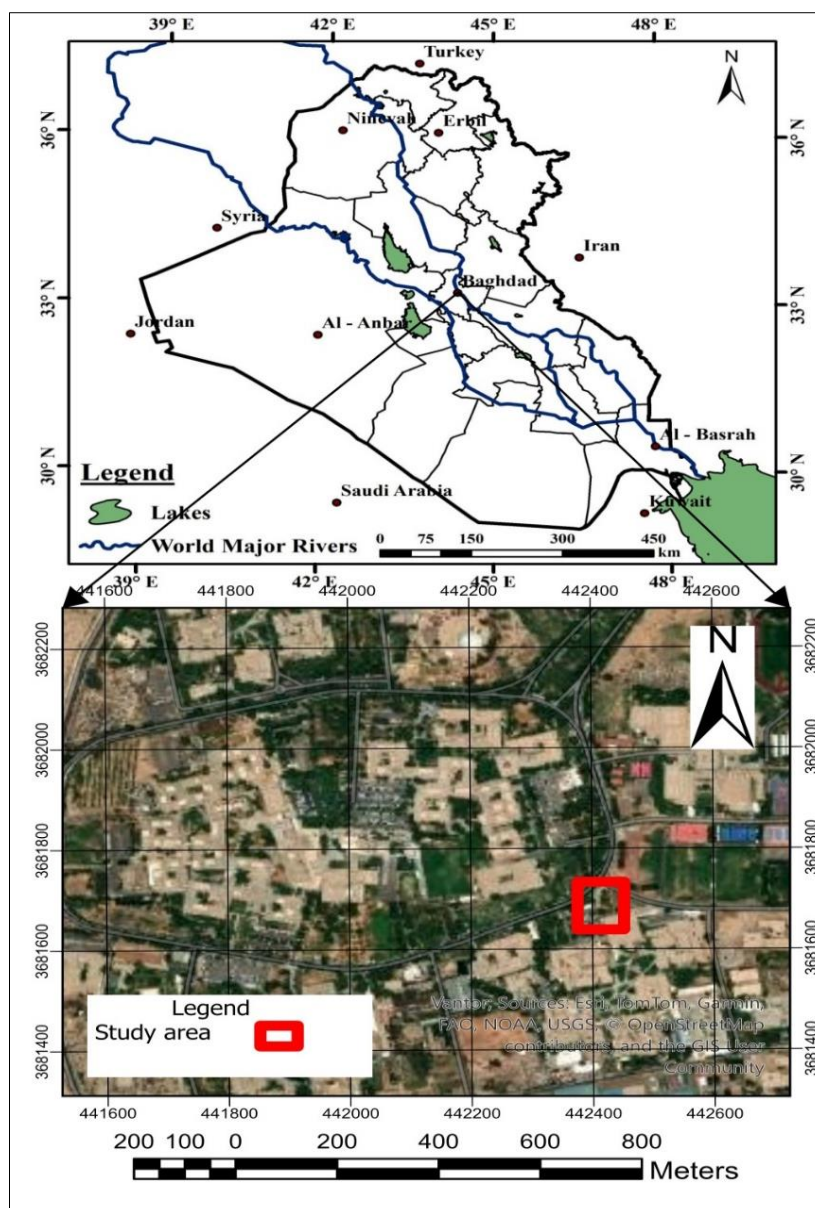


Fig. 1. Location map of the study area

2.2.2. Processing of GPR data

The GPR profile data were processed using Reflex-Win v.5.0.5 (Sandmeier Software, 2008) through the application of a set of common filters that includes Dewow filter (removes low-frequency components caused by electromagnetic induction and the instrument instability), and Time-zero correction was performed to adjust the surface reflection position. The static correction (adjust for elevation changes across the profile), background removal (eliminate horizontal noise), manual gain (y) (enhance the weak signals by multiplying radar amplitudes), and band-pass filter (remove unwanted frequencies), were also used, respectively (Cassidy, 2009). The above-mentioned processing steps were applied to all profiles. However, profile D is shown as an example in Figs. 3 and 4.

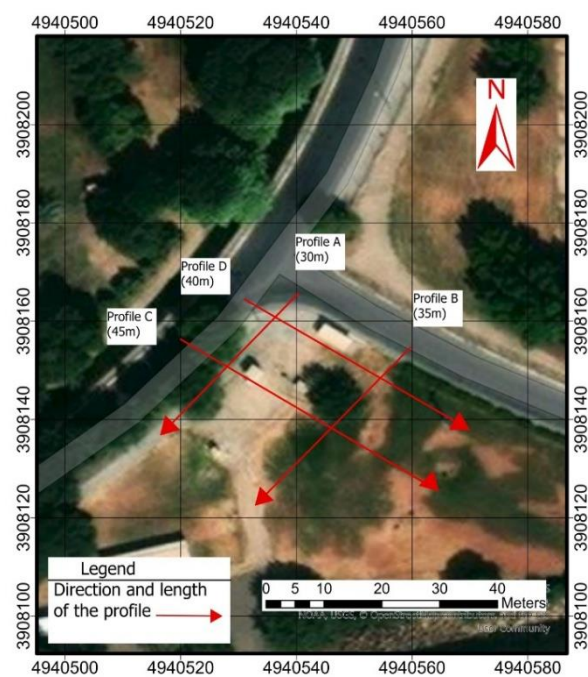


Fig. 2. Locations of profiles in the study site

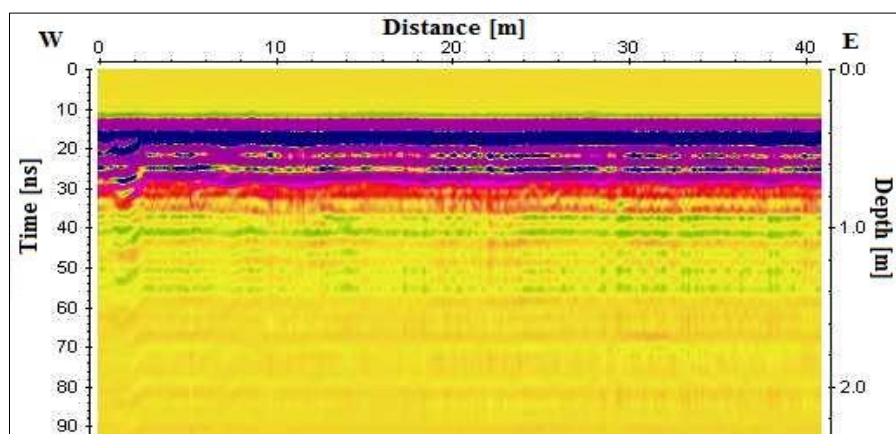


Fig. 3. The raw data profile (D) before applying processing filters

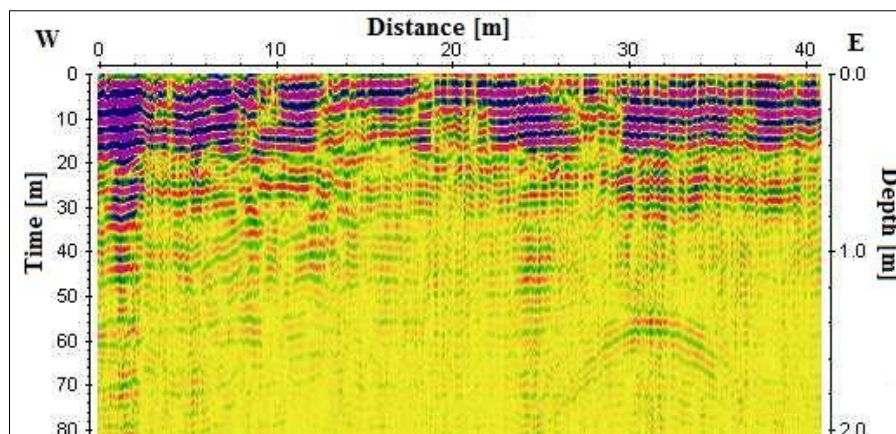


Fig. 4. GPR profile (D) after applying processing filters

3. Results and Discussions

3.1. Profile A

The GPR radargram of profile A shows the effect of strong continuous reflection corresponding to a concrete slab layer extending along the profile; at a depth of about 0.5 m, where the boundaries between slab blocks are clearly visible. Beneath this layer, within the depth interval 0.5–1.5 m, irregular reflections are observed, which likely indicate variations in soil properties and compaction. A distinct reflection is observed at a distance of approximately 14 m along the profile at a depth of about 1.5 m. Another reflection anomaly appears at approximately 23 m along the profile at a similar depth of 1.5 m. These reflection signatures are typically associated with point reflectors, which may represent buried utilities such as electrical cables. The remaining weak reflections in the radargram are mainly attributed to the background noise and signal attenuation along the profile, as shown in Fig. 5.

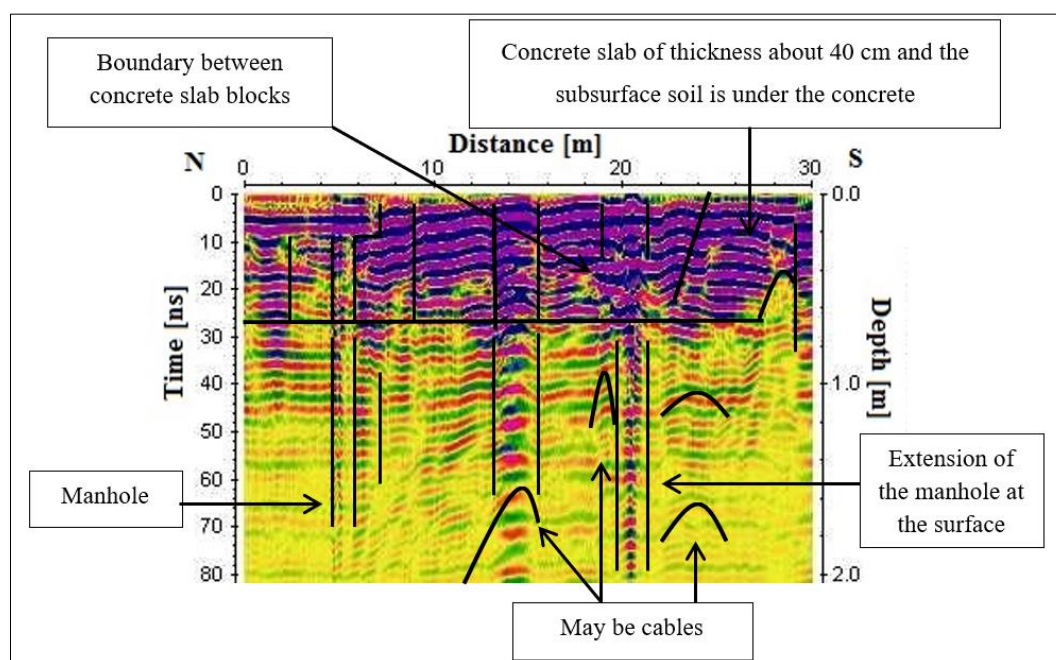


Fig. 5. GPR Radargram of Profile-A

3.2. Profile B

The GPR radargram along profile B indicates the presence of the soil surface at a depth of 0.4 m, which may reflect variation in soil compaction and irregularities along the profile. Beneath this layer, within the depth of 0.4–2.0 m, the radar reflections appear relatively homogeneous, suggesting fairly uniform subsurface conditions. However, a distinct reflection is observed at a distance of about 11 m along the profile, depth of about 1.5 m. This reflection anomaly may represent a buried object, such as an electrical cable (Fig. 6).

3.3. Profile C

The GPR radargram of profile C indicate relatively homogeneous radar reflections in the upper layer along the profile to a depth of 0.5 m, with some local variations observed at distance of 2 – 4 m, 18 – 22 m and 29 – 32 m. These variations may be related to changes in the subsurface materials or soil compaction. Below a depth of approximately 0.8 m, the radar reflections appear relatively uniform, indicating more homogeneous subsurface condition. A reflection is detected at a distance of approximately 3 m along the profile at a depth about 1.4 m. Another reflection anomaly is observed at a

distance of 22 m, with a depth of approximately 0.8 m, which may represent a buried utility such as cable or pipe (Fig. 7).

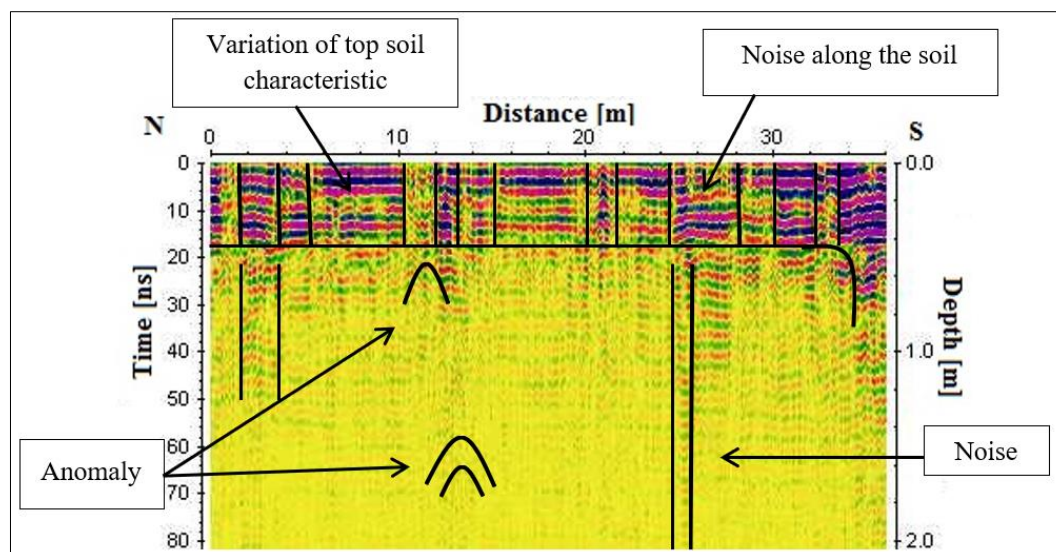


Fig. 6. GPR Radargram of Profile-B

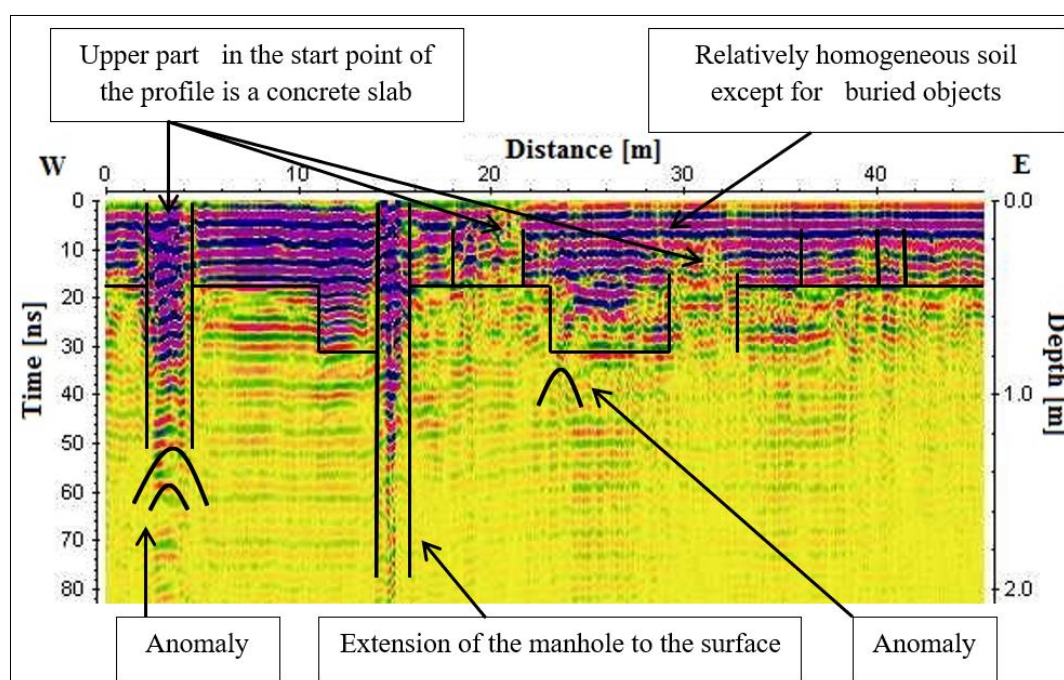


Fig. 7. GPR Radargram of Profile-C

3.4. Profile D

The GPR radargram of profile D shows variation in the upper soil layer to a depth of approximately 0.5 m, which may be related to the variations in the soil compaction or surface construction materials. Several anomalies are detected along this profile. The first anomaly is located at a distance of 2 m, depth of 1.2 m. The second anomaly is observed between 10 m and 12 m along the profile at a depth of approximately 1.0 m. A third anomaly (hyperbolic) reflection appears at a distance of approximately 32 m, depth of 1.4 m. Profile C (Fig. 7) above and profile D, however, suggested that the anomaly which located near 2 m along the profile, depth of approximately 1.4 m, may represent a continuous buried object extending cross both profiles (Fig. 8).

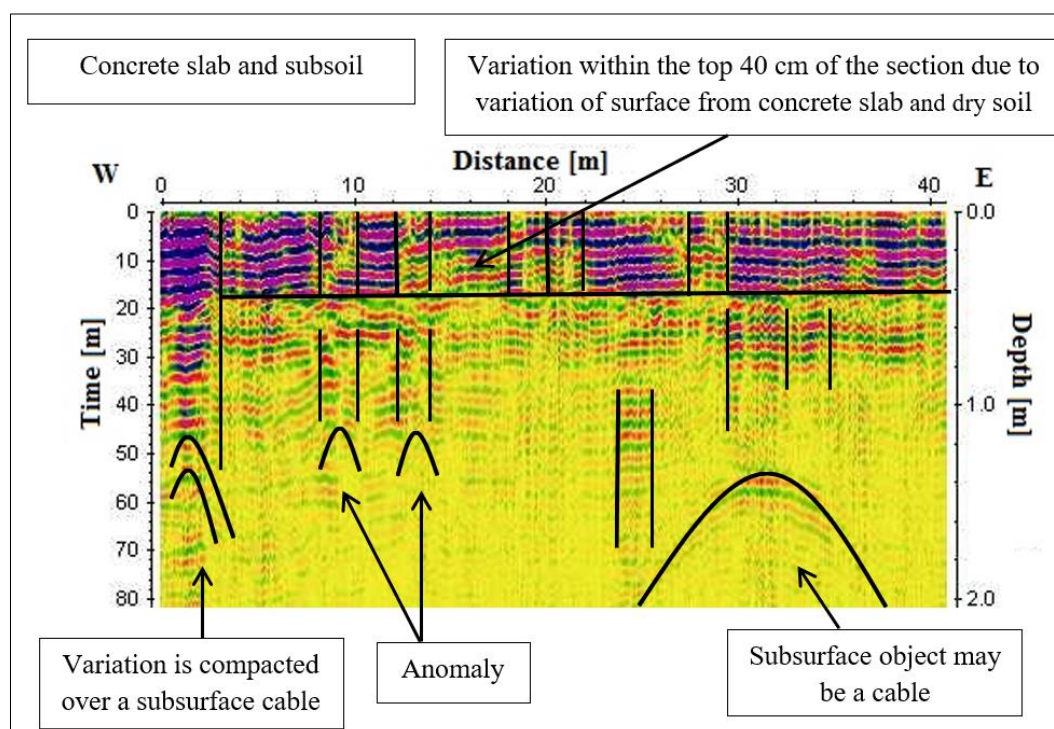


Fig. 8. GPR Radargram of Profile-D

4. Discussion

The study site is characterized by the presence of several obstacles, including many engineering utilities, manholes and surface irrigation pipes and variation in the ground conditions ranging from natural soil to concrete slab surface. These conditions posed challenges during the field survey, data processing significantly improved the visibility of subsurface reflections and enhanced the interpretation of the detected anomalies. A prominent anomaly observed in all four radar profiles is interpreted as a buried electrical cable, appearing at a depth of approximately 1.5 m. The location of this anomaly coincides with the route of electrical cables shown on the engineering project map of the study site. Two additional anomalies were detected only in Profiles C and D, with depths not exceeding 1.0 m. Based on field observations and their spatial positions, these anomalies are interpreted as buried water pipelines. The locations of these features correspond well with the expected routes of underground utilities within the study area (Fig. 9).

5. Conclusions

The interpreted GPR radargrams reveal the presence of a concrete slab layer (according to the field observation) in the upper part of the ground in several locations along the surveyed profiles, with an approximate thickness of about 0.5 m. Variations within the upper soil layer reveal a soil with different degree of compaction. The soil below the approximate depth of 0.8 m appear relatively homogeneous. Several buried anomalies were detected across the four GPR profiles at depths of approximately 1.5 m. These anomalies are interpreted as buried high-voltage electrical cables or pipes, based on their positions correspondence with the engineering utility map of the study area. Additional shallow anomalies were detected at depths ranging between 0.5 and 1.0 m, which are likely associated with buried water pipelines. Some noise signals were observed in the radar sections, particularly beneath the concrete slabs and within dry soil layers, which slightly affected the clarity of deeper reflections. Finally, the results demonstrated that ground penetrating radar is an effective and non-destructive geophysical technique in detecting buried objects in urban areas.

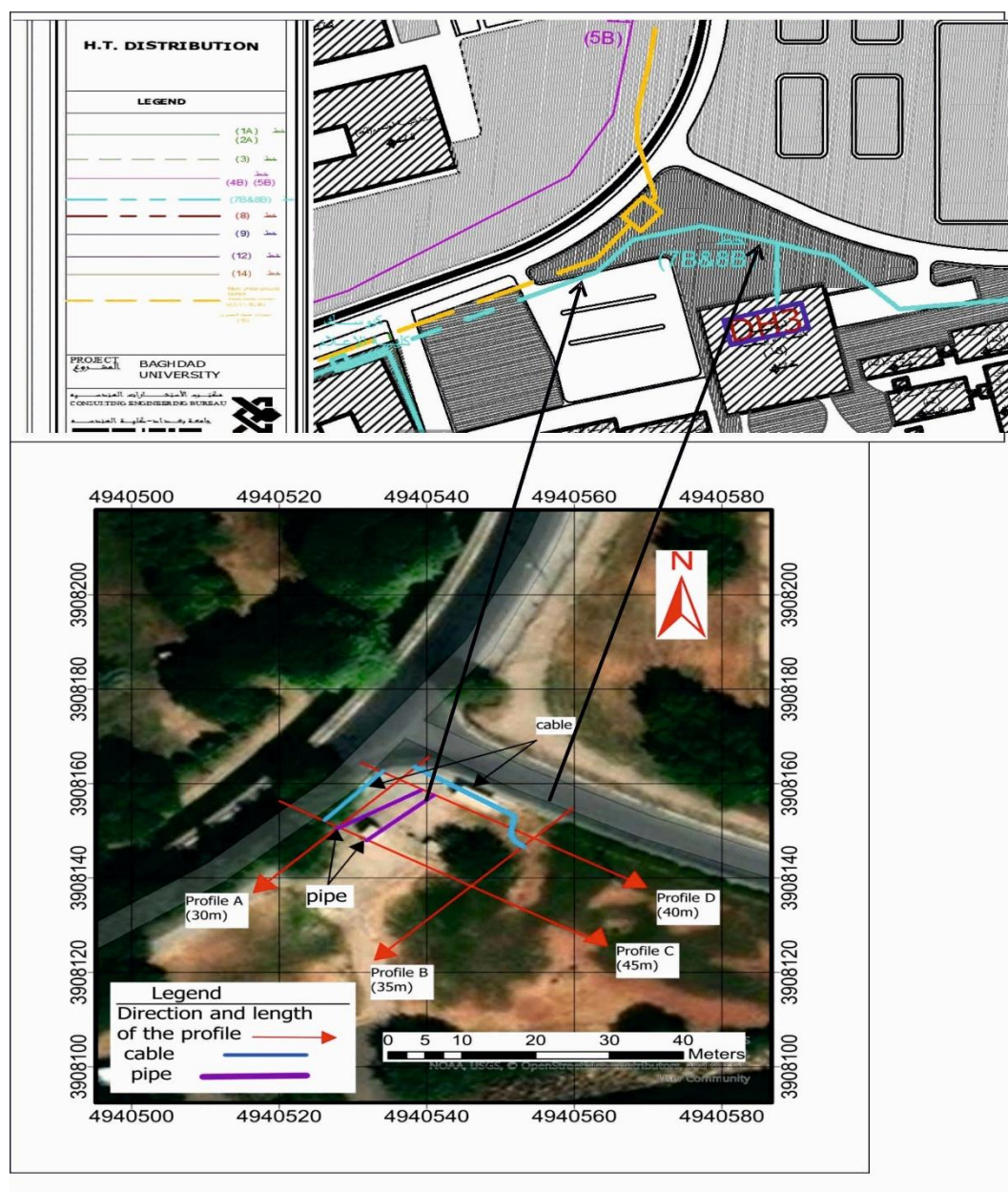


Fig. 9. The expect extension of the cables and pipeline depending on the GPR survey and the cables and pipeline from the engineering map of the site

Declaration of Competing Interest

The authors declare that they have no competing financial interests or personal relationships that could influence the work reported in this study.

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Data Availability

The data of this study were measured directly by the authors for investigation in this study site. No part of this data may be used without the permission of the authors.

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