Detection of Buried Archeological Remains Using GPR Technique at Kifel Town to the South of Hilla /Iraq

***Ameen Ibrahim AL-Yasi **Hamid Ali Naser ***Amer Atia Al- Khalidy**

*University of Baghdad/ College of Science, Baghdad- Iraq

**Foundation of Technical Education/ Technical Institute, Babil- Iraq

***University of Babil/ College of Science, Babil- Iraq

E_mail: ameenalysi@yahoo.com

Abstract

A Ground Penetrating Radar survey was carried out to detect archaeological remains at Kifel region, antennas of 500 MHz, 250 MHz, and 25 MHz were used. The topsoil resistivity values of the study area are low at many places and not more than 5ohms. This low resistivity has limited the GPR applications. The penetrating depths for the radar waves are around 3.0, 8.0, and 28.0 meters for 500MHz, 250MHz, and 25MHz antennas respectively. However, the clear radar signals are restricted to 1 meter depth. Data filtering and processing are needed for deep weak singles. Nevertheless, the GPR survey results have detected the underground archeological walls, tunnel, pipe and grave. The walls can be followed along the parallel GPR surveyed profiles.

Keywords: Ground Penetrating Radar, Archaeological, Tunnel and Pipe.

التحري عن مواقع أثرية باستخدام تقنية رادار الاختراق الأرضي في الكفل جنوب الحلة/ العراق

امين ابراهيم الياسي* حامد علي ناصر ** عامر عطية الخالدي***

*جامعة بغداد/كلية العلوم، بغداد- العراق

**هيئة التعليم الفني/ المعهد الفني، بابل- العراق

***جامعة بابل/ كلية العلوم، بابل- العراق

الخلاصــة

اجري مسح جيوفيزيائي باستخدام رادار الاختراق الأرضي في منطقة الكفل لغرض التحري عن البقايا الاثارية في منطقة الدراسة استخدمت هوائيات مختلفة وهي 500 ميغاهيرتز و250 ميغاهيرتز و25 ميغاهيرتز، وكانت التربة ذات مقاومة كهربائية ضعيفة في بعض الأماكن بمقدار 5 أوم وهذا يحد من عمل رادار الاختراق الأرضي، وكان اختراق موجات الرادار هي 3 امتار و8 امتار و28 متراً لكل من الهوائيات 500 و250 و25 ميغاهيرتز على التوالي. وكانت إشارات الرادار واضحة في المتر الأول من الاختراقات المذكورة أعلاه واحتاجت إشارات الرادار إلى المعالجة والمرشحات وقد تم اكتشاف جدران وأنفاق وقبور وأنابيب تحت سطح الأرض وان الجدران يمكن متابعتها على امتداد مسار رادار الاختراق الأرضي.

الكلمات المفتاحية: رادار الاختراق الأرضي، أثرى، أنفاق وأنابيب.

Introduction

Ground-penetrating radar offers a rapid and inexpensive method for identifying subsurface archaeological features without excavation. Although the technique has been used for archaeological exploration and mapping since the 1970s.Recent advances in GPR equipment and the computer processing of geophysical data have revolutionized its effectiveness. Ground penetrating radar maps and illustrate buried features in three dimensions have become not only a tool for discovering buried archaeological materials, but a key part of archeological data recovery and a part of the overall assemblage of a site. (Lawrence, 2000).

GPR raw data has all the original information, and we must extract desired information included in it. The amount of the information cannot be improved by any signal processing, but the value or the quality of the information for users can greatly be improved by proper signal processing. However, if we do not understand the meaning of each processing, the processing can produce serious artifact. These artifacts mislead the interpretation of GPR data. This text is prepared to explain fundamental physics and mathematics, which are used for GPR signal processing (Motoyuki, 2001). GPR has been used in numerous studies in related areas such as the detection of textural interfaces (Kung and Lu,1993; Boll, *et al*., 1993) the mapping of soil and rock stratigraphy (Davis and Annan,1989), mapping depth to bedrock (Collins, *et al*., 1989), the study of soil micro variability (Collins and Doolittle,1987) and soil thickness (Shih and Doolittle,1984), the use ofGPR for soil moisture estimation has been rather limited (Weiler, *et al*., 1998).Despite this, there has been an increase in research in the field, with several Ph.D. theses produced recently (Howe, 2000; Charlton, 2002; Huisman, 2002; Galagedeara, 2003) testifying to the potential of the technique offers. The objective of GPR data presentation is to provide a display of the processed data that is closely approximates an image of the subsurface, with the anomalies that are associated with the objects of interest located in their proper spatial positions. Data display is central to data interpretation. In fact, producing a good display is an integral part of interpretation (Jeffrey, 2000).

In all the geophysical studies, there are varying proportions for the accuracy of matching or correlation between the collected field information and possible geologic models under the earth surface. This ambiguity can only be resolved using geologic, geophysical, and other available information along with the experience of the interpreter.

GPR sections can be presented as gray scale or color images that use the different shades of grey or colors to represent the variation in the signal amplitude. Although, it is generally assumed that at any instance, the recorded waveform is composed of reflections from targets located directly below the antenna, the image is often complicated by the fact that the waveform spreads out on a spherical wave front, so that the strong reflectors of the side will be superimposed over other weaker reflections from another location. Another complication will occur when reflections from above ground sources will be superimposed on the underground reflectors (Griffin and Pippett, 2002). The radar antennas are moved over the ground surface simultaneously. The depth to the reflectors is determined from the two-way travel time (TWTT) coupled with the signal propagation velocity in the ground, which must be obtained from independent velocity soundings (Davis and Annan, 1989). The wide-angle reflection and refraction (WARR) sounding mode is the electromagnetic equivalent of seismic refraction and gives an independent estimate of the radar signal velocity versus depth in the ground (Davis and Annan, 1989). The transmitter is kept at a fixed location and receiver is towed away at increasing offsets. An alternative and preferable deployment for the same analysis is the common mid-point sounding (CMP) where both the transmitter and receiver are moved apart. Derivation of velocity using CMP analyses is vital to the determination of v using radar. In transillumination mode the transmitter and receiver are placed on opposite sides of the medium under investigation. In a zero-offset gather (ZOG), measurements are taken at varying depths using the two antennas with no vertical offset and by picking the direct arrivals. Alternatively, in multiple-offset gathers (MOG) one antenna is kept at a fixed depth while the second is moved incrementally. The side-scrolling image created by the GPR unit reveals what seems to be a myriad of black and white lines, gray indiscriminate fuzz, and random parabolas that crises-cross the display screen. The initial shock of interpreting the nonsense on the screen may seem overwhelming. However, with the knowledge of what to look for, data interpretation, while not easy, will in time become much less confusing. Certain buried targets create unique GPR reflections.

The primary aim of interpretation for GPR data in this study is to determine the two ways travel time from the different types of boundaries such as (artifacts), or any possible geologic structures. Aims of the study are:

1- To delineate the subsurface geological sequence and structures

2- To identify subsurface geologic features such as faults, sinkholes, and cavities (Weak Zones) in locations proneto subsidenceand geologicinstabilities.

3- To determine the depth of the water table in the study area.

4- To evaluate the suitability of the study area for the construction of AL-Kifelrefinery project.

Materials and Methods

Location of the Study Area

The Kifel area is located southwest of Baghdad the study area lies in south and middle of Iraq between Najaf and Hillah governorates (West of the Euphrates River) as shown in the Figure (1).

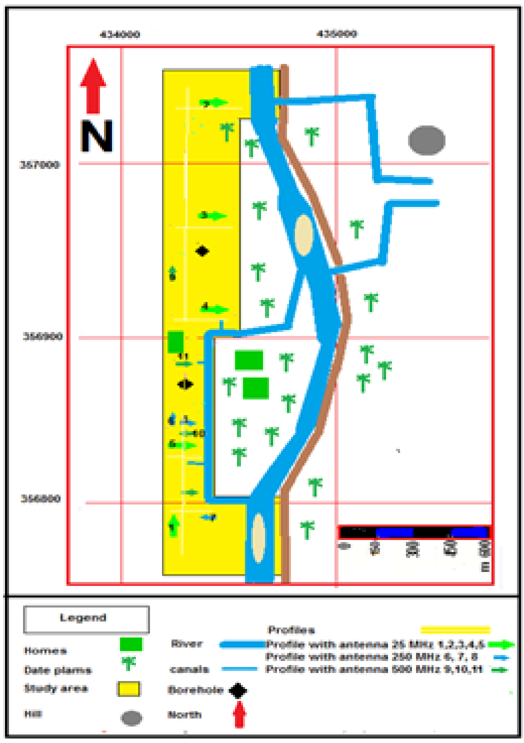

Fig. (1) Map Showing the Study Area and the Eleven Profiles, Their Locations and Directions That Have Been Surveyed Using 25 MHz, 250 MHz, and 500 MHz Antennas.

The Geology of the Study Area

The study area was covered by Quaternary deposits which belong to upper Miocene. The deposits of Quaternary are characterized by flood plain deposits from both of Tigris and Euphrates rivers. and lies within the tectonically stable Mesopotamian basin between the Zagros fold belt and Arabian shield. Depressions filled with stream deposits. These deposits accumulated because of flooding, and generally consist of thin layers of fine sand, silt, mud, and silty clay, as shown in the geological map Figure (2). Aeolian deposits in the eastern parts of the area, in addition, dry marsh deposits in various parts of the area exist, and it is called Sabkha, which is salt flats. Salt flats occupy several areas of the lower part of the sedimentary plain, including Musayyib, Al-Elexandriyah, Kifel, Hillah, Hashmiyah, and Mahmoudiyah. Accumulated deposits, which are formed because of human activities, like constructing irrigation channels and small archaeological remains which represented the population settlement after long years of extinction have become natural phenomena in lands on the sedimentary plain. They are clearly seen in the archaeological city of Babylon. Some exposures of Injana Formation may observe, they belong to the upper Miocene in some parts, located to the northwestern part of the Babylon province as shown in (Figure 2), (Jassim and Goff,2006).

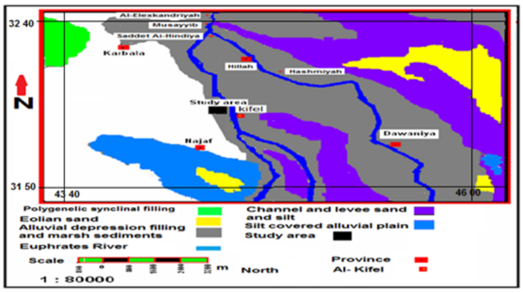

Fig. (2) Geological Map of the Study Area and Surrounding (Jassim and Goff, 2006).

Field Survey

The instrument used in the field work is MALA/ Sweden type (RAMAC Ground Vision). It is composed of radar control unit with 12 V. battery, as shown in Figure (3). The GPR survey is carried out along eleven profiles having various lengths, with chosen covering an area (3000 x 300) m^2. The all length of profiles are (9086) m. and the distance between profiles is (500) m, with orientation of these profiles in north-south direction and east-west. Each profile is surveyed by three antennas frequencies (25, 250 and 500 MHz), and they started at profile No. 1 and ended at profile No. 11 in (Figure 1) and using the GPR apparatus with three shielded antennas frequencies of (25, 250 and 500 MHz) were used in conducting the survey and record the raw data as shown in figures (5 to 16).

Data Processing

The collected raw data (Profiles) in this study are presented in 2D sections (Radargrams). The profiles were imported into Rad Explorer ground Version 1.4.6 software, to enhance the quality of these profiles which come directly from the field without any type of processing (Figure 3). Several filters were applied on all performed profiles related to this project as follows: -

A. Data Editing

Data editing is the first processing procedure which applied on the collected raw data. The editing includes re-organization and renames of the recoded files. For instance, from DAT-504-rad to profile-1, and registered the survey information, for instance, the antenna frequency 25MHz, sampling interval equals to 0.030 m, spacing interval is 1 m, velocity is 100 m/µs…. etc. The results of data editing are essential before further processing in many situations.

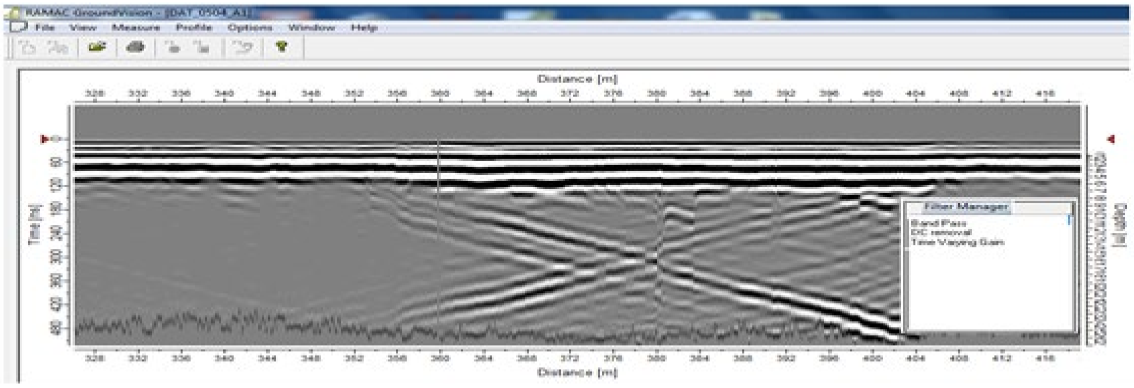

Fig. (3) Shows Examples for Such Profile Preprocessing (Profile – 1)

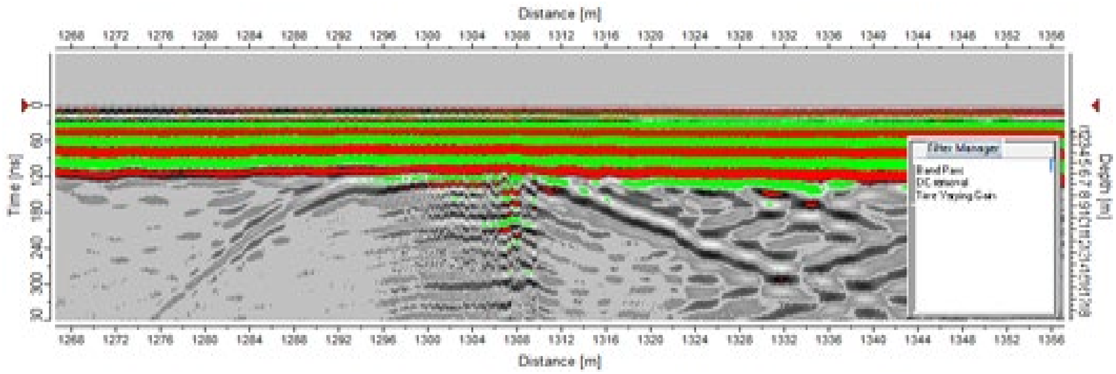

Fig. (4) The Processing Filters That May Be Applied on Such Profile -1

B. Processing Filters

Filtering of radar data is used to remove unwanted noise, and correctly position reflectors on the radar record. The steps of applying the filters depend on the accuracy of both collected profiles and the aim of survey. Each case of the profiles has different processing procedure. All the profiles in this study were processed with the same range of the filter values, because the studied area contains subsurface targets which have approximately the same original characteristics (little Clay, Silt, Sand and Smooth Gravel). There are several types of filters on the right side of the software screen that belongs to Processing Routines (Figure 4). The list of the filters mentioned below includes effective and non-effective filters. Not all filters were applied on the profiles of the studied area. Some of these filters have no effects on the profiles when they are applied. The important filters used are Band Pass, Time Varying Gain and DC removed.

C. Data Interpretation

Antenna 25 MHz Results

Five GPR profiles trending in two directions and with different lengths have been surveyed in the study area by using antenna 25 MHz (Figure 1). The survey was conducted in stages at different times. The spacing intervals between four of them (Which are Parallel) trending N-S is 500 m. The fifth one is surveyed in perpendicular direction; and this was done to test the whole study area and to test the orientation of the buried features. The radar grams were processed by applying Band Pass and DC filters. Few chosen examples of these radar grams will be discussed. These (Figures 7, 8, 9 and 10) contain diagrams of profiles from 1 to 5 by using antenna 25 MHz with velocity 100 m/s and first arrival 60 ns.

Table (1) Antenna Types, Lengths and Number of Profiles in GPR Survey.

Antenna	Profile Number	Profile Length (m)	Velocity	First Arrival	Depth
25	1	2711	100 m/s	60 ns	28
25	2	302	100 m/s	60 ns	28
25	3	302	100 m/s	60 ns	28
25	4	278	100 m/s	60 ns	28
25	5	562	100 m/s	60 ns	28
250	6	2012	100 m/s	18 ns	8
250	7	382	100 m/s	18 ns	8
250	8	70	100 m/s	18 ns	8
500	9	2011	100 m/s	8 ns	3
500	10	384	100 m/s	8 ns	3
500	11	72	100 m/s	8 ns	3
Total Profile Length (m)		9086			

D. Antenna 250 MHz Results

Three GPR profiles have been conducted using antenna 250 MHz These profiles were performed one after another using 250 MHz (Figure1). A standard measuring setting as shown in Table (1) was used for this GPR surveys and shown in (Figures 11 and 12). Profiles six, seven and eight are found in Figures, in all these profiles antenna 250 MHz are used with velocity 100 m/s and first arrival 18 ns (Figure 1).

Antenna 500 MHz Results

Three GPR profiles have been conducted using antenna 500MHz. all these profiles are conducted by using antenna 500MHz too (Figure 1). A standard measuring setting as shown in Table (1) was used for this GPR surveys and shown in (Figures 13, 14, 15 and 16). Profiles nine, ten and eleven are performed by using antenna 500 MHz with velocity 100 m/s and first arrival 8 ns.

Interpreting Subsurface Anomalies

The side-scrolling image created by the GPR unit reveals what seems to be a myriad of black and white lines, gray indiscriminate fuzz, and random parabolas that crises-cross the display screen. The initial shock of interpreting the nonsense on the screen may seem overwhelming. However, with the knowledge of what to look for, data interpretation, while not easy, will in time become much less confusing. Certain buried targets create unique GPR reflections. An understanding of why each type of signature appears as it does will allow the researcher to interpret many common subsurface anomalies while in the field. This will in turn cut down on post-acquisition processing time.

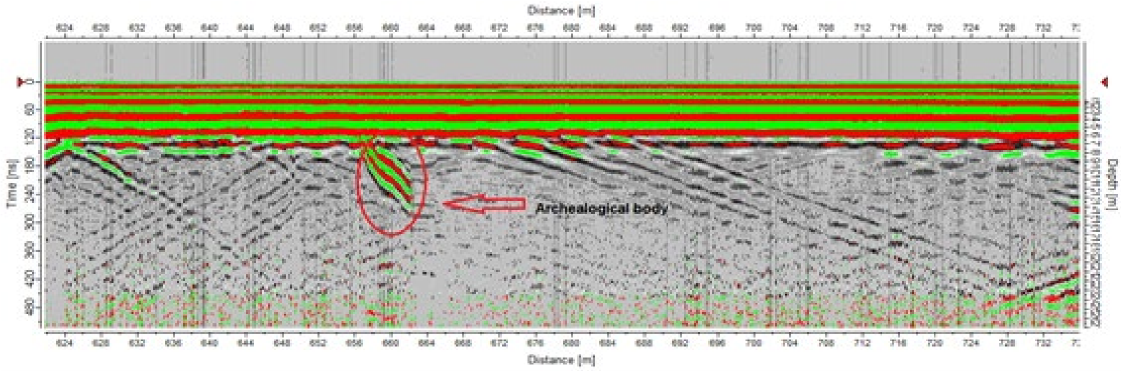

Fig. (5) The Radargram of Profile (1) after Applying the Band Pass Filter and Time-varying Gain. (25 MHz).

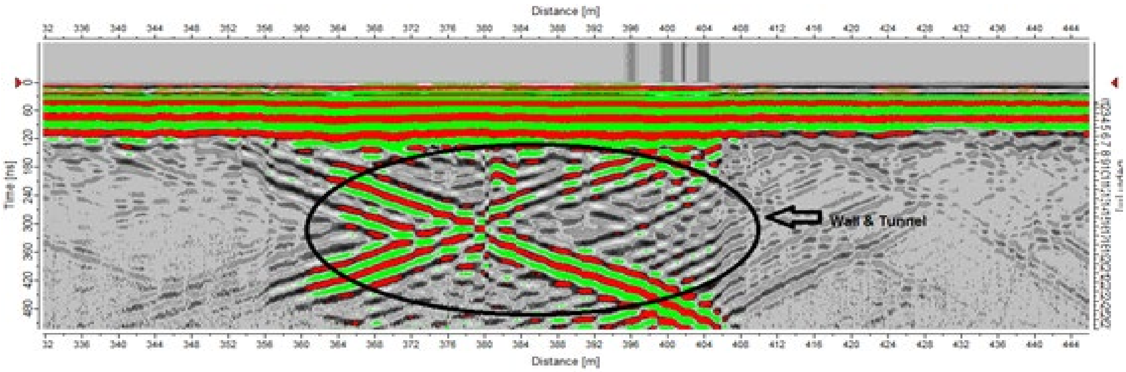

Figure (6) The Radargram of Profile (1) after Applying the Band Pass Filter and Time-varying Gain. (25 MHz).

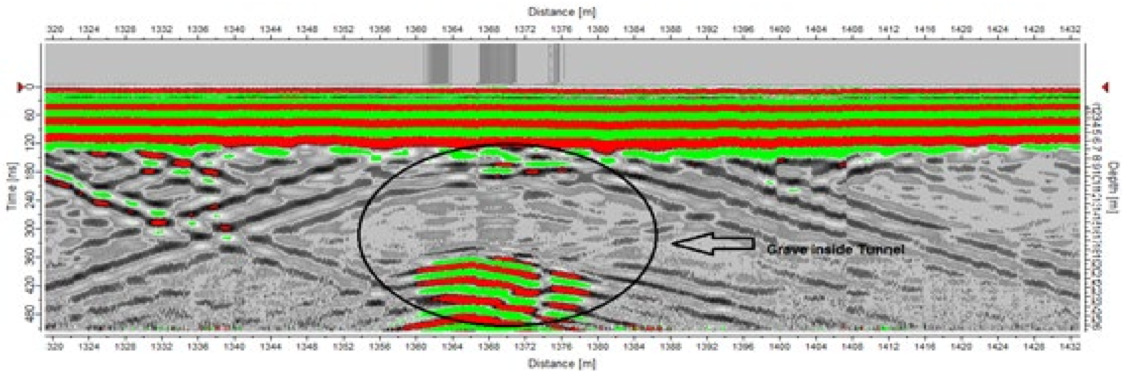

Fig. (7) The Radargram of Profile (1) after Applying the Band Pass Filter and Time-varying Gain. (25 MHz).

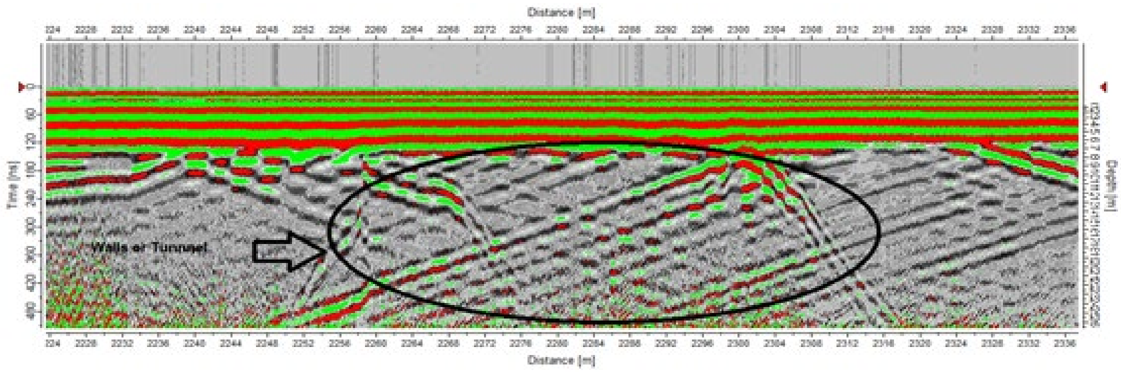

Fig. (8) The Radargram of Profile (1) after Applying the Band Pass Filter and Time-varying Gain. (25 MHz).

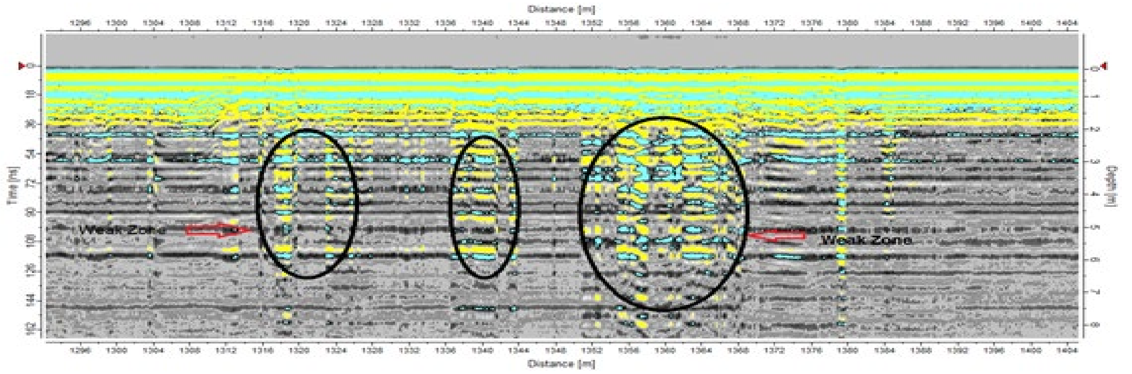

Fig. (9) The Radargram of Profile (6) after Applying the Band Pass Filter and Time-varying Gain. (250 MHz).

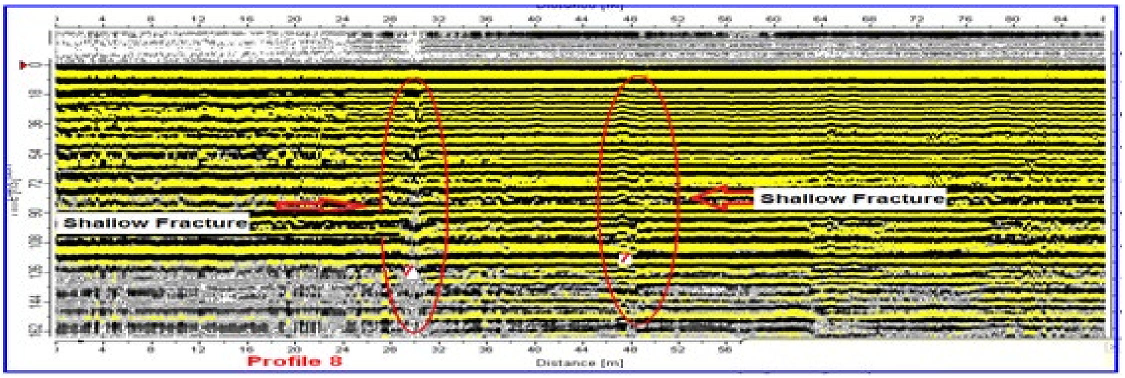

Fig. (10) The Radargram of Profile (8) after Applying the Band Pass Filter and Time-varying Gain. (250 MHz).

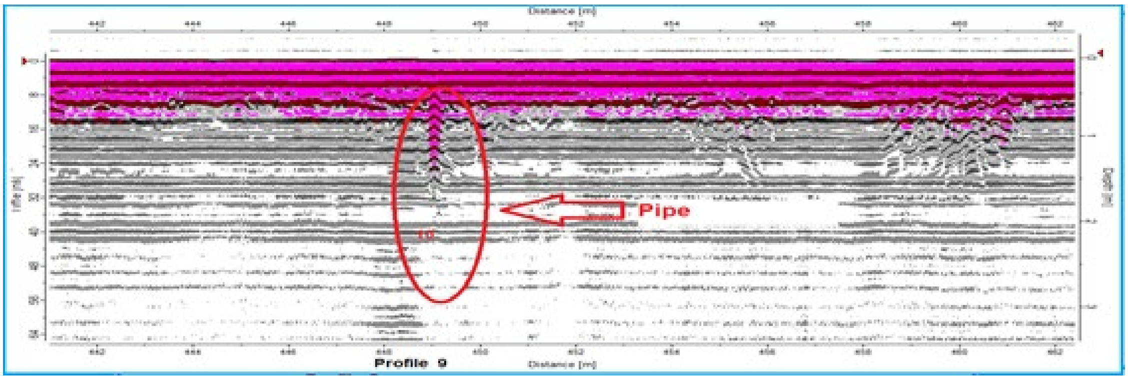

Fig. (11) The Radargram of Profile (9) after Applying the Band Pass Filter and Time-varying Gain. (500 MHz).

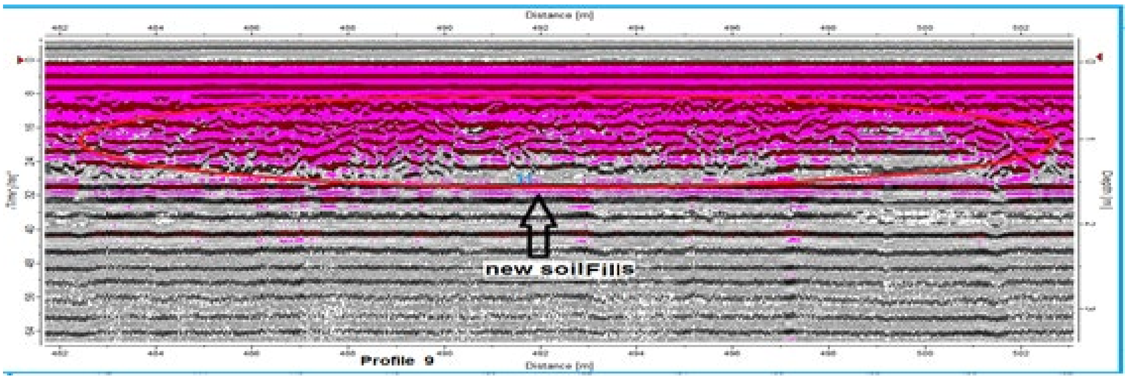

Fig. (12) The Radargram of Profile (9) after Applying the Band Pass Filter and Time-varying Gain. (500 MHz).

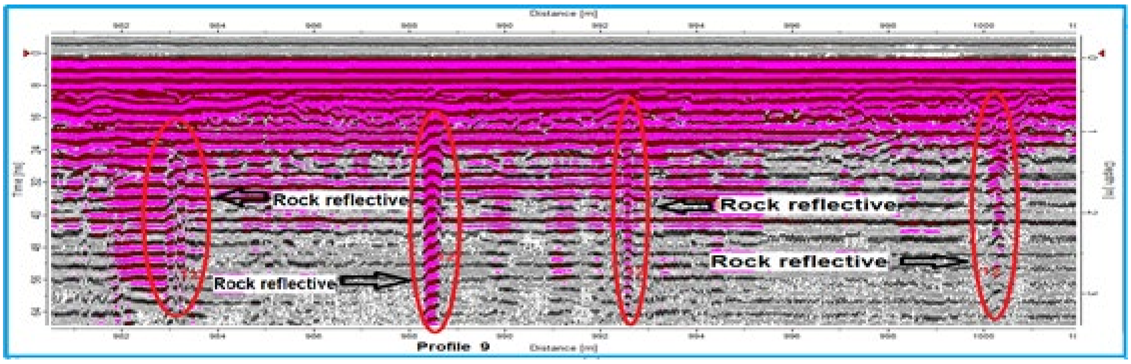

Fig. (13) The Radargram of Profile (9) after Applying the Band Pass Filter and Time-varying Gain (500 MHz).

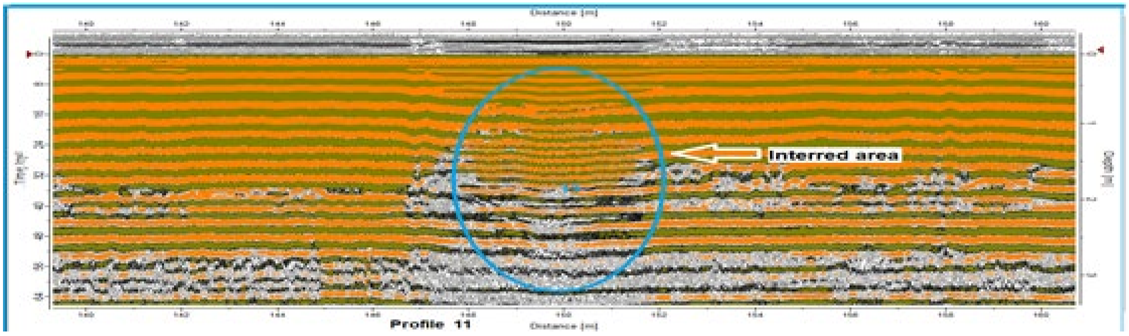

Fig. (14) The Radargram of Profile (11) After Applying the Band Pass Filter and Time-varying Gain. (500 MHz).

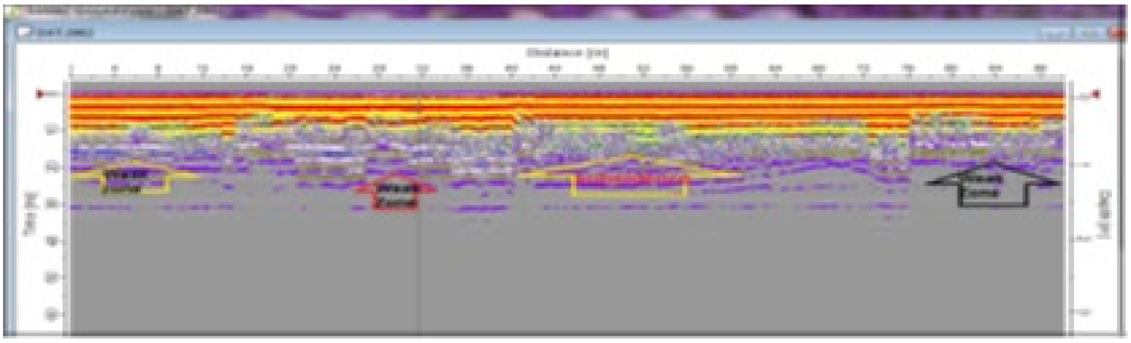

Fig. (15) Interpret Weak Zone after (Al – Shiejiri, 2013) the Figure (10) Describes the Weak Zone, and this is Similar to Figure 15 as in Number Research (Al – Shiejiri, 2013).

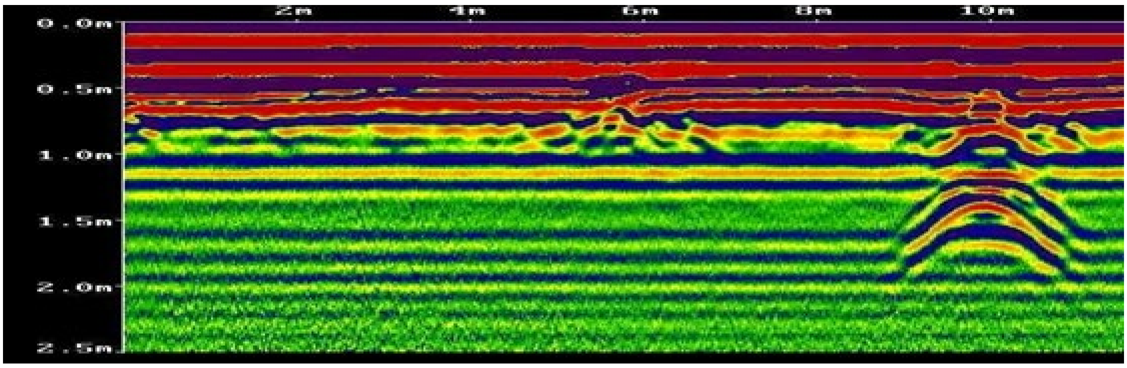

Fig. (16) Interpret Pipe after (Divya, 2010) the Figure (11) Describes Pipe and This Similar for Figure 18 as in Number Research (Divya, 2010).

Results and Interpretation

1. The one Geoelectric section in the study area are drawn. They show the buried geological structures and the spots of saline and drinkable water in the area
2. The main underground water reservoir is of the unconfined type. The direction of water flow is from the north to south namely towards low water levels in the area. This corresponds with the general direction of underground flow
3. The depth of underground water level ranges 2.40 m
4. It has proved that the GPR is a very simple tool to be used in delineation of the weak zones and subsidence on soil section.
5. The studied area contains a lot of subsurface features. Most of the main subsurface feature anomalies are due to weak zones.

The approximated depths (20 m) of these features vary between 1.5-28.0 m.

6. No hard rock beds occur in the studied area. The first layer is composed of fill material which extends from the surface to a depth of 1.5 m. This layer consists of very loose sand, silt and rock fragments. The second layer is composed of sandy clayey silt which reaches to the depth of 10.5 m.
7. Some obstacles related to ground condition may affect the radargram images. This can be overcome by utilizing some filters which give high resolutions after processing.
8. Before processing, most of the raw data of radargrams do not display the presence of weak zone. By applying suitable filters and other interpretation tools, many of the investigated subsurface structures appeared clearly that reflect the high resolving power of the technique.
9. The best detected depths of the zones are at depth 3.5 and 28.5 m when the antenna with frequencies of 250,500 and 25 MHz respectively used.
10. The extracted information after using processing with the assistance of RadExplorer software show that the values of dielectric constant and
11. From this study, it is found that the best detecting depths for 25, 250 and 500 MHz antennas are28.5, 9 and 3.5 m respectively at which the weak zones appear after processing.
12. The GPR survey using 250 MHz antenna has given a limited penetrating depth of less than 8.5 m. However only those features of depth less than 3.5 m can be detected clearly. While the GPR Survey using 500 MHz antenna has also given a limited depth penetrating of about 3.5 m. However, it is hard to detect clear GPR signal at depth more than one meter. Filtering and processing are needed for depth more than one meter.
13. The GPR survey using 25 MHz antenna has given better depth penetrating results down to 28.0 meters. In some places it reaches 29.0 meters. However, the radargrams show many reflected features. Some of these are just noise related to air reflections or slope effects. Data filtering and processing are needed in order to detect the real GPR signals.
14. Most of GPR distinguished anomalies in this study are caused by Point-source reflections and Planar Reflections.
15. As well as the GPR showed presence of bodies at different depths some of these bodies show continuity, which can be followed through several surveyed parallel profiles and sometimes can be correlated with the walls that emerge from the excavatiation at the surface or in the valleys.
16. One of the GPR profiles (Antenna 25 MHz) shows a distinguished longitudinal feature at depth more than 28.0 m, which could be related to.

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