# Investigation of Cavities at Petrochemical Construction, Basra South of Iraq by Using Ground Penetration Radar (GPR) Technique

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**Abstract**

The present paper deals with an area located at southwest of Basra were many strategic projects were constructed, where gypsiferous soils caves have been occur. The existence of these caves and sinkholes represents for such new urban area. Therefore, it is important to know the size, position and depth of natural voids and cavities before building or reconstruction. Recently, cavity imaging using geophysical surveys has become common. In this paper, Ground Penetration Radar (GPR) technique have been applied to the petrochemical construction at Al-Zubair town to image shallow subsurface cavities. The radar survey was conducted along 11 profiles passing through 3 units, Cooling, Ethylene and Energy unit. The data were processed and interpreted integrally to image the cave. As a result, many cavities were determined which are extended with variable depths, most of these cavities were noticed especially at the Energy unit. This is because of creating solution in gypsum sediments as found with soil that caused by leaking in artificial water pipes.

## Introduction

Many strategic projects were constructed at area limited between and around the highway connection Al-Zubair, Um-Qaser and Safwan cities at southwest of Basra governorate. These projects suffer damaged at many locations due to collapsibility of gypsiferous soils and subsidence of the ground. This situation has become a serious problem and requires a solution; in this study (GPR) technique has been applied to investigate subsurface cavities located under the petrochemical construction which was constructed at Al-Zubair town.

Basically, (GPR) survey is useful method for shallow engineering investigation (Olhoeft, 1988) and cavities (Wadhwa, 2008); it has been a very efficient tool for mapping shallow targets for applications such as geological engineering and environmental management (Fisher et al, 1992). The best result are obtained when the topographic cover is rather smooth and when the penetrated material is dry (Reynolds,1997). One of the major advantages of GPR is the capability to perform scans in a continuous way, over a wide area in a relatively short time. In addition data can be viewed in real – time, enabling one to assess the quality of the acquired data directly in the field, and eventually adjust acquisition parameters and settings. The main aim of this study is assessment of effectiveness of GPR survey to identify cavities or voids within gypsiferous sandy soil.

**The study area**

The study area located at Al-Zubair town, south- western part of Basra Governorate with an area of 1600 $km^2$ fig. (1). The study area is considered a part of Dibddibba sediments basin, Dibddibba aquifer has acquired its name according to Dibddibba Formation, which is composed of unconsolidated deposits; i.e. alluvial, often represented by the most common exploited aquifer. It has high values of permeability, direct recharge within rainstorms, accessibility and association with soils suitable for cultivation (Lanen and Rivera 1998). According to Aziz, 2007, the study indicated, 1- the tests results of soils at study area are gravelly sand gypsiferous soils contain high percentage of salt, these salts composed mainly of gypsum, calcite and halite and gypsum represent the highest percentage between salts, 2- the main reason of soil collapsibility at these locations is percolation of industrial water from old pipes and sewage channels of factories which dissolve gypsum and other salt causing a decrease in volume of soil that support the foundations and cause the settlement of building and their damage. Petrochemical construction one of these constructions located at Al-Zubair town, fig. (2) illustrated the lithology of the study area by well drilling on it.

**The method**

The GPR technique exploits the reflection of high – frequency electromagnetic pulses generated and transferred into the ground. This way, it enables one to detected dielectric discontinuity existing into the material through which the pulse travels. It is the contrast in the dielectric permittivity at the layer boundaries between the bulk medium and the buried targets that causes reflection: the greater the difference in dielectric permittivity, the greater of coefficient of reflectivity (Conyers and Goodman, 1997). These differences are often associated with change in textural lithology, porosity and density of material, but especially with water content. Water content mainly controls the signal energy, causing a loss in the wave energy, and changes in water content may produce abrupt jumps in relative dielectric permittivity. The transmitting antenna broadcasts over the ground electro-magnetic pulses at a certain frequency, the pulse spread into the ground at a velocity typical of that terrain. When the transmitted wave encounters a discontinuity in the dielectric properties, a certain amount of energy is reflected and picked- up by a receiving antenna, the remaining part of the wave continues to travel towards deeper areas, fig.(3 –a,b)

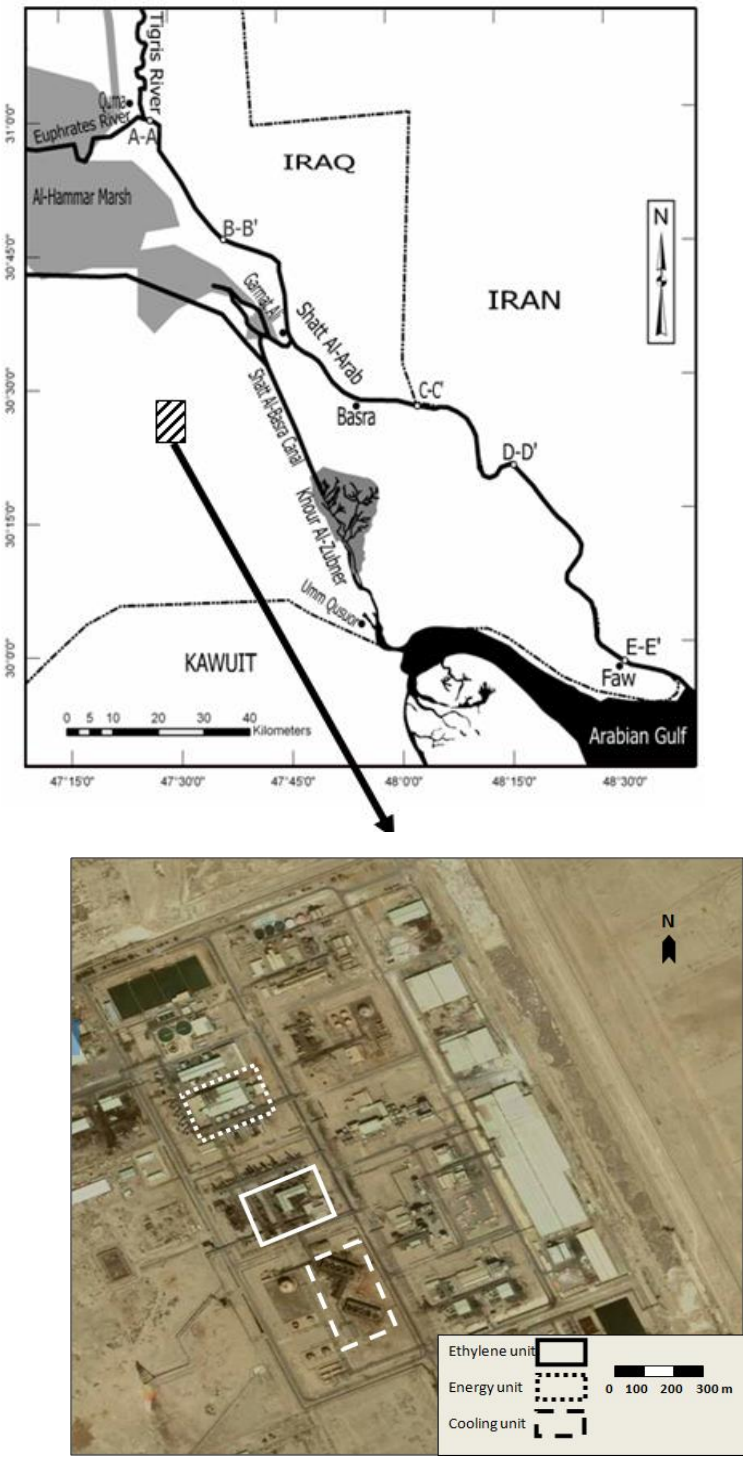



**Figure (1): Location map of the study area**

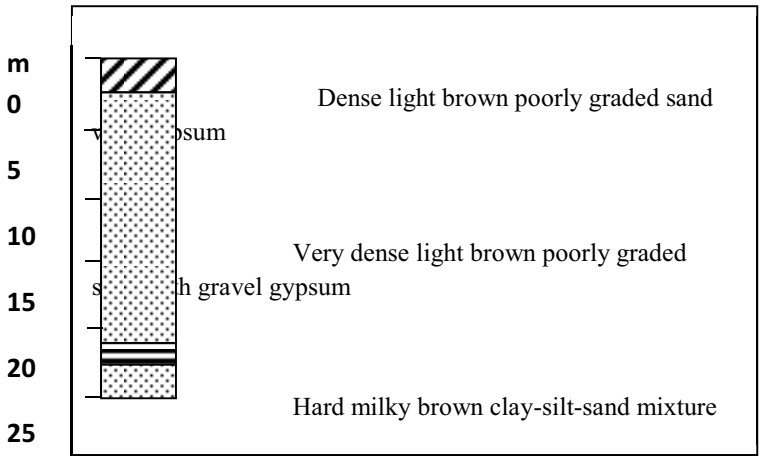



**Figure (2): Lithology of the study area**

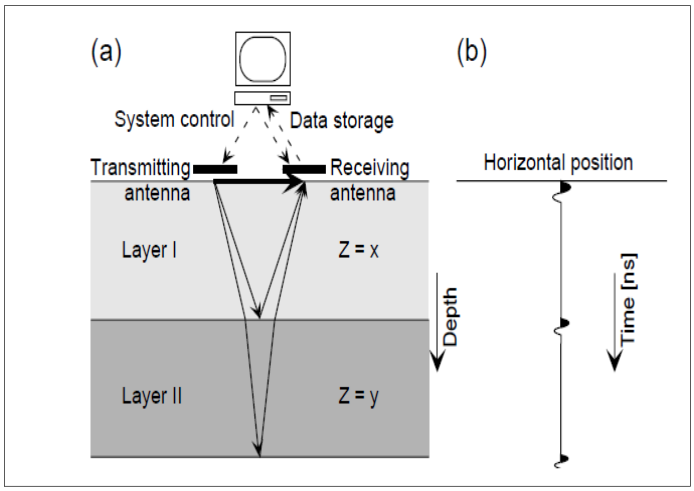



**Figure (3): (a) Ground-penetrating radar setup and method and (b) resulting radar section.(Van Dam, 2001)**

The equipment was used in this paper is a RAMAC/GPR, Mala Geosciences Co., Sweden, equipped with a 250 MHz antenna and a RAMAC control unit. This is a general – purpose antenna, usually employed for surveys at medium depth and medium resolution. A 250 MHz antenna, in ideal conditions and slightly conductive terrain, can reach a maximum value of depth of 9 m, however in field conditions, the presence of water reduce this value.

**Field work and data processing**

Eleven GPR profiles were carried out at the study area with several length in order to determine the cavities, these profiles were distributed at three units, three at unit no.1 (cooling), three at unit no. 2 (Ethylene), four at unit no. 3 (Energy) and one profile between units no.2 and no.3, figs. (4) and (5) shown the locations of these profiles in these units.

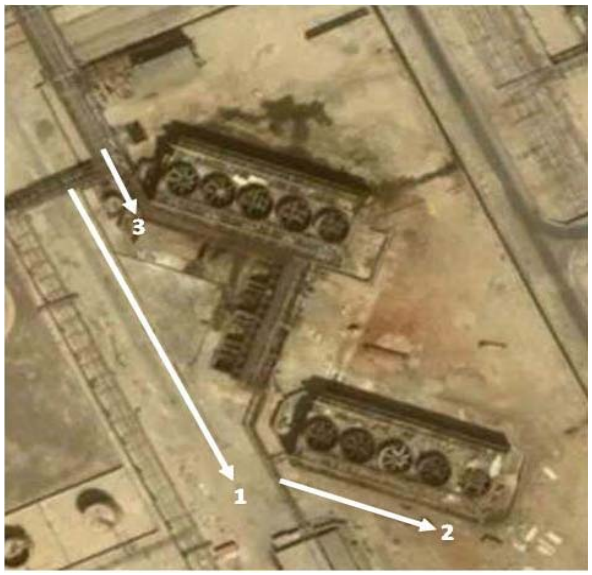
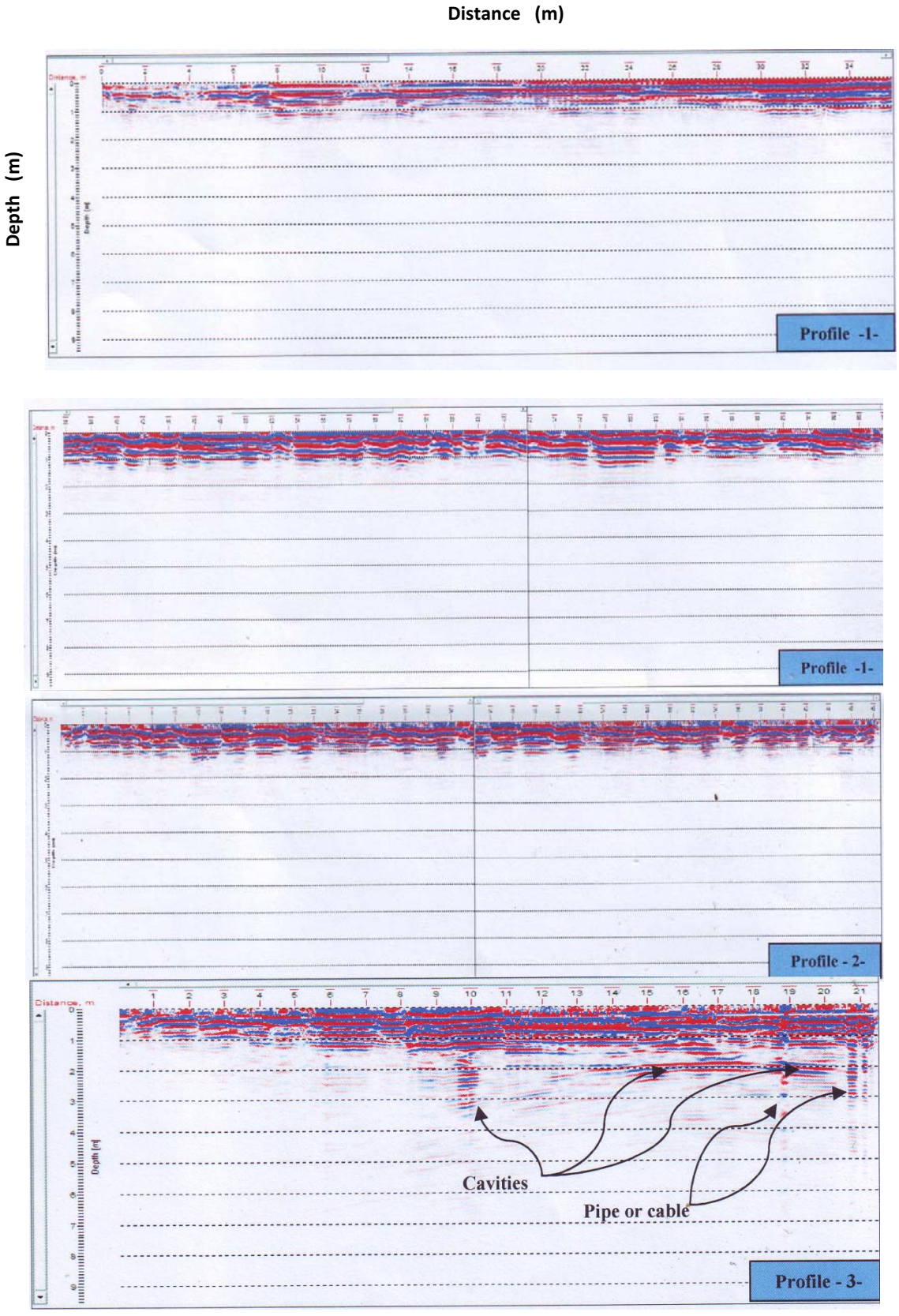
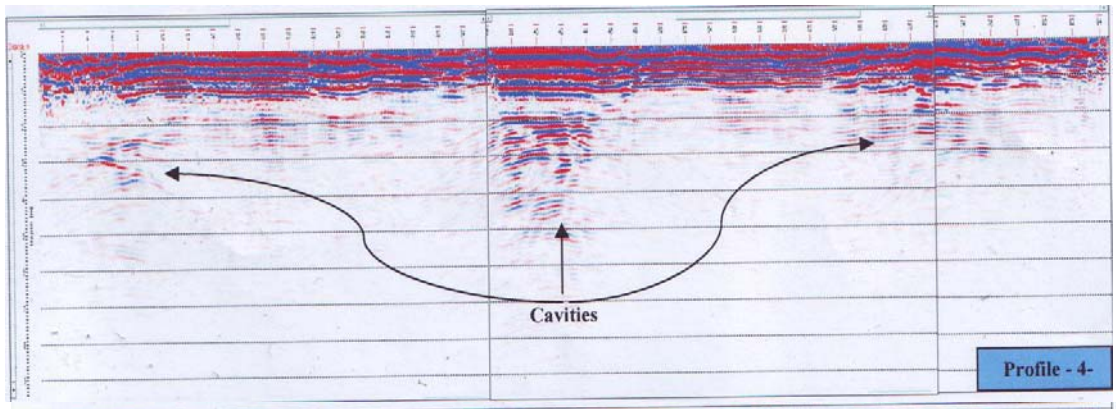


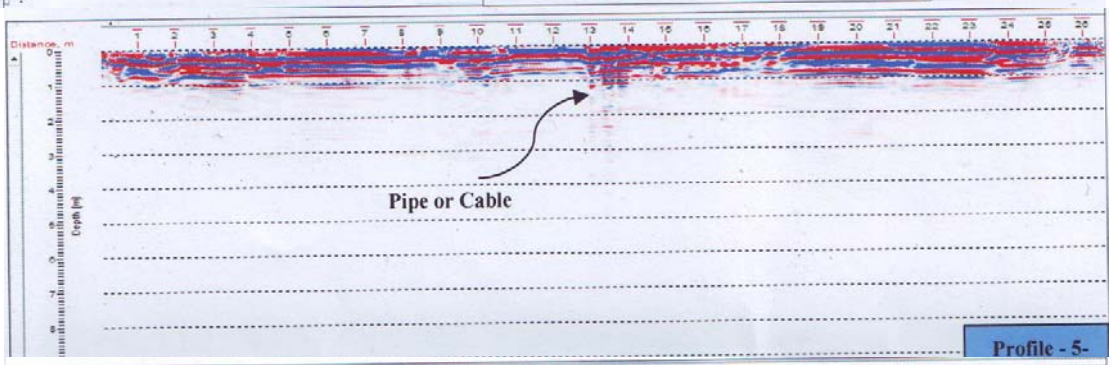

**Figure (4): Unit no.1 with GPR profiles**

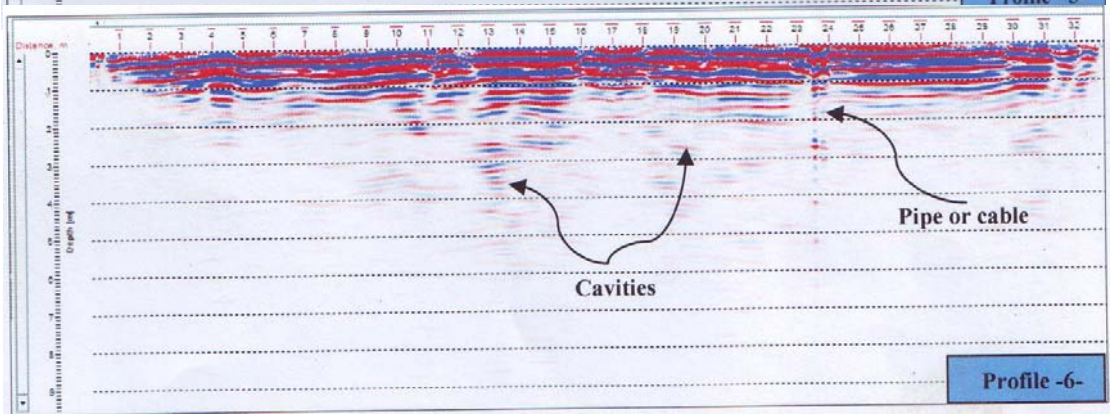

**Figure (5): Units no. 2 and no.3 with GPR profiles**

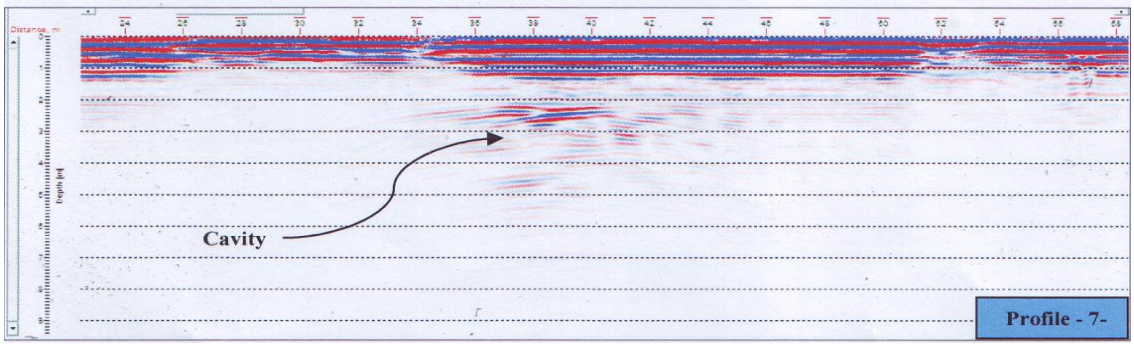
Nevertheless, after the visual inspection, the inspection on extent and distribution of cavities were still very sparse. For processing and interpretation the data, Rad Explorer software (DECO, 2005) was used a number of data processing methods which are available in this software, usually the choice is based on the operator analysis of the acquired traces that may depend on the quality of the data, presence of noise, signal attenuation, GPR setting used during the survey and the purpose of the survey (Monica Di Prinzio, *et al*, 2010), fig. (6) shown the interpretation of GPR profiles with many cavities location in these profiles.


Distance (m)
Depth (m)
Profile -1-
Profile -1-
Profile - 2-
Distance, m
Depth [m]
Cavities
Pipe or cable
Profile - 3-


Cavities
Profile - 4-


Pipe or Cable
Profile - 5-


Pipe or cable
Cavities
Profile -6-


Cavity
Profile - 7-

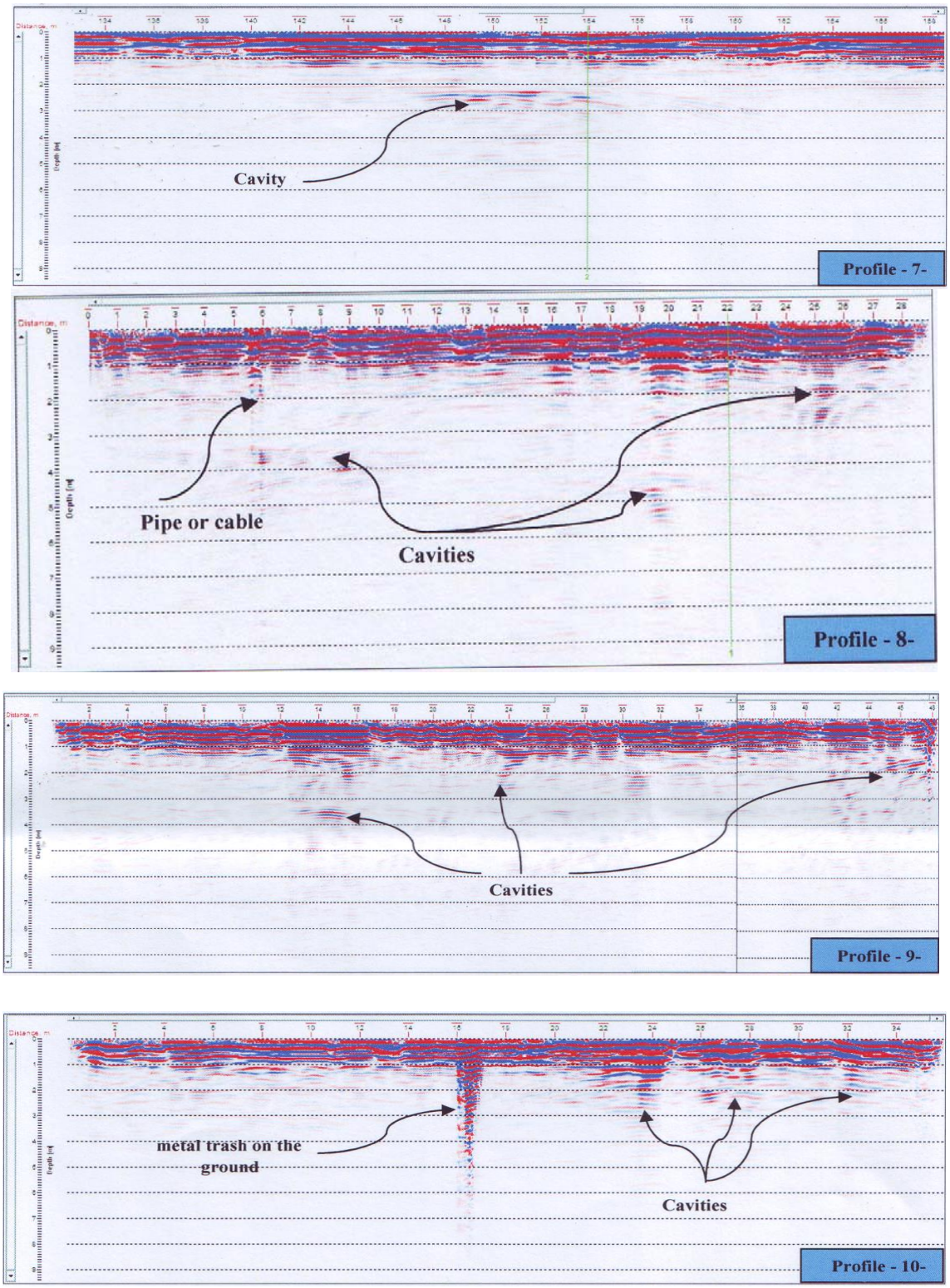



**Figure (6): GPR profiles interpreted shown many locations of cavities**

**Results and Discussion**

Interpretation of the acquired GPR data along each profile is summarized in a schematic cross section, table (1) showing the results to this interpretation. Many of cavities were determined for some interpreting profiles; meanwhile, no cavities were determined at other. Also, it was noticed that these cavities extended with variable depth and distance. This depends on quantity of artificial water that percolated to the soil. Most of these cavities were observed especially at unit no.3 this may be due to increasing leaking in the artificial water pipes at this unit, however, this led to creating solution in gypsum sediments as found with soil, moreover, detection of cavities there are many anomalies were appeared in GPR sections may be refer to existence of pipes or cables. In conclusion, these results show that the GPR technique have proved to be effective tool for imaging subsurface cavities in gypsferous soil at shallow depth, finally, to get perfect results, it should better correlate drilling work analysis with GPR section, as well as using of GPR survey with antenna 500 KHz and grid survey to detection cavities.

**Table (1): Results of interpreted GPR data along each profile**

| Pro. | Distance (m) | Unit | Location of cavity in a profile | Depth (m) | Other structures |
|---|---|---|---|---|---|
| 1 | 100 | 1 | Between 21-24m | 2 | - |
| 2 | 48 | 1 | - | | - |
| 3 | 21 | 1 | Between 9.5-10.5m<br>Between 14-20m | 2<br>3 | Pipe or cable at 19m<br>Pipe or cable at 21m |
| 4 | 85 | 2 | Between 4-10m<br>Between 18-19m<br>Between36-44m<br>Between 71-75m | 4<br>2.5<br>5<br>3 | - |
| 5 | 26 | 2 | - | | - |
| 6 | 33 | 2 | Between 12.5-15m<br>Between 30-31m | 3.5<br>2 | Pipe or cable at 23.5m |
| 7 | `286 | Paved road | Between 42-43m<br>Between 148-156m | 3<br>3 | - |
| 8 | 29 | 3 | Between 6-9m<br>Between 19-20m<br>Between 24.5-20m | 5<br>6<br>3 | Pipe or cable at 5.5m |
| 9 | 48 | 3 | Between 14-16m<br>Between 30-31m<br>Between 42-43m | 2.5<br>2.5<br>4 | - |
| 10 | 36 | 3 | Between 22-24m<br>Between 26-28m<br>Between 32-34m | 2<br>2<br>2 | Metal trash on the surface at 16 m |
| 11 | 16 | 3 | Between 3-4m<br>Between 10.5-12.5m | 2<br>2.5 | - |

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# التحري عن التكهفات في موقع معمل البتروكيمياويات غرب مدينة البصرة باستخدام تقنية الاختراق الراداري الأرضي (GPR)

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**الخلاصة**

يتعلق البحث الحالي بدراسة عدد من المواقع في أحد المنشات الواقعة غرب البصرة والتي تتميز بترب تحتوي على نسب عالية من الترسبات الجبسية والتي تكون عرضة لحدوث تكهفات ومناطق ضعف فيما لوتميز بترب تحتوي على نسب عالية من الترسبات الجبسية والتي تكون عرضة لحدوث تكهفات ومناطق ضعف فيما لو توفرت هنالك كميات من المياه التي من شأنها تسبب حصول عمليات أذابة لهذه الترسبات. من المعلوم ان دراسة وتحديد التكهفات والفجوات ومعرفة امتدادها وأعماقها تعتبر ضرورة ملحة عند اقامة أي منشاة، لذلك أستخدمت التحريات الجيوفيزيائية في التحري والكشف عن هذه التكهفات ومناطق الضعف، وفي هذه الدراسة تم أستخدام تقنية الاختراق الراداري الارضي (GPR) والتي تعتبر من التقنيات الجيوفيزيائية الحديثة في الكشف عن مناطق الضعف وتحديد التكهفات في عدد من المواقع في معمل البتروكيمياويات. تم انجاز 11 مساراً مقسمة على ثلاث وحدات تابعة للمعمل، وتمت عملية معالجة وتفسير البيانات والحصول على المقاطع الجيوراداراية ومن ثم الحصول نتائج أشارت الى وجود عدد من الشواذ والتي يمكن أن تشير الى وجود مناطق ضعف وتكهفات على مسافات وأعماق مختلفة، حيث تميز الموقع أو الوحدة الثالثة بأنها تمتلك العدد الأكثر من مناطق الضعف، والسبب يعود الى وجود كميات من المياه الصناعية المتسربة من الانابيب التابعة لهذه الوحدة والذي سبب بدورة الى تغلغل وأختراق هذه المياه الى التربة ومن ثم حصول عمليات اذابة للمواد الجبسية الرابطة.