Detect And Locate Buried Pipes Using Ground Penetration Radar

Ahmed Fouad Nashait *

Received on:9/3/2010
Accepted on:7/10/2010

Abstract

Data collection using traditional methods for detecting and mapping subsurface features can be need more time consuming and costly. Beside that the geological research project and Job cost estimating require accurate information about subsurface condition. Ground Penetrating Radar (GPR) can map and detect bedrock, buried objects (pipes, cables, etc), water table, soil profile, faults, voids and sinkholes quickly, easily, accurately, and cost effectively. The accurate location of buried utilities is imperative for contractors. Hitting a high voltage power line or water main con be dangerous, disruptive to citizens, as well as expensive.

The main objective of this research is to introduce utility of using GPR in locate features such as buried tanks and pipes, locating underground pipes for efficient pipes system management and for avoiding damage during excavation have become a relevant issue in metropolitan areas.

Gathering data inside the boundary of the University of Technology with the area approximately equal to (4320 m^2), data processing using RAD EXPLORAR software with the helping of Geographic Information System (GIS) and Global Positioning System (GPS) to produce a GIS map have been carried out. The discussion of the result is included with the basic recommendation.

Keywords: Ground Penetrating Radar, Rad Explorar, Hyperbola, Background Removal, Global Positing System.

الكشف عن الانابيب المطمورة تحت الارض وتحديد مواقعها بأستخدام جهاز كشف الاعماق

الخلاصة

استخدام الطرق التقليدية لتخطيط وتحديد مواقع البنى التحتية يستغرق الكثير من الوقت والكلفة. بالأضافة الى ان مشاريع البحوث الجيولوجية وتخمين الكلف للاعمال تتطلب معلومات دقيقة عن المعالم تحت الارض. جهاز كشف الاعماق يستطيع تخطيط وتحديد مواقع الاهداف المدفونة تحت الارض كـــ (الانابيب , الاسلاك ,الخ) , مستوى المياه الجوفية , مقاطع التربة , التصدعات , الشقوق بسرعة وبسهولة وبدقة وبكلفة اقل.

يعتبر تخمين الموقع الدقيق للبنى التحتية من المتطلبات الملحة والعاجلة لاي مسؤول عن تنفيذ الاعمال,حيث ان الحاق الاذى بخط كهربائي عالي الفولتية او خط ماء رئيسي هو امر خطير ومثير للفوضى بين المواطنين بالاضافة الى كونه امر مكلف .

الهدف الرئيسي لهذا البحث هو بيان الفائدة من استخدام تقنيات كشف الاعماق في معرفة مواقع الانابيب المدفونه تحت الارض وتجنب تدميرها خلال اعمال الحفريات والذي اصبح امر وثيق الصلة في المدن الرئيسية او العواصم وبما يؤدي الى تكوين نظام ادارة انابيب كفوء وقدير.

***Building and Construction Department, University of Technology/ Baghdad**

https://doi.org/10.30684/etj.28.20.18
2412-0758/University of Technology-Iraq, Baghdad, Iraq

تم جمع البيانات داخل محيط الجامعة التكنولوجية وكانت مساحة منطقة الدراسة = 4320 م2 , ومعالجتها بأستخدام برنامج (Rad Explorar) بالاضافة الى انتاج خارطة موضوعية بمساعدة نظام المعلومات الجغرافي ونظام الاحداثيات العالمي. اخيراً تم مناقشة النتائج المستحصلة والتوصل الى بعض التوصيات.

1. Introduction

The radar technique principally detect back –scattered energy form a target; anomalies within a material give rise to reflections and if the radar antenna is scanned over the material an image of the anomalies can be generated .The principle of radar is well understood and radar for detecting buried objects or ground penetration radar (GPR) uses the same fundamental physical principle as conventional radar.

GPR is the general term applied to techniques which employ radio wave, typically I the (1 to 5000 MHZ) frequency range, to map structure and features buried in the ground or in manmade structures. Last time GPR has been used in non-destructive testing of non- metallic structures.(Sigurdsson, T.,1993)

A major advantage of the radar technique over the non-destructive testing methods such as (ultrasonic) is that it is possible to use an antenna (transducer) which is non-conducting. Thus it is technically feasible to scan areas of interest extremely quickly (up to 30 km/h).

The majority of targets sought using sub-surface radar methods are non-metallic so that their scattering cross-section is dependent upon the properties of the surrounding dielectric medium. Most targets and voids in particular have a lower relative permittivity and there is not phase change at an interface that is observed when the scattering is a metallic boundary. (Annan, A.P. and Cosway, S.W.,1992).

2. GPR instrument:

This may be used as way of distinguishing between conducting and non –conducting targets.

A radar system includes a radio transmitter and receiver, connected to a pair of antennas coupled to the ground. The transmitted signal penetrates to a short distance into the ground and some of it reflects off any object with different electrical properties than the host dirt. Since plastic pipe and voids are different than dirt, these are some of the object which reflects the signal. The GPR signal that reflects from the object in the ground arrives a little later in time. (Figure 1) .

When an electromagnetic wave travels through two different materials, energy will be reflected and transmitted at the interface. (Saarenketo,T.,and Scullion,T.,1994).

The proportion of energy reflected, given by the reflected coefficient (R), is determined by the contrast in radio velocities, and more fundamentally, by the contrast in the relative dielectric permittivity of adjacent media.

The amplitude reflection coefficient is:

$$R= (V_1 – V_2)/ (V_1 + V_2) \quad \text{……..(1)}$$

Where:

V_1: the radiowave velocities of the first layer.

V_2: the radiowave velocities of the second layer.

Also:

$$R= (\sqrt{\varepsilon_2} - \sqrt{\varepsilon_1})/ (\sqrt{\varepsilon_2} + \sqrt{\varepsilon_1}) \quad \text{…..(2)}$$

Where:

ε_1: the relative permittivity of the first layer
ε_2: the relative permittivity of the second layer

Equations (1, 2) are considered the basis for interpreting GPR data. To construct an image that the operator can interpret, the radar plots the echo from the object on some sort of display (usually a screen like a computer). The GPR is moved along the ground and each new echo is plotted alongside the previous ones. When enough of these signals are plotted side-by-side the operator can see a pattern which he can interpret as an object. (Figure 2) .

When the object is ahead of the GPR, it takes more time for the echo to bounce back to the antenna. As it passes over, the time grows shorter, and then longer again as it goes past the object. This effect causes the image take the shape of a curve called (hyperbola).Experienced users recognize that a hyperbola (inverted U) is actually the image of a smaller object (like a pipe). Other patterns are produced by different structures, for example. A buried tank might have a flat image with curves down from either end. (Maser, K.R., 1996). (Figure 3) .

A hyperbola resulted from crossing pipe. But what if you follow one? The image is a straight line, since the distance from the pipe doesn't change. The problem is that other conditions will produce the same effect, especially layers in the soil, bedrock, or the groundwater table. So, it is difficult to map pipes by following them as is done with other locating methods. Instead, a meandering crossing of the pipe is needed. (Figure 4) .

3. Depth of Penetration:

The depth of penetration of GPR depends on the frequency of the radar signal as well as the electrical properties of the subsurface. The power of the radar transmitter, the sensitivity of the receiver and numerical signal processing of the acquired data are also important considerations.

The lower the frequency the better is the penetration but the poorer the resolution and vice versa. This relationship is not constant and depends on the material characteristics and the presence of humidity. (Liu, L., 2004)

Commercially viable GPR typically fall into two categories, shallow penetrating systems operating to depth of (five feet or less) and very deep penetrating systems operating to depth of (hundreds or even thousands of feet).

Numerous manufactures produce both impulse and spread spectrum shallow penetrating radars designed to look for pipes or similar objects near the surface. While a limited number of very deep penetrating radar have been built. These very deep penetrating radar systems, custom built for oil and gas exploration.

For a short transmitter – receiver offset relative to the total depth , the transect depth ,D, can be calculated as half of the time window ,Tw, multiplied b the average propagation velocity ,V, of the pulse inside the geological media (i.e., D=t x v/2) .(zeng.x.and G.A. McMechan,1997).

4. Experimental Works:

The field equipment comprised a portable RAMAC/GPR CUII system, figure (5). The system consist basically of a radar control unit with (12 volt) battery, monitor for data acquisition and storage, 500 MHZ shielded antenna with a power source (batteries) were all used.

4.1. GPS Measurement:

An important aspect of survey design is establishment of survey grid and co-ordinate system. The use of a standardized co-ordinate system for position recording is very important; the best data in the world useless if no one knows where they came from. To achieve this goal we used Global Positioning System (TRIMBLE) receiver as shown in figure (6) which is a high performance six -channel hand-held receiver. It can be used as a battery- powered unit or can be connected to any other source of power using the cable provided. This makes it ideal for portable field use. The receiver can be used for navigation and to store position and attribute information for point, line or area features. The best time to collect GPS data, based on where the satellites will be, needs to be determined. (Daniels.j.j,1989)

Now that there is 24-hour/day satellite coverage, the chance that there are too few satellites to collect data is very slim. Still such planning will avoid frustration in the field and assist in achieving good accuracy. The antenna of the GPS needs a clear view of the sky to receive satellite signals. People, buildings, heavy tree cover, large vehicles, or Powerful transmitters block signals. The signals could go through leaves, plastic, glass, and rain although this may weaken the signal.

Signals can be received from any directions, but if the antenna is covered the GPS can lose the satellites and stop computing positions. Another problem can occur when using the receiver around obstructions. The antenna not only receives the direct signals but also reflected signals. This resulted in less accurate positions.

4.2. Data collection:

During the February 2010, a detailed field exploration was carried out to assess the feasibility of detecting the infrastructure utilities to the University of Technology using GPR (Ground Penetrating Radar).

Survey lines are established which run perpendicular to the trend of the feature under investigation in order to reduce the number of survey lines. Line spacing is dictated by the degree of target variation in the trend direction.

The selection of survey line location and orientation should be made such as to maximize target detection. All survey line should be oriented perpendicular to the strike of the target if the target has a preferred strike direction. In attempting to cover an area to map a feature such as bedrock depth, the survey lines should be oriented perpendicular to the bedrock relief and line spacing should be selected to adequately sample along –strike variations without aliasing. In situation where strike is known and the structure 2-dimentional, a very large spacing between lines can be employed. If there is not two dimensionality to the structure, then line spacing must be the same as the station spacing to assure that the ground response is not aliased.

The field site has a rectangular shape with dimension (12m X 360m). The field area was covered by (5) horizontal and (37) vertical profiles, and to get a good coverage a distance of (3 m) between the horizontal profiles and (10 m) between the vertical profiles were kept. So, the

number of samples will equal to (185).
Before we are going to acquire data, we must answer several equations as follows:

- Is GPR suitable to solve the problem?
- What is the depth of the target?
- What is the geometry of the target?
- What is the resistivity property of the area?
- Is there enough contrast (a difference in the physical properties) between the host and the target?
- What is the host material?
- What is the survey environment?

All of the above equations have taken into consideration during the field work

4.3. Measurement settings:

The following settings were used:
Time window: 456 ns
Stacks: Auto
Sampling frequency: 1180 MHz
Point distance: 0.005 cm
Velocity: 100 m\µs

4.4. Software and Data processing:

Rad Explorar which is designed for GPR survey data processing and interpretation were used. The programme allows accomplishing the whole process of GPR survey data processing and interpretation within the framework of one single system :reading and visualization of radargram , DC removal , background removal , trace edit and spatial interpolation on equal profile interval ,amplitude correction , deconvolution, 2D and bandpass filtering , migration, topography correction, determination of dielectric constant/electromagnetic wave propagation velocity ,time to depth conversion .This does not mean that one must always apply all the routines or is not allowed changing the order of routines. One should apply only those routines that are required in every specific case.
Basic data processing addresses some of the fundamental manipulations applied to data to make a more acceptable product for initial interpretation and data evaluation. In most instances this type of processing is already applied in real-time to generate the real-time display. The advantage of post survey processing is that the basic processing can be done more systematically and non-causal operators to remove or enhance certain features can be applied.
The Rad-Explorer software contains standard routines of digital GPR data processing that are used for improving signal-to-noise ratio, increasing resolution, etc. With the help of a variety of techniques of signal processing one shall try to reduce the undesired waves and noise, remove or at least define them on the radargrams for not taking them into account during the interpretation.

5. Data Analysis and Results:

5.1. Background Removal:

The most intensive signal received by the ground-penetrating radar is the signal that arrives directly from the transmitting antenna – a direct wave. The application of Background removal" routine is necessary when the instrument noise blocks up the desired signal. The essence of this technique is in subtraction of the mean trace determined in the window with fixed size running along the profile from the whole set of traces. It results in removing a constant instrument component from recording. But in this case one should always keep in mind that along with the undesired signal, the signal from real sub-horizontal boundaries can be lost.

The result of applied (Background Removal) routine as shown in figure (8).

5.2. Stolt F-K Migration

The "Stolt F-K Migration" routine is applied in order to restore the real location and shape of reflecting boundaries in a section plane. Particularly, if the routine has been applied correctly the hyperbolic reflections (the diffracted waves) gather in points which locations correspond to diffracting local objects.

The migration algorithm used in the programme (Stolt migration algorithm in F-K domain), as compared with other migration algorithms, is very fast. The main restriction of this algorithm is that the wave propagation velocity within the limits of the section fragment that is under processing considers being constant.

Figure (9) Shows the target (pipe) after applying this routine, it clearly seen that the pipe showed well (as clear hyperbola, marked with an arrow) on the radargram.

5.3. Time Adjustment:

The "Time Adjustment" routine is meant for adjusting the zero-point of the vertical time scale to the time-zero, i.e. the moment when the wave has actually left the emitting antenna.

After applying this routine, it was found that the majority of the pipe work system was buried at a depth = 2.4 m, as shown in figure (10)

5.4. Trace Edit:

The "Trace Edit" module allows the user to exclude the invalid and undesired traces and record intervals from the initial record.

With the help of this routine, approximate (1000) un-useful traces were neglected, as shown in figure (11)

Results

Below an example presented as a GIS map (figure 12). The result show that the GPR serve as a useful tool for detecting and locating underground pipes for efficient pipes system management and for avoiding damage during excavation which is become a relevant issue in metropolitan areas.

In addition the result shows that the combination with the GPS data to determine the coordinate for pipe points is needed.

Conclusions

1) GPR´s high resolution capabilities allow detection of closely spaced utilities which is often the case under roadways in urban areas.
2) GPR can assist the horizontal drilling techniques by predicting obstacles and a voiding damage.
3) To increase the pace of work the whole area of the University of Technology could have been measured as a continuous long profile with a direct interpretation along the measurement.
4) This investigation give the constructor sufficient information to a void certain areas for further construction work ,and to know where the pipe work has to be improved.

References

[1]Sigurdsson,T., Ground Penetrating Radar for Geological Mapping, Thesis, Aarhus University, Department Of Earth Sciences, Aarhus, Denmark, August, 1993.

[2] Annan, A.P. and Cosway, S.W., Ground Penetrating Radar Survey

Design: Proceedings of the SymposiumOn the Application of Geophysics to Engineering and Environmental Problems, SAGEEP'92, April 26-29, 1992,Oakbrook, IL, pp. 329-351.
[3] Proceedings of the Eighth International Conference on Ground Penetrating Radar (GPR 2000), Goldcoast,Australia, May 23-26, 2000, SPIE vol. 4084.
[4] Saarenketo, T., and Scullion, T., "Ground Penetrating Radar Applications on Roads and Highways",Texas Transportation Institute Research Report 1923-2F, 1994.
[5]Maser,K.R.,"Condition assessment of Transportation Infrastructure Using Ground Penetrating Radar," ASCE Journal of Infrastructure systems, V.2 (2), June, pp. 94-101, 1996.
[6] Liu, L., Detection of possible old buried graves in the Pickett District Cemetery with Ground penetrating radar (GPR) in New Milford, Connecticut, Technical Report to Connecticut Department of Transportation, 23 pp , 2004.
[7] zeng.x.and G.A. McMechan,GPR characterization of buried tanks and pipes,Geophysics,62(3),797-806, 1997.
[8]Daniels.j.j,Fundamentals of ground penetrating radar, in proceedings of the symposium on the application of geophysics to engineering and environmental problems SAGEEP,89,Golden,62-142 , 1989.

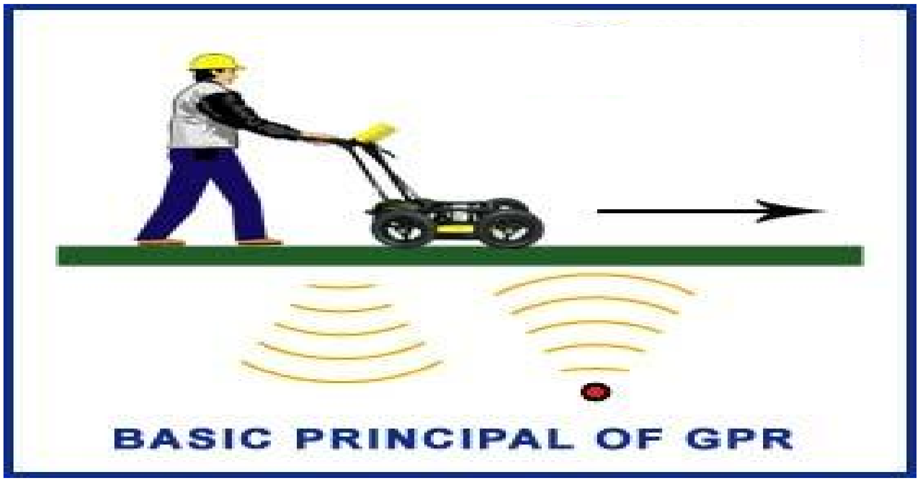

Figure (1) Basic Principle of GPR

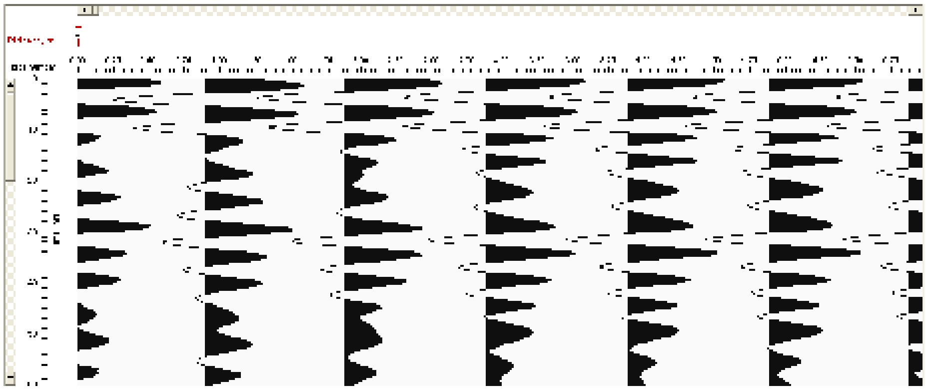

Figure (2) Scene of the GPR

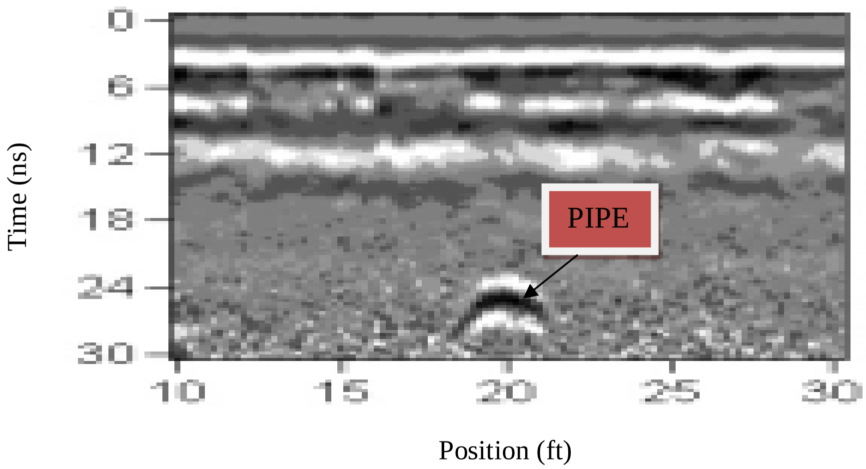

Figure (3) GPR data over clay drainage pipe perpendicular to pipe direction

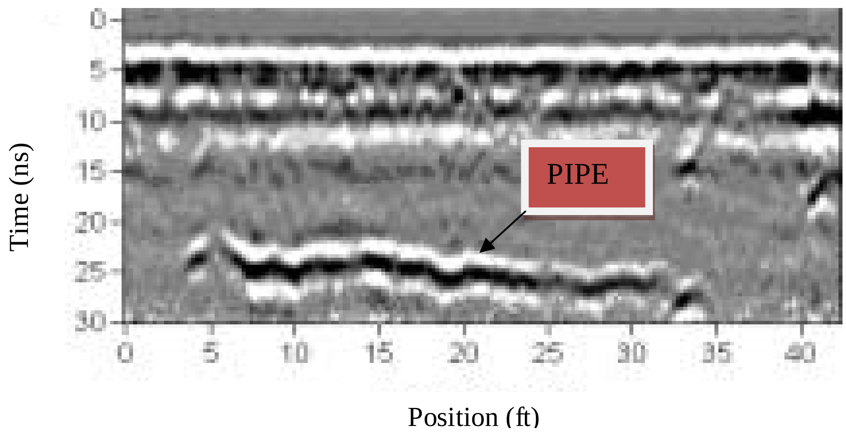

Figure (4) GPR data over a clay drainage pipe parallel to pipe direction

Figure (5) RAMAC/GPR System

Figure (6) GPS (TRIMBLE) receiver

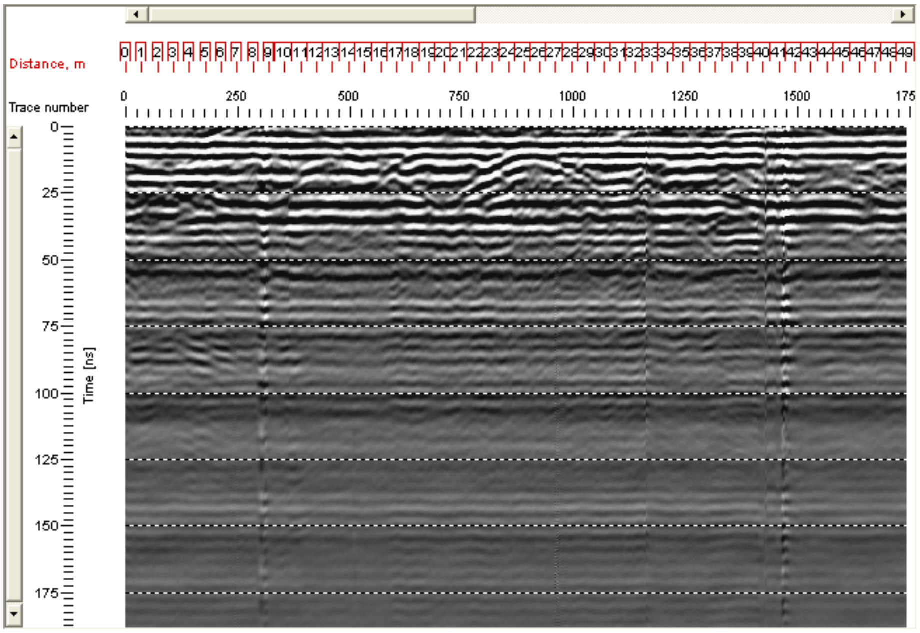

Figure (7) Row Data

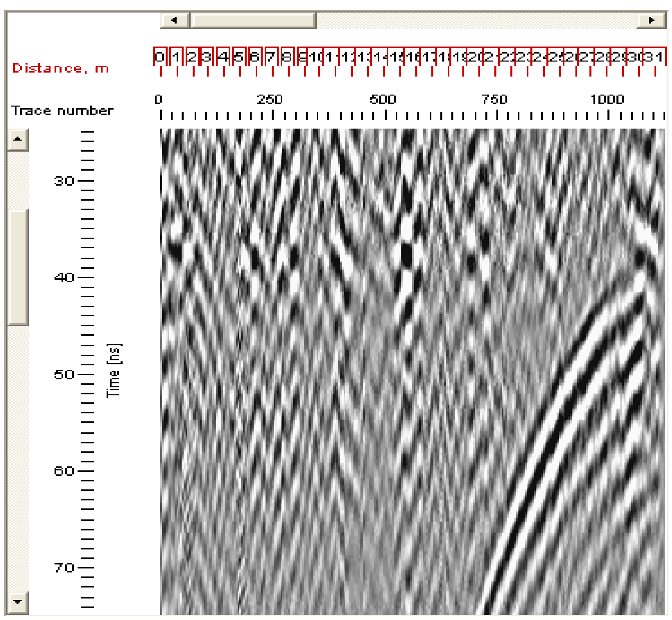

Figure (8) after (Background Removal) routine applied

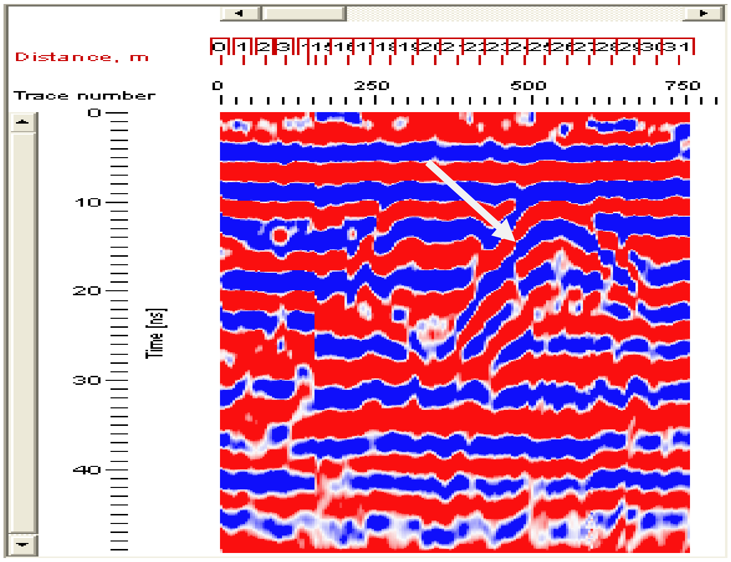

Figure (9) after (Stolt F-K Migration) routine applied

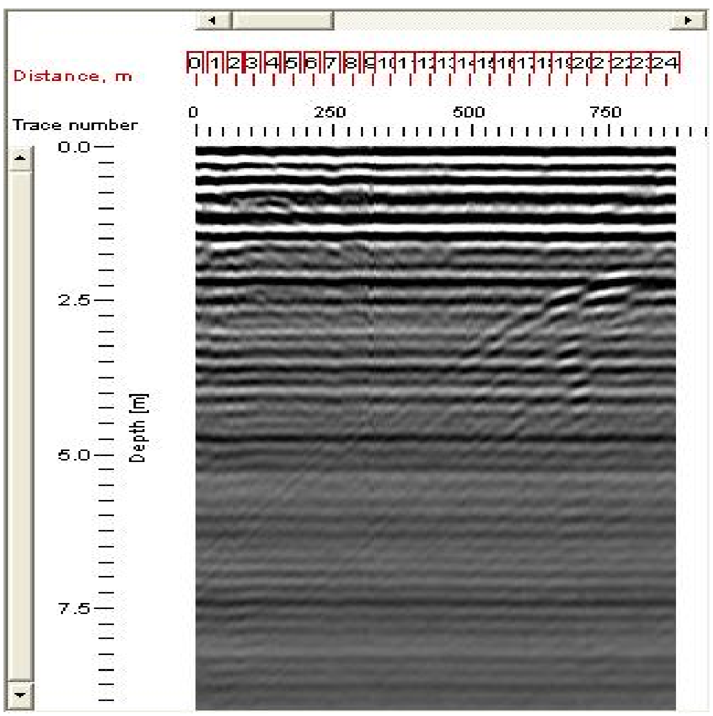

Figure (10) after (Time Adjustment) routine applied

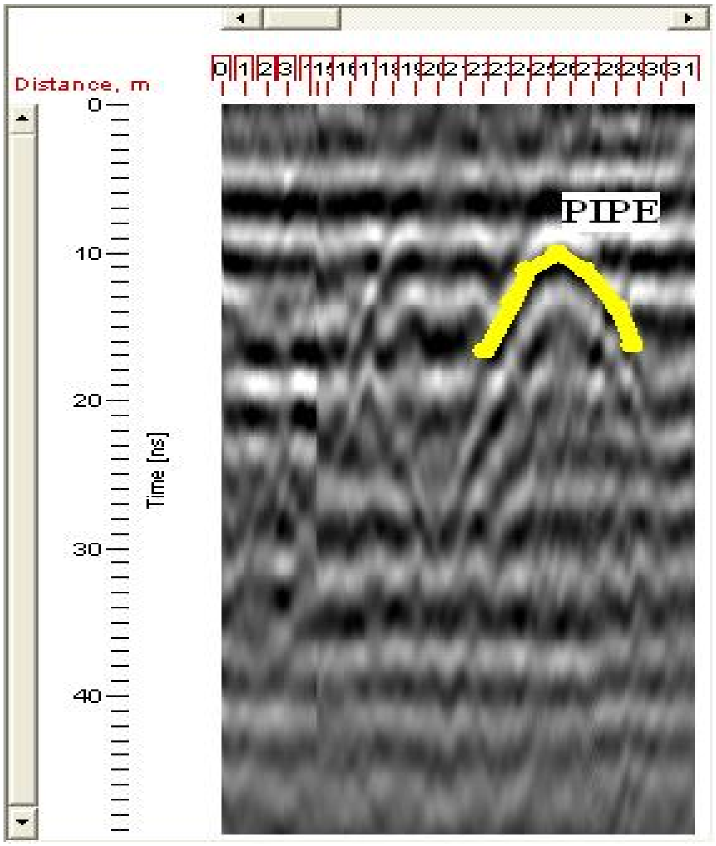

Figure (11) after (Trace Edit) routine applied

Figure (12) GIS map