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THE QANATS EXPLOITATION AND GROUND PENETRATION RADAR

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ABSTRACT

Exploitation of qanat water is one of the most important problems in Iran and other countriesover the world; therefore this study aimed to deep the understanding of the usability of ground penetrating radar in the groundwater and qanat studies. Ground penetrating radar is a geophysical technique that has been extensively used to map the relatively shallow subsurface features at scales from kilometers to centimeters. It is useful to determine the behavior of groundwater table; to estimate of water content, properties of aquifers and qanats; to detect the hidden canals and qanats, etc.

Key words: Qanat, Ground Penetration Radar (GPR), ground water and Aquifer,hidden canals.

INTRODUCTION

A qanat is one of the most common ways of underground water exploitation in Iran and other dry countries in the world. It is a water transporting system that can reach to surface without having a mechanical force. Its cross-section is shown in Fig1.Lenghts of qanat are from 5km to 30m and its mother well depth is normally less than 50 km. Qanat discharge varies seasonally. Generally, applications of geophysical methods for groundwater exploitation are similar to qanats one.Therefore in the present study, investigations are focused on both ground water and qanats.

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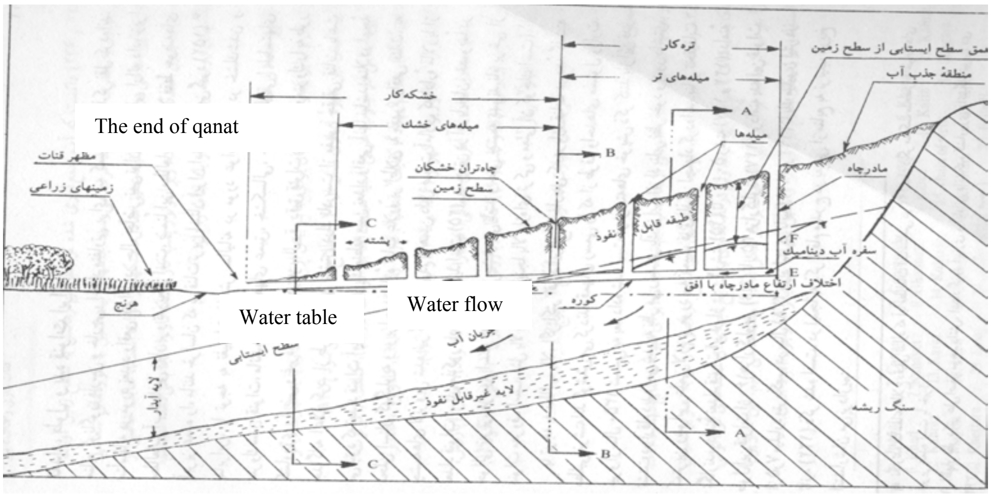


Figure 1. A cross-section along a qanat [1].

Because of the correlation that often exist between electrical properties, geologic formations and their fluid content, electrical and electromagnetic techniques can be employed in groundwater and qanat geophysical investigations.

Ground penetrating radar (GPR) is an electromagnetic technique for measuring the displacement currents in the ground and based on the measurement of the rate of propagation of electromagnetic waves through the subsurface. It is a tool for tracking the movements of the water table that its top has a very high electromagnetic impedance contrast. Also it can be used to locate buried objects; to calculate the change in water stored above a buried object, water content in a hidden canal (such as qanat); to locate metallic and non-metallic objects (such as water pipe), to map the geologic conditions that include depth to bedrock, depth to the water table and thickness of soil and sediment strata on land and under fresh water and the location of subsurface cavities and fractures in bedrock, cavities utilities, voids, fill layers and materials. Some specific applications include the location of underground storage tanks and the delineation of drum piles, the locations of pipes or other buried man made objects such as timbers.

Advantages

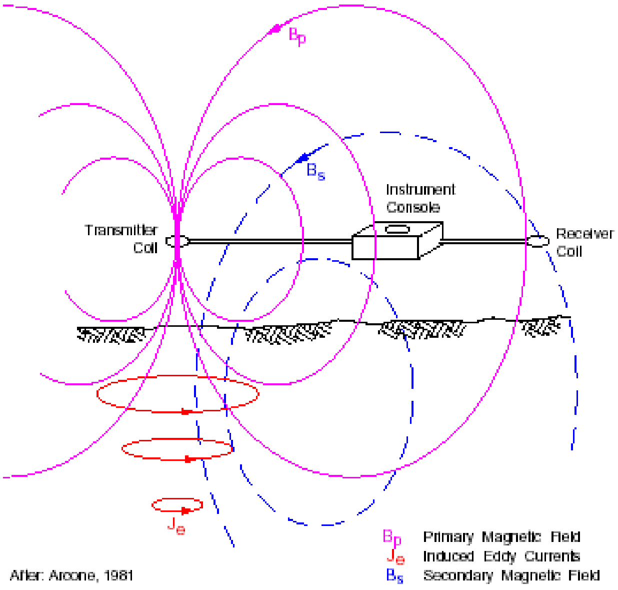
GPR measurements are relatively easy to make and are not intrusive. Antennas may be pulled by hand or with a vehicle from 0.8 to 8 kph, or more, that can produce considerable data/unit time. GPR data can often be interpreted right in the field without data processing. Graphic displays of GPR data often resemble geologic cross sections. When GPR data are collected on closely spaced (less than 1 meter) lines, these data can be used to generate dimensional views of radar data greatly improving the ability to interpret subsurface conditions.

Limitations

The major limitation of GPR is its site specific performance. Often, the depth of penetration is limited by the presence of mineralogic clays or high conductivity pore fluid.

MATERIAL AND METHODS:

These EM instruments do not require any ground contact or surface disturbance; therefore, they are rapid, relatively inexpensive, and can be run with little or no exposure to buried toxic materials. The basic principle of operation of the EM method is illustrated in Figure 1. A transmitter coil radiates an electromagnetic field, which induces electrical currents (termed eddy currents, Je) in the earth below the coil. These eddy currents in turn generate a secondary magnetic field (Bs). The receiver coil detects and measures this secondary field. The instrument output, calibrated to read in units of terrain conductivity (apparent conductivity), is obtained by comparing the strength of the quadrature phase component of the secondary field to the strength of the primary field. The apparent conductivity measurement represents a weighted average of subsurface conductivity from the ground surface to the effective depth of exploration of the instrument. The depth of exploration depends on the separation between the transmitter coil and the receiver coil, as well as on the coil orientation (coil axis/dipole horizontal or vertical).



After: Arcone, 1981

Figure 1. Operation of electromagnetic survey.

In the GPR method, a transmitter is used to send electromagnetic energy into the ground that then reflects from geologic interfaces where a dielectric contrast exists. The reflected energy is recorded by a receiver and produces a picture of the reflected waves. If the system is used over water, it will be placed on or immediately above the surface of the water. The transmitter produces short period (frequencies in megahertz range) pulsed electromagnetic signals at regular time or distance intervals as it towed across or above the surface of the water. Some of this pulsed electromagnetic (EM) energy is reflected from the water bottom and other prominent dielectric interfaces (facies contacts) and returned to the receiver. The arrival time and magnitude of the reflected energy are recorded at the surface by the receiver antenna. Traces from adjacent source locations are generally plotted side-by-side to form an essentially continuous time-depth profile of the stream bottom and shallow sub-strata (including in-filled scour features). Estimated EM velocities can be used to transform the time-depth profile into a depth profile. Velocities are a function of suspended sediment load and can vary appreciably. Figure 2 shows the GPR transmitter and receiver along with the transmitted and reflected waves. Also analysis & interpretation of GPR pulses is depicted in Figure3.

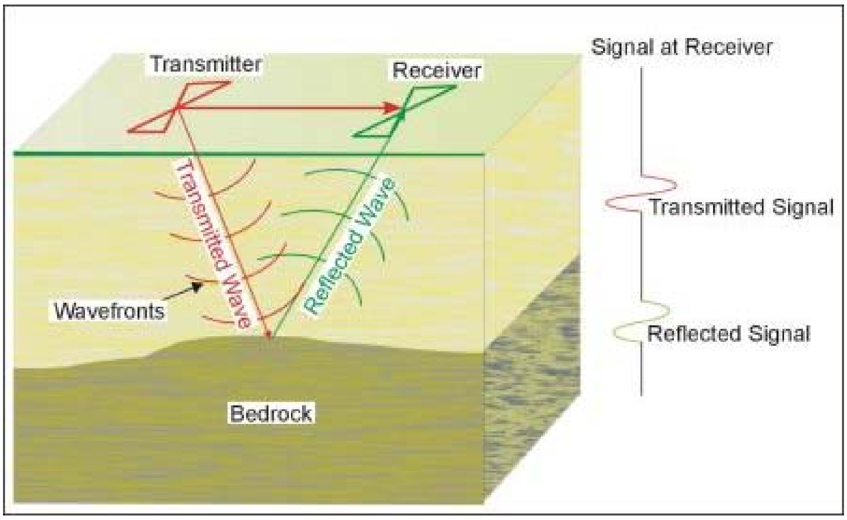


Figure 2. Ground Penetrating Radar System.

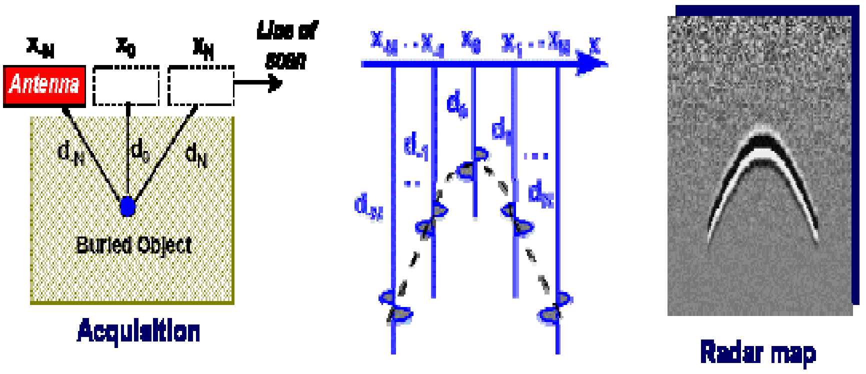


Figure 3. Analysis and interpretation of GPR pulses.

GPR data can be viewed without any processing. However, some processing is often desirable. The common processing steps used are:

1- Distance normalization
2- Horizontal scaling (stacking)
3- Vertical frequency filtering
4- Horizontal filtering
5- Velocity corrections
6- Migration
7- Gain

The above processing steps usually increase the interpretability of the GPR profiles by removing unwanted random noise and enhancing the amplitude events of interest

RESULTS

As illustrated above, GPR is a powerful tool for solving the hydrology and geology problems. This example shows that the GPR led to the detection of abrupt variations in the depth of the water table, which are caused by steeply dipping clay layers. The top of the water table appears at a time between 120 and 170 ns, which corresponds to a depth between13m and 15m.At the abscissa of 285m on the line, the 30ns jump corresponds to an abrupt 1.7m drop of the water table. Notice that the right axis has been converted to depth through the use of an assumed water content profile through the subsurface. GPR has been used to identify soil stratigraphy, to locate water table (Fig 4), to map the location and burial depth of drums, underground storage tanks (Fig 5, 6), to follow wetting front movement, to measure soil water content, to identify the subsurface hydraulic parameter, to assess soil salinity, and also to support the monitoring of contaminants.We propose to use GPR to measure the water content of the shallow subsurface beneath the qanat bed and to detect hidden qanats, underground water flow.

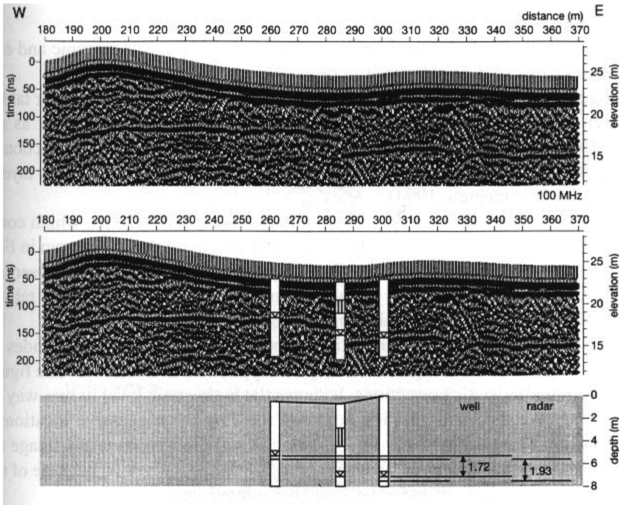


Figure 4- Detection of the top of the water table by GPR [11].

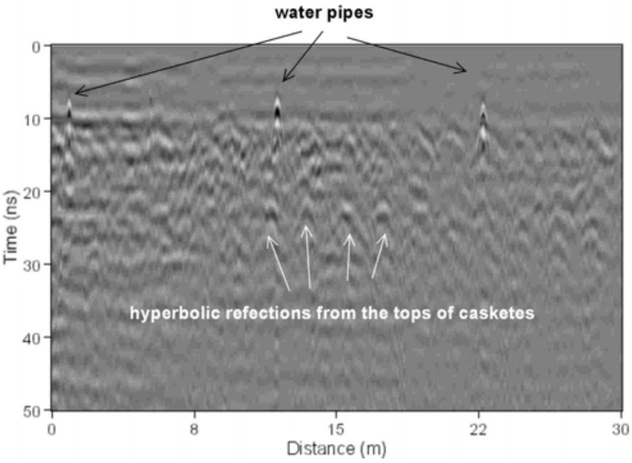


Figure5.Water pipe detection using GPR

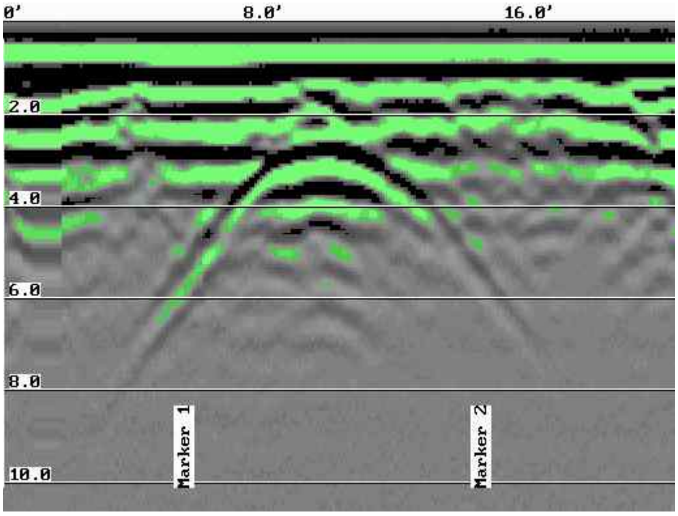


Figure6. GPR profile across the apex of an underground storage tank.
The two markers indicate the edges of the associated metal detector anomaly.

The soil water content is an important variable in soil physics. At small scales, TDR-probes (Time Domain Reflectometry) can measure the water content and especially changes of water content with very high accuracy. But there is still a lack of methods suitable for areas and measurements of heterogeneity of soil water content. Using TDR, a high number of probes have to be installed, which leads to considerable costs and work. To determine small-scale heterogeneities, the TDR also has the disadvantage of disturbing the area by installing probes. For these cases, GPR is an alternative measuring device. It can be used for areas in the range square meters with high spatial resolution. A shielded antenna was used with centre frequency of approximately 750 MHz. GPR measurements were carried out on different soil surfaces (bare soil, grassland and on an organic layer in a forest) and compared to TDR measurements. All measurements showed a good agreement between GPR and TDR results.

Figure 7 (left) shows the in-crease in water content over a 60 by 60 m area measured with GPR, witch was calculated by subtracting the water content map before irrigation from the water content map after irrigation. The resulting soil water increase map for TDR is presented in Fig. 7 (right). Clearly, there is a good general agreement between both methods since they show similar patterns in soil water increase caused by the heterogeneous application of water.

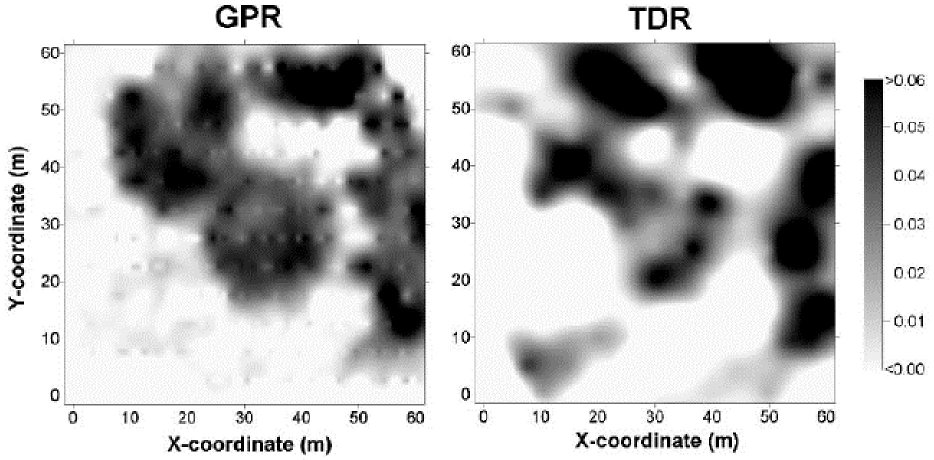


Figure7. Maps illustrating the increase in soil water content obtained using ground penetrating radar (GPR) ground wave and time domain reflectometry (TDR) measurements.

Soil and groundwater quality are geoindicators that assess the effect of human activities on environment. Some potential causes of contamination are industrial and agricultural activities, leakage in municipal landfills, septic tanks, underground storage tanks, ducts and injection wells. Contamination modifies soil properties such as hydraulic conductivity, wettability, dielectric permittivity, swelling potential, crack formation and electric conductivity. The influence of contamination on soil electrical properties allows using geophysical exploration (based on electrical properties or electric waves propagation) to detect the presence of contaminants.

GPRused to calculate the discharge of a river without having any of the measuring equipment in the water. The combined radar data sets were used to calculate the river discharge and the results compared closely to the discharge measurement made by using the standard in-water measurement techniques.

CONCLUSION

GPR is a relatively modern technique; it is used widely in the last decades to explore the shallow subsurface phenomenon In this study, applications of Ground Penetration Radar (GPR) for explorating & exploiting of qanat systems and groundwater were presented. Some presentations are:

- Detecting the water table level; estimating of water content, depth of aquifers and qanats, substructure layer thicknesses; detecting the hidden canals and qanats
- Mapping the location and burial depth of drums, underground storage tanks
- Imaging man-made subsurface structures
- Delineating disposal pits, trenches, and landfill boundaries
- Locating voids and washouts along pipelines, under roadways, parking lots, and building floors

- Delineating inorganic and organic free-phase contamination plumes
- Evaluate mine and quarry rock
- Investigate archaeological sites and cemeteries

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