Rev. Mar. Sci. Agron. Vét. (2016) 4 (1):5-8

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Potential of Ground Penetrating Radar for the characterization of the shallow water table in the Mnasra region (Morocco)

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Abstract

Morocco is a water-scarce country confronted with a severe dependence on rain-fed agriculture and dwindling groundwater reserves. Since 1995, new water regulation laws and management strategies have been promulgated providing a comprehensive framework for an integrated management. Moreover, water managers should have precise data on the current state of water tables depth in strategic aquifers. Unfortunately, the main sources of these data are sporadic wells with no automated monitoring systems making the assessment of water table dynamics costly, time consuming and out-phased with decision maker needs. In this respect, this paper focuses on the capability of Ground Penetrating Radar (GPR) to determine the depth of shallow water table in Mnasra region, located in the Gharb region of Morocco as a pilot study to generalize its use in the future for groundwater dynamic monitoring purposes in Morocco. The experiment was undertaken using Mala 800 MHz shielded antennas and was able to probe the depth of the upper fresh water table at 3.75 m deep in the semi-arid conditions of Mnasra aquifer. Data collected by GPR can be used as substitute for well logs to enhance the monitoring of water tables in water stressed areas during droughts and excessive recharges during rainy season

Keywords: Ground Penetrating Radar, Shallow water table, Mnasra, Gharb region, Mala 800 Mhz antenna, Monitoring of water table

Résumé

Le Maroc est un pays à ressources en eau limitées confronté à une dépendance à l'agriculture pluviale et une diminution des réserves des eaux souterraines. Depuis 1995, de nouvelles lois de réglementation d'eau et des stratégies de sa gestion ont été promulguées fournissant un cadre global de gestion intégrée. Par ailleurs, les gestionnaires doivent disposer de données précises et actualisées sur le niveau des nappes stratégiques. Malheureusement, la principale source des données est celle des puits sporadiques sans systèmes de suivi automatisés rendant l'évaluation des dynamiques des nappes coûteuse, exigeante en temps et en déphasage avec les besoins des décideurs. Ainsi, cet article se focalise sur la capacité des sondeurs radar (GPR) à déterminer la profondeur de la nappe souterraine de Mnasra, zone pilote située dans la région du Gharb au Maroc e vue de généraliser son utilisation pour le suivi des nappes au Maroc. Il était possible de sonder, en utilisant des antennes Mala 800 MHz, le niveau de la nappe à une profondeur de 3,75 m dans des conditions semi-arides. Les données GPR collectées peuvent être utilisées comme substitut aux puits pour améliorer le suivi des nappes dans les zones arides durant les périodes de sécheresse et de recharge intense.

Mots-clés: Sondeur Radar, nappe non profonde, Mnasra, Région de Gharb, Antenne Mala 800 Mhz, suivi des nappes.

INTRODUCTION

In Morocco, water scarcity has reached an alarming point, where a drop of water supplies of 15% to 20% is noticed during the last 30 years (State Secretariat in charge of Water and Environment, 2010). An additional drop of water supply of ~10% to 20% around 2020 and the loss of important water volumes due to the silting of dams (about 75 million cubic meters/year) is foreseen. Since 1995, new water regulation laws and new management strategies have been promulgated providing a comprehensive framework for an integrated resource assessment.

Since its independence, Morocco has adopted a water resource management policy. Indeed, the establishment of dams by His Majesty the late King Hassan II resulted in the storage of water, irrigation of more than one million hectares and substantial reduction of flood risks. Moreover, since 1995, new water regulation laws and new management strategies have been promulgated providing a comprehensive framework for an integrated resource assessment. Also, for a better management of water resources, Morocco has created nine (09) Hydraulic Basin Agencies (HBA). This allowed each HBA to conduct an internal management of its water resources.

Despite this strategy, the water resources management system proves inefficient and lacks organizational

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framework. In addition, it faces:

● An unfavorable climatic context explained by a succession of dry years and low and irregular rainfall with uneven spatial and temporal distribution;

● Excessive, uncontrolled exploitation of resources;

● Excessive exploitation of water resources accompanied by degradation of water quality and decreased groundwater levels of the charges of the aquifer.

In addition, it is important to regulate the exploitation of water resources, set up a control system, giving more autonomy to the HBA in terms of responsibility and use new technology for acquisition and water resource mapping for rigorous monitoring of groundwater levels table.

By focusing on this last aspect, it is worth mentioning that in order to manage, one must first have an accurate and reliable assessment of water resources, realize the mapping coverage and undertake the monitoring process. To reach this goal, there are several acquisition techniques of water resources data which may be used.

In fact, to be able to find appropriate places to dig wells, several techniques ranging from traditional to sophisticated ones are used. The so called "dowsing", "divining", "double bugging" and "water witching" are all names for the methods carried out by men who have the ability to define the presence of water in a site. While walking on a surface of a site, they use different types of rods such as metal rods shaped dwigs, Harmann lobs or the lecher antennas (Ndlovu *et al.*, 2010). Another approach is the seismic technique. This one is known to have the capacity of defining the structured

futures present in the subsurface. It is used mainly for hydrocarbons identification, gas and oil exploration but also for underground water determination such as buried structured valleys. It produces a large amount of data, requires intense logistics and a heavy budget. Another constraint which should be mentioned is that the results are very difficult to interpret. Actually, an enhanced technique is developed which seems to be less costly. The so called Multichannel Analysis of Surface Waves (MASW) is an enhanced seismic survey method. This technique can be seen as a non-expert approach since data acquisition and processing steps are very easy to learn (Xia, 2006). The Proton Magnetic Resonance (PMR) is another technique that detects underground water (Wyns *et al.*, 2004). In this method, electric currents are sent into the ground and then the signals emitted by the nuclei of hydrogen atoms present in water molecules are measured. In this article, we focus on the capability of Ground Penetrating Radar (GPR) technology to determine the depth of shallow water table.

POTENTIAL OF GROUND PENETRATING RADAR (GPR)

GPR fundamentals

The Ground-penetrating radar (GPR) is a geophysical survey technique that uses electromagnetic waves and detects the reflected signals from subsurface structures (Jol, 2009). It is a non-destructive solution for detecting, identifying and monitoring subsurface materials having electrical properties that are in contrast with the surrounding
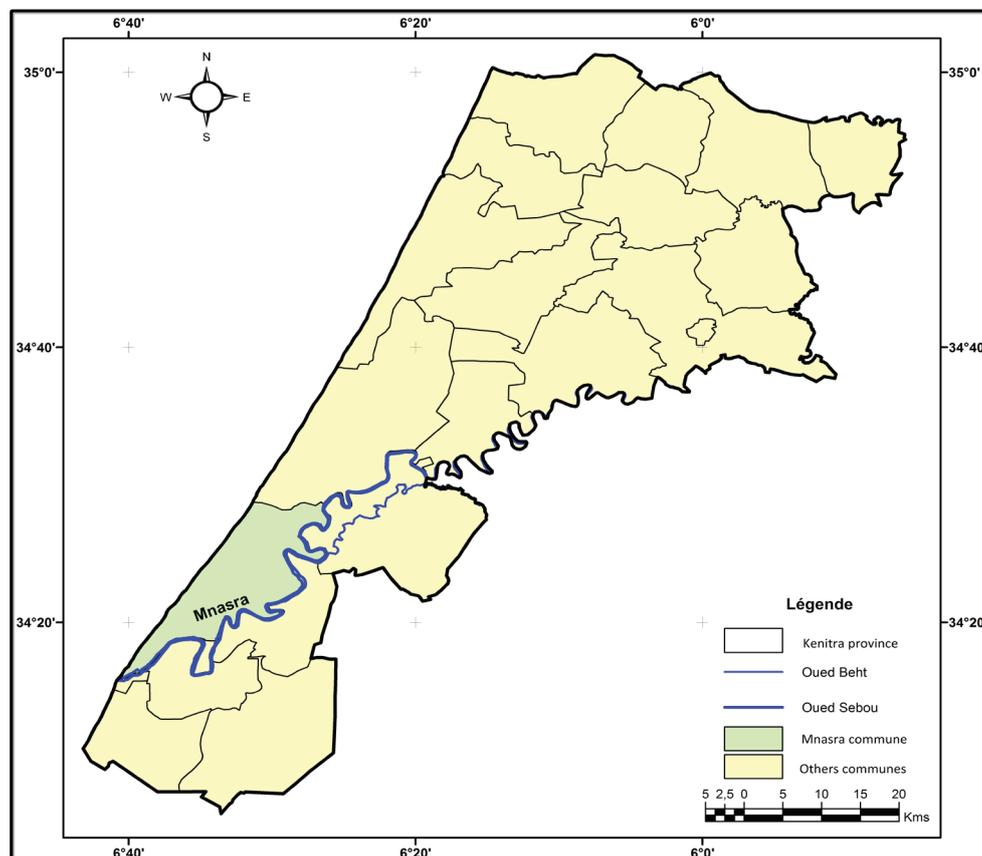

Figure 1: Study area

medium. The antennas used vary in frequency depending on the depth to reach. For example, the antennas 50 - 70 MHz may reach a depth of 50 m or more. 500 - 800 MHz antennas, on the other hand, may reach 8 m or more of depth. It is worth mentioning that the resolution is directly proportional to the frequency but the depth investigated and antenna(s) size(s) are inversely proportional to the frequency. The GPR is a tool which may be used in different applications such as civil engineering, groundwater, archaeology, etc. The available GPR in the market are bi-static and it is difficult to specify the maximum investigation depth and the in depth resolution as it depends on the subsoil.

Study area

The experiment was carried out in the Mnasra commune which covers a portion of the Mnasra aquifer, located in the province of Kenitra (Morocco). The water table is characterized by (HBA of Sebou, 2015):

● A piezometric depth up to 7 m;

● A water table depth from 5 to 40 m;

● A salinity level <= 10 g/l;

● A conductivity <= 2 mS/cm;

● A conductivity layer made of deep Pliocene and clay;

● A dominance of sand and sandy stones of quaternary deposits.

Figure 2: the Ground Penetrating Radar used for the survey

Equipment

For the present study, the Mala antenna with 800 Mhz frequency was used. It consists of a transmitter - receiver. The reflected signal is picked up by the antenna, amplified, digitized and stored for further processing. The advantage is that the result can be displayed on a computer monitor during the field survey. Figure 2 shows Dr. Heggy Essam, USA, and Dr. Ali Al Makhtoumi, Oman, members of the research team, preparing the material for the survey.

PROCESSING AND RESULTS

Figure 3 shows the processing flow for analyzing the GPR data (Dojack, 2012). The first step involves vertical and horizontal scale correction. The second step involves removal of horizontal banding in reflection profiles. The third step involves removal of high-frequency noise and multiple reflections. The final step involves the collapsing of point hyperbolas (Conyers, 2004). For each step, numerous algorithms can be used. Each data set is unique, and will require different processing steps to eliminate its undesired characteristics and enhance those of interest. For our case, we applied the following algorithms: remove background filter, energy decay and frequency filter 200-800 MHz.
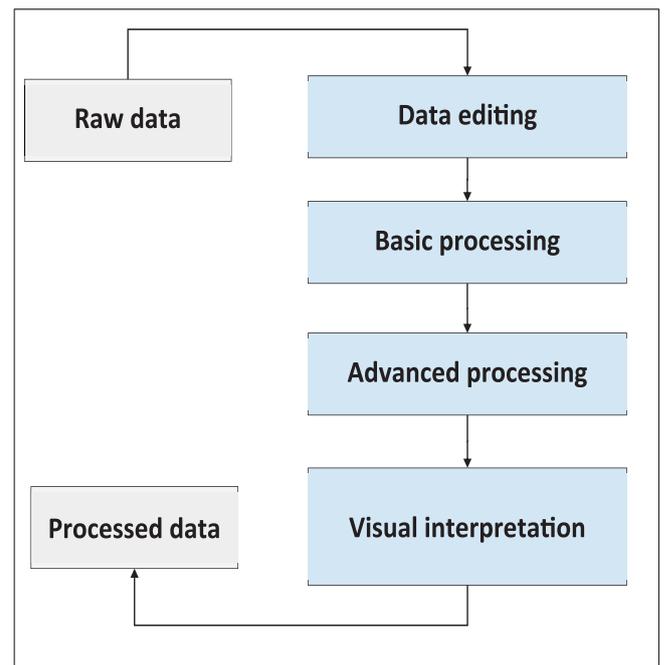

Figure 3: GPR processing flow

We used Reflexw software to process the data. Reflexw has a modular character (Sandmeier, 2014). We used the 2D-data analysis module that offers a numerous possibilities of processing, analysis and display. The figure 4 represents the processed radar gram. The red line shows the limit of the water table. The GPR measurements estimated the water table to an average depth of 3.75 m. The estimated value was validated by nearby boreholes and was within the range of their depths.
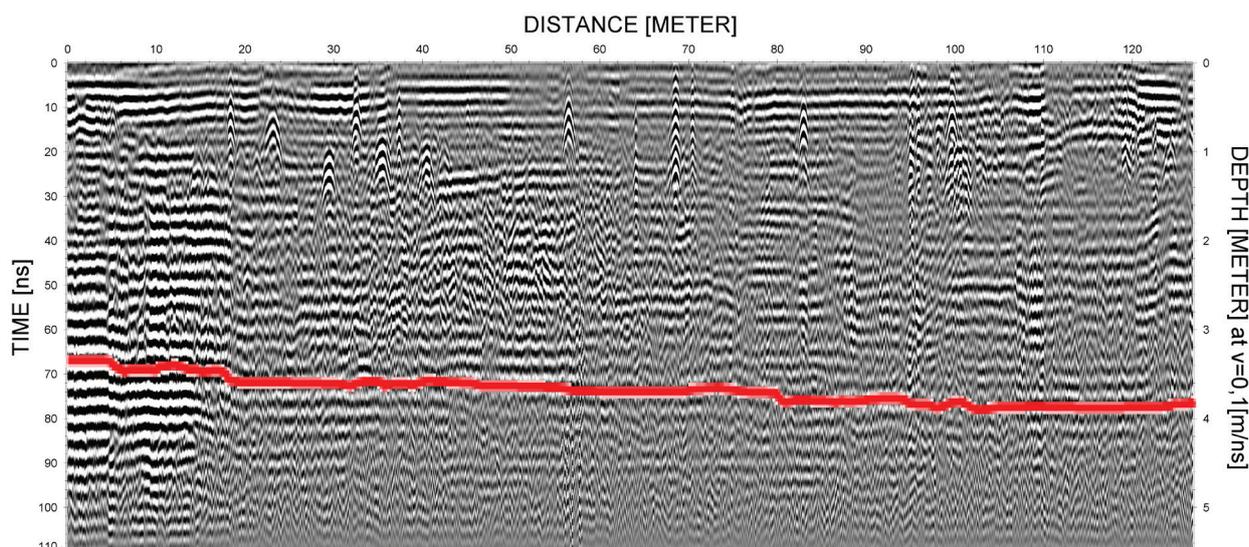
Figure 4: Processed radar gram. The solid line indicates the limit of the water table

CONCLUSION

The results of this study are promising regarding the detection of the water table and the determination of its depth. Data collected by GPR can be used as substitute for well logs to improve the monitoring of water tables in water stressed areas during droughts and excessive recharges during the rainy season. This work can be extended by combining collected GPR data with hydro-geological data in order to provide more hydraulic properties of the aquifer.

ACKNOWLEDGMENT

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