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Characterization by electrical and electromagnetic geophysical methods of the shallow hydrogeological system at Hebron (West Bank, Palestine) in a semi-arid zone

Caractérisation des systèmes hydrogéologiques superficiels à Hébron (Cisjordanie, Palestine) en zone semi-aride par des méthodes géophysiques électriques et électromagnétiques

Asal Sirhan [a,*,b,c], Mohammad O. Hamidi [c]

[a] *Department of Electronic Engineering, Faculty of Engineering, AL-Quds University, PO Box 51000 Jerusalem, West Bank, Palestine*
[b] *Université Pierre and Marie Curie, Paris 06, CNRS-UMR 7619 SISYPHE, 75252 Paris cedex 05, France*
[c] *French-Palestinian Interdisciplinary Studies Centre, AL-Quds University, Jerusalem, West Bank, Palestine*

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ABSTRACT

Multi-electrode geo-electrical and transient electromagnetic surveys were carried out to characterize the nature of the subsurface infiltration zones (5 to 20 m) related to a series of groundwater outlets, and to reveal the geometry of the different aquifers at Bani-Naim, in the south-eastern foothills of the Hebron area, West Bank, Palestine. The purpose of the surveys was to understand the link between water storage/transfer and the characteristics of the geological formations. The strata in this semi-arid region are composed of alternate layers of chalky limestone, hard limestone, marl and chalk. A total of 30 ERT and 15 TDEM were conducted at Bani Naim-Jahir and Bani Naim-Birein. A correlation between the results indicates various infiltration pathways: fractures, feature heterogeneities, and porous chalk. The local heterogeneity on the eastern side were the major pathways for the water infiltration, whereas the thick marl layer underneath acts as a natural impermeable barrier preventing water from infiltrating deeper. A combination of the different geophysical results identified conductive features that correspond to the infiltration zones supplying the dug wells with water. Furthermore, it was established that the fractured chalk and porous chalky limestone act as an aquifer. A three-dimensional visualization of the resistivity allowed a useful reconstruction of the shallow hydrogeological system. Consequently, these studies contribute to regional sustainable development projects in this semi-arid region.

Mots clés :
Méthodes géophysiques géoélectriques
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RÉSUMÉ

Des campagnes géophysiques électriques multi-électrodes et électromagnétiques en transitoire ont été effectuées aux piedmonts sud-est du plateau d'Hébron (Cisjordanie, Palestine), pour caractériser la nature des zones d'infiltration superficielles (5 à 20 m)

* Corresponding author.
E-mail addresses: asal.sarhan@eng.alquds.edu, asal_sirhan@yahoo.com (A. Sirhan).

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alimentant une série de sources, ainsi que la géométrie des différents aquifères dans la région de Bani Naim. Le but de ces campagnes était de comprendre le lien entre le stockage et le transfert de l'eau et les caractéristiques des formations géologiques. Celles-ci sont composées, dans cette région semi-aride, d'alternances de calcaires crayeux, de calcaires compacts, de marnes et de craie. Une série de 30 profils tomographiques de résistivité et de 15 sondages électromagnétiques transitoires a été réalisée à Bani Naim-Jahir et Bani Naim-Birein. La bonne corrélation entre les résultats obtenus montre qu'il existe plusieurs chemins d'infiltration : des fractures, des hétérogénéités des formations, et la craie poreuse. L'hétérogénéité locale sur le côté est de la zone étudiée joue le rôle principal pour imposer les chemins d'infiltration, tandis que la couche épaisse de marnes sous-jacente joue le rôle de barrière empêchant l'infiltration de l'eau à plus grande profondeur. La synthèse des résultats géophysiques permet de façon efficace de localiser les structures conductrices par où s'infiltrent les eaux qui alimentent les puits traditionnels. Il a, de plus, été établi que la craie fracturée et les calcaires crayeux poreux constituent des aquifères. Une visualisation en 3-D du champ de résistivité fournit une reconstruction utile du système hydrogéologique superficiel. Ce type d'études contribue donc grandement au succès des projets de développement durable dans cette région semi-aride.

1. Introduction

The rapid growth of the population in the West Bank area (6000 km^2, and 2.5 million inhabitants) prompts an in-depth investigation of the hydrogeological system to avoid the establishment of unsustainable conditions in this semi-arid region that suffers from limited water resources. Groundwater is recharged by rainfall at both shallow and deeper depths; natural springs also used to play an important role in providing water for drinking, agriculture and domestic use. However, due to the overexploitation of the groundwater, the water flow rate is decreasing with a major impact on the quality of the population's lives (Alatout, 2000; Sbeih, 1990).

Prior to obtaining complex official permissions for field prospection, non-invasive geophysical techniques were employed on the West Bank to improve the knowledge of the subsurface hydrogeological system near a series of springs and dug wells; the present study was requested by the municipality of Bani Naim (Fig. 1) in the Hebron District (31°32′00″N to 35°05′42″E).

Limited studies have already been made in the region, while a hydrogeology study was carried out on the Al-Aroub drainage basin in north-eastern Hebron (Qannam, 2003), and the groundwater beneath the Ram Allah District (Mimi and Assi, 2009) is being exploited. An accurate understanding of the hydrogeological system is required and must take into account the complexity of the in situ conditions. Therefore, electrical and electromagnetic techniques were chosen to improve the hydrogeological knowledge by determining subsurface resistivity (of the upper 20 m), where rain water might circulate through the chalk, chalky limestone, limestone and rock fractures. The aim of this study is to characterize the subsurface infiltration zones and the geometry of the infiltration features, as well as to determine the interfaces between the different layers. A further aim is to understand the link between water storage and infiltration mechanisms within the chalky limestone, limestone and heterogeneous chalky geological formations usually considered as aquitards.

2. General site characteristics

2.1. Geological context

On the West Bank, the outcrops are composed of carbonate sediments and Tertiary, Cretaceous and Jurassic rocks. Older rocks are not visible at the surface although their existence is known from boreholes. The oldest exposed rocks belong to the Bajocian-Bathonian/Jurassic at Wadi Almaleh in the North-East of the West Bank, overlain by younger strata of the Albian, Cenomanian, Turonian, Senonian (Cretaceous), Paleocene and Eocene (Tertiary), exposed on both flanks of the anticlinal axis in the West Bank. Whilst the Cenomanian and Turonian limestones are generally very hard and resemble marble, the Senonian and Eocene limestones are generally soft and chalky. In the Jordan valley and on the shores of the Dead Sea, as well as in the wadis and the interior valleys, younger formations of Pleistocene/Holocene age are found (Fig. 1a). The Tertiary, Cretaceous and Jurassic rocks on the West Bank are mainly limestone, dolomite, chalk and marl with flint bands (Abed and Alwishahe, 1999; Qannam, 2003). The morphology of the West Bank is a result of folding, faulting and subsequent denudation. The dominant geomorphological features of the West Bank are found in the Hebron region, which reaches 1020 m in elevation. These features turn northwards into the Jerusalem Mountains, Nablus Mountains and Jenin Hills (300–400 m). The Jordan River valley and its Dead Sea terminal are significant geomorphological features (200 m above sea level to 410 m below sea level).

As an example of a region situated in the southern part of the West Bank, the studied Bani Naim area is located in the Hebron formation, in the upper younger strata of the Cenomanian Hebron. At a regional scale this formation is composed of karstified grey dolomite, dolomitic limestone and the basement is hard dolomite and dolomitic limestone with some silicification. The porosity is mainly secondary and the rocks are karstified (Qannam, 2003). Based on observations of geological