XXXVIII IAH Congress

Groundwater Quality Sustainability
Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University of Silesia Press 2010

abstract id: **324**

topic: **3**
Aquifer management

3.3
Geophysical, geological and geochemical methods in groundwater exploration

title: **Geophysical investigations for groundwater augmenting in sand dunes area, BinhThuan, Vietnam**

author(s): **Nguyen Van Giang**
Institute of Geophysics — VAST, Vietnam, nvgiang189@yahoo.com

keywords: geophysical tool, investigation, groundwater augmenting, monitoring well

INTRODUCTION

The study area is a driest part of Vietnam which extensive red-sand coastal dunes occur by mostly of hills and coastal plains with variable relief from west to east. The main objective of the present study was to delineate the subsurface distribution of groundwater in this sand dunes area — Binh Thuan, Vietnam by geophysical techniques. In addition to this result, the relationships between the surface/subsurface layer's parameters are proposed and shown to be useful in identifying new sites that are suitable for groundwater monitoring and exploitation wells on the studying area.

Geoelectrical methods are commonly employed in hydrogeological investigations, as they have been proven to be successful and are cost-effective. The direct current (DC) resistivity method is a popular tool for groundwater exploration, and usually the Schlumberger and Wenner layouts are preferred (Vertical electrical sounding — VES and Electrical profiling — EP). Like other geophysical methods however, resistivity data have a non-unique solution. Non-uniqueness of the interpretation makes it difficult to select the best model (i.e. that is closest to the real geological model). This non-uniqueness can be reduced by combining different geophysical methods.

In the present study, layered models have been obtained not only by using a stable interactive interpretation program but also by including other geophysical tools as well as magnetic prospecting (MP), magnetotelluric sounding (MTS), very low frequency electromagnetic method (VLF), transient electromagnetic method (TEM), magnetic resonance sounding (MRS) and seismic refraction (SR) for hydrogeological targets. The sites of prospecting and monitoring boreholes were located by the combinated geophysical interpretation data on the studying area.

OVERVIEW OF THE STUDYING AREA

The study area is located between 11°01'00 and 11°05'00 N, and 108°15'00 and 108°22'00 E (Fig. 1). The general climatic conditions in the coastal area are characterized by low rainfall and a long, hot, dry season. There is suitable agricultural land that can only grow crops during the very short wet season. Extensive red-sand coastal dunes occur throughout studying area. Geological units of the coastal sand dunes area of Binh Thuan are mainly Pleistocene sediments, consisting of marine-aeolian sediments of Phan Thiet formation (mvQII-IIIpt), alluvial-marine (amQII-III), and marine (mQI, mQIII) sediments. Pleistocene aquifers are unconfined but in some places groundwater is confined with low pressure head. Aquifer lithology is from fine- to medium-grained quartz sand, mixed with some silt and clay, of typical red color.

Underlying Quaternary and Neogene sediments are hard rocks of igneous and metamorphic origins like dacite-ryodacite with very low permeability which cannot be considered as likely aquifers. Groundwater is exploited through direct pumping where the aquifer emerges (Ta Zon, Bau Trang) or through shallow hand-dug wells. Surface water is only from rain-water collected on rooftops or by artificial reservoirs E and W of mount Bau Thieu but the quality of water there is not satisfactory (Fig.1).

Figure 1. The location of geophysical stations and profiles on the sand dunes studying area Binh Thuan, Vietnam (VES — Vertical Electrical Sounding; EP — Electrical Profiling; VLF — Very Low Frequency; MTS — Magnetotelluric Sounding; MP — Magnetic Prospecting; MRS — Magnetic Resonance Sounding; TEM — Transient Electromagnetic Method; SR — Seismic Refraction; LK1 — Well number 1).

METHODOLOGY

DC resistivity method: The acquisition and interpretation of Vertical Electrical Sounding (VES) data are based on assumptions that the earth is composed of a finite number of horizontally stratified, homogeneous and isotropic layers. In the application of VES to groundwater exploration, water resources management and water pollution studies, the concept of an isotropic, homogeneous and stratified earth is valid. The theory and practice of VES is well documented in the literature (Keller, Frischknecht, 1966; Zhdanov, Keller, 1994; Griffiths, King, 1986). The apparent resistivity for various electrode configurations can be computed from the expression for surface potential (V) and the current injected (I) into the ground through current electrodes using the expression:

$$\rho_a = K \frac{\Delta V}{I}$$

where: ρ_a — the apparent resistivity; K — a geometric factor that depends on electrode array; ΔV — the potential difference between measuring electrodes. he depth of investigation in the Schlumberger sounding configuration varies between 0.25 L and 0.5 L (Roy, Elliot, 1981).

Magnetic prospecting maps variations in the magnetic field of the earth that are related to spatial changes of structure or magnetic susceptibility in subsurface rocks. Sedimentary rocks generally have a very low susceptibility compared to igneous or metamorphic rocks that have

higher iron oxide content, and so most magnetic surveys are designed to map magnetic basement. Interpretation of magnetic data is subject to the non-uniqueness inherent to all potential field methods. To locate the position and estimate the strength of the magnetic sources, the algorithms of reduction to the pole and combine with analytic signal were used.

The electromagnetic (EM) methods provide significant advantages for shallow geophysical exploration and useful for aquifer's location. Among these techniques, the Magnetic Resonance Sounding (MRS) and the Transient Electromagnetic Sounding (TEM) are used for hydrogeological structure and water content estimation. But, before using these tools, the tests measuring should used on the studying area for reducing the noise and increasing the signal for choosing optimum configuration. Datasets are proceessed and interpreted by modeling program for investigation of hydrogeological condition, as well as layering structure and aquifers (Lubczynski, Roy, 2004).

FIELD DATA ACQUISITION

Fourty-eight VES stations were conducted by Schlumberger configuration with maximum distance between current electrodes AB=1000 m to delineate the depth and thickness of the layers, so that the 10 proposed profiles in the area were covered. Those profiles are distributed on 3 sub-regions (mount BauThieu, NuocNoi pond and TaZon). All data were collected by a Terrameter SAS 300C and 4000. A pragmatic approach was used for data interpretation. The starting model of the electrical resistivity distribution is constructed and updated by hand after comparison of its calculated response with the observations. The values of resistivities or thicknesses of every layer of the model can be modified instantaneously by various steps from 0.1 to 1000 Ωm or meters for this approach. This procedure allows the interpreter to see directly on the screen the influence of each layer and to use his geological knowledge in order to choose the most suitable model for the hydrogeological problem.

Seven profiles of magnetic exploration in study area have been carried out using the ENVI-MAG proton magnetometter to measure the total intensity of the geomagnetic field. Those profiles are distributed on sub-region Bau Thieu and Nuoc Noi with 6500 m of total length. The observed data have been corrected the time variation, then subtracted the averaged value to obtain the magnetic anomaly field. The depths of the magnetic basement are estimated by the power-density spectrum technique.

Magnetotelluric method was used for understanding deep geological structure by period range 10^{-3}-10^{3} sec and by MT Geo-Instrument system.

VLF-WADI is used for collecting data along 1250m of profile1 with a 5 m spacing by frequency of VLF transmitter 19.8 kHz. 8000 m of seismic refraction by 3 profiles were carried out by Terraloc Mk6 24 channels for location of bedrock in the studying area. Two profiles of MRS by 12 stations were measured by Numis Plus equipment for water content estimation and 1200 m of TEM profile were investigated for aquifer location by Protem 57 instrument.

RESULTS AND DISCUSSIONS

The criterion for geoelectrical interpretation is based on the range of resistivity values for different kind of geological formations. As we know that the sediment of study area consists of mainly red sand and white sand. The samples of those materials are collected and measured resistivity and shown in the Tab. 1.

Table 1. The range of resistivity for sedimentary materials of studying area.

Sedimentary material	Resistivity in Ωm	Sedimentary material	Resistivity in Ωm
Red dry sand	1500–2500	White moistured sand	200–400
Red moistured sand	300–600	White saturated sand	40–100
Red saturated sand	80–150	Moistured clay	20–40
White dry sand	1000–1600	Saturated clay	10–20

The result of VES and EP interpretation give useful information regarding the water table.There are two sub-regions in the studying area were chosen for their groundwater potential on the basis of geoelectrical investigations. The first is the sub-region TaZon where the water table is at 40–50 m. The second sub-region is NuocNoi where the water table is at 50m (Fig. 2). Ground water in the aquifers is fresh because the values of resistivity calculated by geoelectrical data are about 20 Ω·m.

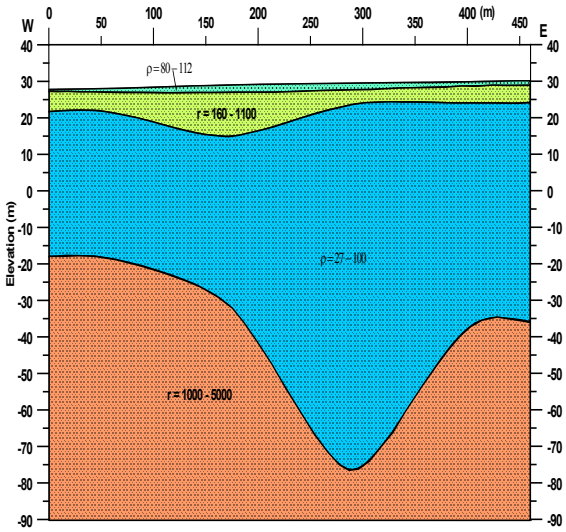

Figure 2. The geoelectrical cross-section by Vertical Electrical Sounding (VES) data for sub-region Nuoc Noi. (Aquifer = third layer = 27-60 Ω.m.).

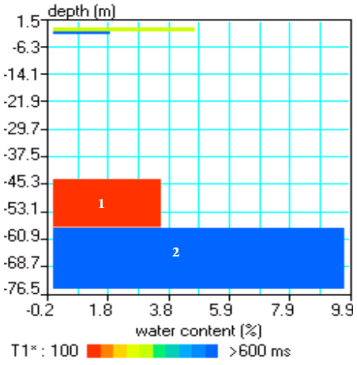

Figure 3. The inversion of MRS for 40/10 station (water content for aquifer1=3.6% and aquifer2=9.8%).

The magnetotelluric sounding curve has been modeled by a 1D structure consisting of 7 layers. The two first layers are identified as sand and fractured dacite by 28–140 Ω.m and 45–120 m.The depths of the magnetic basement are estimated by the power-density spectrum technique and we show that the depth to the magnetic basement in Nuoc Noi varies from about 50 to 150 m. The MRS and TEM data were proceessed and interpreted by modeling program for

investigation of hydrogeological condition as well as layering structure and aquifers. There are two aquifers of groundwater (Fig. 3). The shallow aquifer is located from 20–40 m of depth with poor groundwater (3.6% of water content) and the second aquifer is located from 60–90 m of depth with a good potential groundwater (9.8% of water content). The complex geophysical interpretation by electromagnetic data shows that the MRS and TEM are good correlation tools for location and assessment of aquifer on sand dune area.

The seismic refraction investigation was carried out by means of a 8,000 m long section for the depth to bedrock determination. Fig. 4 shows the fragment of cross seismic section in Binh Thuan (Giang et al., 2006). The interpretation of the seismic data indicates the occurrence of the ryo-dacitic bedrock at depths between 60 and 140 m below ground level, and the occurrence in the sand deposits of a potential aquifer of the same thickness.

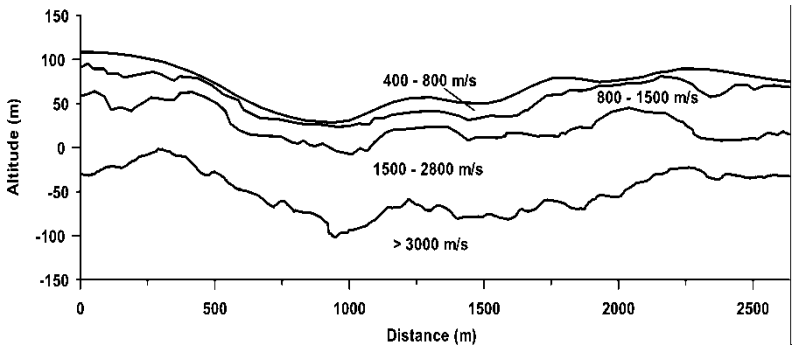

Figure 4. The fragment of 8000 m seismic cross-section on studying area (the values of seismic velocity >3000 m/s indicate basement = ryodacit rock).

The shallow geological structure for sand dunes area Binh Thuan, Vietnam is determined by complex geophysical interpretation on the basis of datasets by geoelectrical , electromagnetic, magnetic and seismic techniques. There are two aquifers which are located by MRS, TEM, VES in sediments and the basement (bedrock) is located by SR and MP. The results of geophysical investigation show the sites for suitable making wells. There are 6 monitoring and prospecting wells which made in the period 2005–2007 year (Thoa et al., 2006) For example the well LK1 which is located by coordinator: 11°03'30''N; 108°21'30''E and made in November 10-28, 2007 by 95.8 m of depth. There is a potential aquifer which consists of medium- coarse sand, located from 46 to 71 m of depth.

The investigation included the acquisition and interpretation of existing data, acquisition of geophysical surveys, topographic, geological and hydrogeological maps, aerial and satellite photos, precipitation data, groundwater physio-chemical parameter measurements and groundwater sampling for water quality and isotopes analyses (Bono et al., 2004) show that pH = 4.79–8.42; temperature =26–34°C; electrical conductivity =50 – 1,500 µS/cm for surface and groundwater on the studying area. Then there is suitable for carrying out Management of Aquifer Recharge (MAR) project on the typical sand dunes area in Binh Thuan, Vietnam (Dillon, 2002). During the period of 162 days pumping test, they supplied 220 m^3/day for residents using in 2007 year of good groundwater quality.

CONCLUSIONS

- The geophysical techniques have played an important role in understanding the hydrogeological conditions for studying area. The complex geophysical interpretation by using VES, TEM and MRS show the optimal techniques for aquifers location and the MP with SR are good combination for basement investigation.
- The most important for geophysical application to this kind of dry sand at the surface of the studying area is to choose a suitable period for collecting data, i.e. during the rainy season for good contact of materials by using VES, EP, SR and during the dry season can be use TEM, MRS, VLF and MP.
- There are two aquifers which are located by complex geophysical interpretation data for hydrogeological conditions on sand dunes area. The shallow aquifer (10-25 m of depth) is limited of groundwater and more sensibility of pollution from surface water, but the deeper aquifer (40-80 m of depth) is potential of groundwater augmenting in this area. The results of geophysical investigation are proved by 6 monitoring, prospecting and supplying wells on the studying area.

ACKNOWLEDGEMENTS

The research is supported by MOSTVietnam (DTDL 2004/07), UNESCO IHP 2004-2007.

REFERENCES

Bono P., Gonfiantini R., Alessio M., Fiori C., D'Amelio L., 2004: *Stable isotope ($\delta^{18}O$, $\delta^{2}H$) and Tritium in precipitation: Results and comparison with groundwater perched aquifers in Central Italy.* TEC – DOC (IAEA) 2004.

Dillon P.J. (Editor), 2002: *Management of Aquifer Recharge for Sustainability.* A.A.Balkema Publishers, Australia, 567 p.

Giang N.V., Duan N.B., Khiem L.C., Thanh L.N., Dung N.Q., 2006: *The interpretation of geophysical data for studying hydrogeological characteristics of Bac Binh, Binh Thuan area.* Viet. J. Earth Sci., 28(4), pp. 410–422.

Griffiths D.H. and King R.F., 1986: *Applied geophysics for geologists & engineers.* Pergamon Press, Inc.

Keller G.V. and Frischknecht F.C., 1966: *Electrical methods in geoelectric prospecting.* Pergamon Press, Inc.

Lubczynski M. and Roy J., 2004: *Magnetic Resonance Sounding: New Method for Ground Water Assessment.* Ground Water Vol. 42, No. 2, pp. 291–303.

Roy K.K. and Elliot H.M., 1981: *Some observations regarding depth of exploration in DC electrical methods.* Geoexploration 19, pp. 1–13.

Thoa N.T.K., Arduino G., Giang N.V., Van P.T.K., Vuong B.T., 2006: *The model for Management of Aquifer Recharge in sand dune area of Bac Binh, Binh Thuan.* Viet. J. Earth Sci., 28(4), pp. 389–410.

International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0