26th WEDC Conference Dhaka, Bangladesh, 2000

WATER, SANITATION AND HYGIENE: CHALLENGES OF THE MILLENNIUM

Implementing borehole in Cambodia: geophysical contribution

Jean-Michel Vouillamoz, Cambodia

TO DRILL SUCCESSFUL boreholes, hydrogeologists have to answer fundamental questions, i.e. where is the groundwater? what will be the yield of a borehole ? what is the water quality? Geophysics is very attractive to complete the standard hydrogeological approach to answer these questions, but conventional methods provide information which is not always directly related to groundwater. A new method, called Surface Nuclear Magnetic Resonance (SNMR), is supposed to detect groundwater directly at various depths. A geophysical study was implemented in Cambodia with conventional and SNMR methods to measure the geophysics contribution to a drilling programme.

This paper presents the main technical and financial analyses of this operation.

Context

The Siem Reap province of Cambodia is located North of Tonle Sap Lake, in the North-Western part of the country. The population of the province is about 650,000 (1993) and the drinking water coverage is estimated to about 25%.

The province is mainly located in a sedimentary basin. It consists of late tertiary to quaternary sediments ranges from coarse sand to clay. These rocks lie on secondary to tertiary sediments (sandstone to claystone) and igneous rocks (diorite, granodiorite, basalt and andesite).

The aquifers could be subdivided into : i) a top aquifer (alluvium deposits) which ranges from 2 to 5 meters deep in average, which is sometimes seasonal and almost always polluted by organic matters; ii) a deep aquifer (quaternary sediments, i.e, sand & silt) which ranges from 20 to 80 meters deep.

Since 1992, 900 boreholes have been drilled into this deep aquifer by *Action against Hunger*. Among these boreholes, 180 were unsuccessful, but in some particular areas the failure rate reached more than 50%.

Methodology

We conducted the field surveys in 12 sites, using 4 geophysical methods, i.e. DC 1D & 2D (Direct Current 1 dimension and 2 dimensions), TDEM (Time Domain Electro Magnetism) and SNMR (Surface Nuclear Magnetic Resonance). According to the interpretation of the field data, boreholes were drilled and tested by electrical logging and pumping tests.

The technical contribution of geophysics to the borehole success rate was estimated from these 12 sites, and the financial contribution of geophysics to the borehole programme was calculated with *Action against Hunger* figures. Finally, crossing the technical and financial analyses, a geophysical methodology of borehole implementation was proposed.

A heterogeneous site example: Mukpen village

Three unsuccessful boreholes (yield @ 0.3 m^3/h) were drilled in Mukpen village. Geophysical survey was conducted to locate a new site. The figure 1 presents the synthesis of the surveys implemented both on a previous unsuccessful borehole (Northern site) and on the new site selected for drilling (Western site).

In this heterogeneous context of sandy and clayey materials, one can remark that :

1. Geophysics is very helpful to implement a successful borehole since no other information could be collected with conventional tools (aerial photograph, geomorphology... are useless).
2. The SNMR interpretation proposes a water content (%) as a function of depth, and an estimation of a second parameter, called the decay time, which is related to the water bearing formation porosity. Thus, it becomes possible to have direct information regarding the amount and location of available groundwater
3. The water content and the thickness of the aquifers proposed by the SNMR interpretations are greater for the western site than for the Northern site, which is in accordance with the boreholes lithology and yield.
4. SNMR sounding is the only method which gives a direct picture of groundwater : it allows a non specialised staff to use and interpret easily a geophysical tool.

Results and discussion

The use of geophysics could be useful for two reasons : i) it gives information which help to implement borehole and to increase the drilling success rate (i.e. to improve the proportion of boreholes which provide good quality water out of the total number of drilled holes); ii) it allows to save money at the programme scale by reducing the number of negative boreholes.

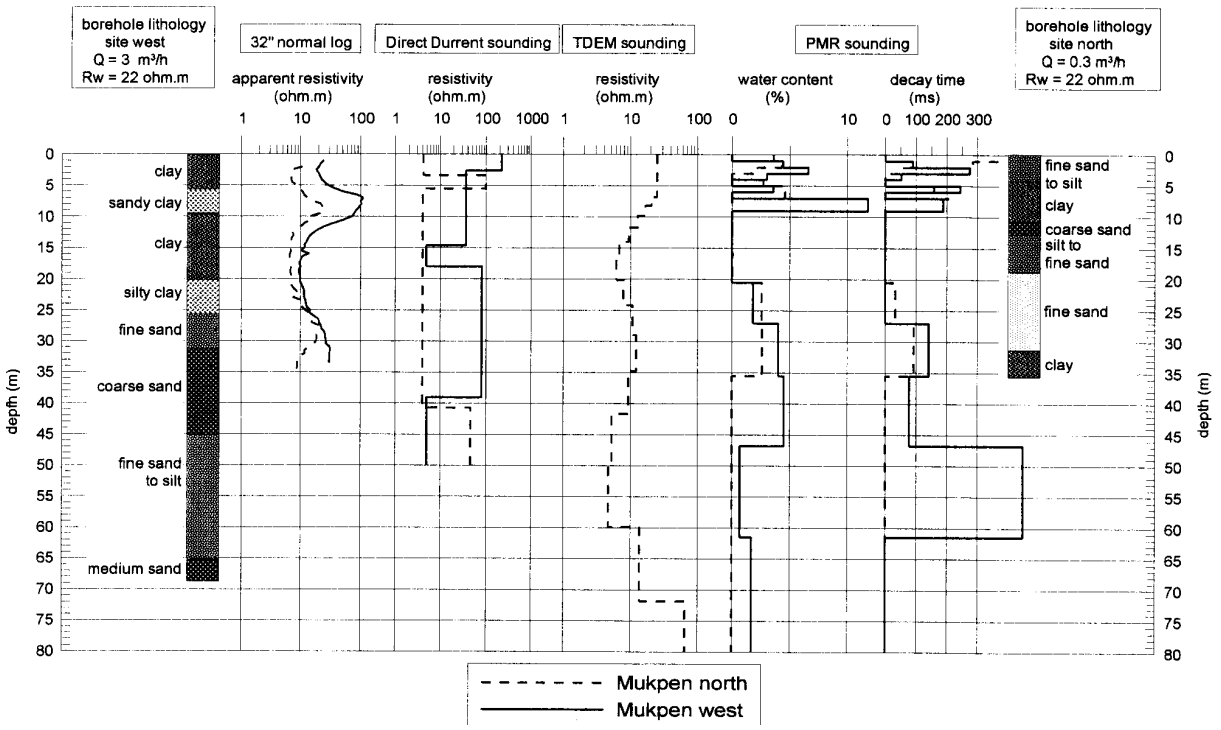


Fig. 1 : Results synthesis – Mukpen village

Geophysical contribution to drilling success rate

Within the 12 investigated sites, the use of geophysical methods increased the borehole success rate from 56 to 90%. The calculation were made for a total number of 36 boreholes which were used for this survey. This improvement of success rate is due to : i) a better choice of the drilling sites, ii) a better management of the drillers who received guideline regarding the depth they have to drill, iii) a better borehole equipment, i.e. screen fixing.

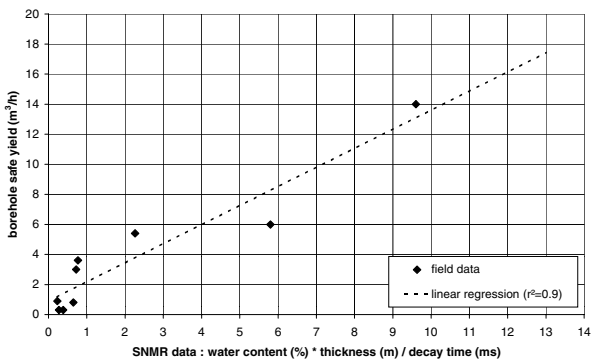


Fig. 2 : Relationship between SNMR record and borehole yield

SNMR contribution

The SNMR soundings give accurate information of water content and decay time in regard to the lithology. The figure 2 shows the relationship between the SNMR data recorded between 10 and 60 meters deep and the borehole safe yield.

Joint use of the methods

Resistivity methods and SNMR can complete each other quite efficiently : SNMR sounding can be implemented to locate groundwater, and resistivity method can be used to check the mineralisation of the water. The TDEM is the most convenient method to integrate to SNMR as it can use the same transmitter coil reducing the set up time.

Financial contribution

The financial analysis aims to measure the impact of geophysics on drilling programme cost.

The figure 3 was prepared using *Action against Hunger* cost in 1998. It shows the economical boundary for saving money using geophysics, in regards to the borehole success rates. On can remark that : i) the integrated use of SNMR, TDEM and DC imagery saves money when the borehole success rate under 40% without geophysics is doubled by the use of geophysics, ii) the joint use of TDEM and SNMR saves money when the success rate is improved by 20 to 30 % by the use of geophysics, iii) the DC methods save money as the success rate is improved by 10 or 20% with geophysics.

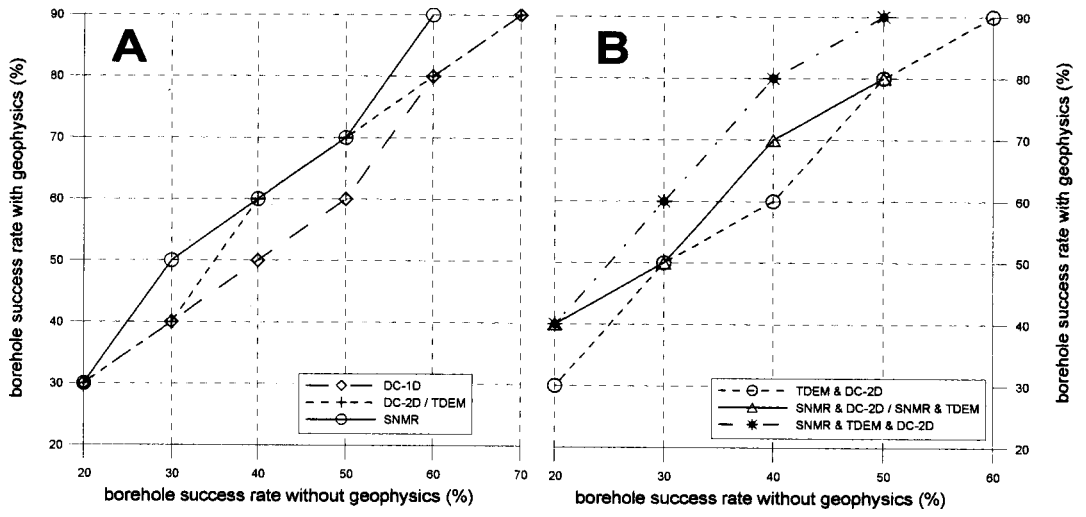


Fig. 3 : Economical boundary of geophysical methods A : use of a single method, B : joint use of methods

Conclusion : Geophysical implementation methodology

Crossing the technical and the financial analysis, it becomes possible to propose a geophysical methodology to implement the borehole in Siem Reap province. According to the areas of the province and their already known or supposed borehole success rate, we can assume that the following methodology could increase the success rate and save money at the programme scale :

- Very difficult area (borehole success rate without geophysics less than 30%) : the joint use of DC 2D, TDEM and SNMR could reduce significantly the number of dry borehole and could save money as soon as the success rate is doubled. An average of one site could be surveyed per day.
- Difficult area (borehole success rate without geophysics between 30 and 50 %) : the joint use of SNMR sounding and resistivity methods is recommended. One can chose either DC 2D to focus on local heterogeneity if necessary, or TDEM sounding which is easier to integrate with the SNMR sounding as the transmitter loop could be the same.
  This joint use of methods could save money as soon as the success rate is increased by 20 to 30%. An average of two sites could be surveyed per day.
- Common area (borehole success rate without geophysics more than 50 %) : DC methods, i.e. DC 2D and 1 D soundings could be used as a standard method. One can save money as the success rate is improved by 10 to 20%, which seems to be realistic up to success rate without geophysics of 60 or 70%. An average of 2 sites could be investigated daily.

Acknowledgements

We thank Yves Albouy, Jean Bernard and Marc Descloitres for their encouragement and help, and the whole *Action Against Hunger* staff which was involved in this study for its field work and stimulating discussion : Ludovic Arnoud, Pierre Fourcassié, Bun Haymeng, Jocelyn Lance, Philippe Pace, Laurent Romagny, Ke Sokeng. A special thanks to the Khmer "Teuk Saat" organisation which drilled part of the borehole.

References

Descloitres, M., 1998. Les sondages électromagnétiques en domaine temporel (TDEM) : application à la prospection d'aquifères sur volcans de Fogo (Cap Vert) et du Piton de la Fournaise (La Réunion). Thesis of Paris 6 University.

Goldman M., Rabinovich B., Rabinovich D., Gilad I., Schirov M., 1994.Application of integrated NMR-TDEM method in groundwater exploration in Israel. Journal of Applied Geophysics, 31, 27-52.

Griffiths D.H. and Barker R.D., 1993. Two-dimensional resistivity imaging and modelling in areas of complex geology. Journal of Applied geophysics, 29, 211-226.

Legchenjo, A.V., Beauce A., Guillen A., Valla P., Bernard J., 1997. Natural variations in the Magnetic resonance signal used in PMR groundwater prospecting from the surface. European Journal of Environmental and Engineering geophysics, 2, 173-190.

Jean-Michel Vouillamoz, Action contre la Faim, 4 rue de Niepce, 75014 Paris, France. jm.vouillamoz@wanadoo.fr