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GEOPHYSICAL INVESTIGATION OF A RURAL WATER POINT INSTALLATION PROGRAM IN NAMPULA PROVINCE, MOZAMBIQUE

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Abstract

There are many projects in Mozambique for poverty reduction. One of these projects is funded by Millennium Challenge Account (MCA) and is aimed to install a total of 600 rural water points in the province of Nampula and Cabo Delgado in crystalline rock zone. Each water point consists of a drilled well, a water pump and a communal washing basin.

Vertical Electrical Sounding (VES) was used for assessing the suitability of the drill sites but despite this many boreholes have come out with an insufficient yield and the failure rates in certain areas are as high as 50%. Continuous Vertical Electrical Sounding (CVES), also known as Electrical Resistivity Tomography (ERT), was carried out in an attempt to explain the high failure rate of boreholes. In total, nine boreholes with sufficient yield, and five boreholes with insufficient yield were investigated. In both VES and ERT, the resistivity values indicate 3 different layers. One surface layer with resistivity between 220-5000+ Ωm, a second layer with lower resistivity value, varying from 10-220 Ωm, less than 10 Ωm in some places, and a third layer with high resistivity values, 220-5000+ Ωm, increasing with Depth. Due to lateral variation, the geology in study area is best described in 3D therefore ERT appears to be a suitable method for groundwater exploration and could probably lower the failure rate.

Introduction

Like other developing countries in sub-Saharan Africa, Mozambique is facing major challenges in water infrastructure. To address this issue, was the government of Mozambique given a large five year grant by a U.S foreign aid agency (Design Report 1, 2010). Starting in September 2008, it has the overall objective of poverty reduction through economic growth. One of the key projects within the grant is to increase access to safe drinking water and sanitation so, a Rural Water Point Installation Program started. A total of 600 rural water points each consisting of a well, a water pump and a communal washing basin, was to be installed in the province of Nampula and Cabo Delgado.

The aim of this study is to address the mechanism behind the high failure rates of boreholes in the district Mogincual in Nampula Province. The research method chosen was vertical electrical sounding (VES) but this method gives point information and in a weathered and fractured zone the lateral variation is not measured. It led to high rate of negative borehole.

Three resistivity layers were identified in the subsurface. A surface and bottom layer with high resistivity values and a middle resistivity layer with low value and interpreted as ground water.

The conclusion is that ERT surveying will handle lateral variation in a better way, and the results are more comprehensive and intuitive. Although the lack of reliable reference data for the region and the complex geology makes interpretation hard.

Hydrogeological Setting

Nampula Province is located in a complex composed by granites and migmatite gneiss (Lächelt, 2004). These rocks have low porosity and hydraulic conductivity and hence low potential for groundwater abstraction (Design Report 2, 2010). Groundwater occurrence and transport is controlled by fractures, fissures and weathered layers.

In Mogincual district, there are three sub classes of aquifers, C1, C2, and C3. In C1 areas there are local aquifers in the weathered migmatite gneiss complex, where the flow will not exceed 5 m^3/h. C1 aquifers are mainly shallow, but they can reach about forty metres in depth and consist of fine to clayey sands above sedimentary rocks. C2 is similar to C1 although with less developed weathering and thickness of aquifer reaches 20 m and the possible yield will not exceed 3 m^3/h. The subclass C3 is an aquifer with limited or no groundwater in gneiss-complex and the expected productivity is under 1 m3/h (Design report 2, 2010).

Method

The ERT measurements were carried out using a version of ABEM Lund Imaging System based on Terrameter LS with a multiple gradient array, where the protocol used 7 channels for the measurement. In total, 81 measurement points were used when measuring with four cables and with a spacing of 5 m between the electrodes. In total, 14 boreholes were investigated using the roll along method.

A perpendicular cross with two 400 m survey lines were made over 9 boreholes and a single 400 m survey line was made over 1 borehole. Additionally, a longer survey line crossing 2 boreholes with a 400 m perpendicular survey line at each borehole was made at 2 sites (4 boreholes). The measured data was inverted by using the software Res2dinv.

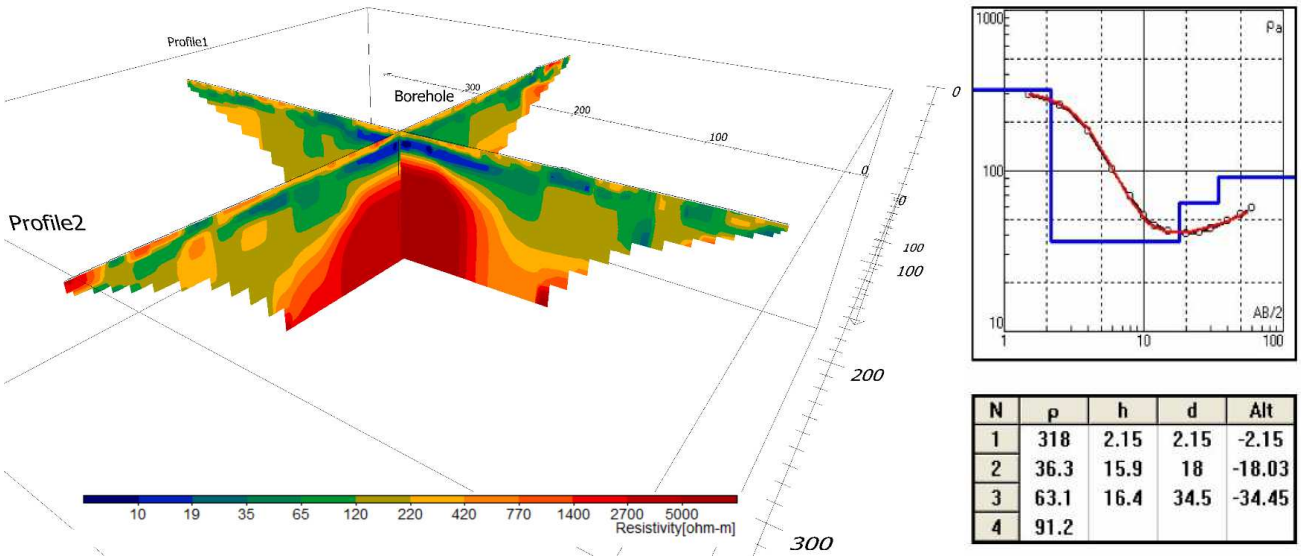
For the pre-investigation, VES was used to identify borehole points. Each borehole has reports with information of drilling rate, borehole logging, casing and pumping tests. The drilling reports were used for interpretation of the ERT results and in comparison with the VES.

Results

The ERT inversions showed minor deviations from the measured readings. The mean residual of all profiles ranged between 0.8-3.3 percent. The ERT results indicate a geological 3D environment with vertical and lateral differences along the perpendicular cross profiles. The subsurface could be divided into three layers. A surface layer with a resistivity variation between 220-5000+ Ωm that is interpreted as dry coarse sand. A lower resistivity (10-220 Ωm) second layer that is interpreted as moist clayey sand

or very weathered gneiss. A higher resistivity third layer where the resistivity increases with depth (220-5000+ Ωm) interpreted as weathered or fractured gneiss that turns less weathered with depth.

Figure 1 shows an example of two inverted cross section in a fence diagram illustrated in 3D. The site presented is Mocone which had an unsuccessful borehole. The borehole was drilled in the middle of both profiles straight down into a higher resistivity unit. This situation with a borehole straight above a high resistive unit occurs on several sites investigated.



N	ρ	h	d	Alt
1	318	2.15	2.15	-2.15
2	36.3	15.9	18	-18.03
3	63.1	16.4	34.5	-34.45
4	91.2			

Figure 1: This image is an example of one site investigated. It is showing both resistivity profiles and VES graph at the dry borehole at Mocone. The borehole is the black line located in the cross point. The placement of 'Profile1' and 'Profile2' indicated the end of the profiles.

Discussion and Conclusion

The results acquired during the field survey reflect the resistivity values of the subsurface and not the actual geological environment. The interpretation of the resistivity values were based on the work of Acworth (1987) and Palacky (1987), showing which resistivity value correspond to which earth material and which part of the weather process. As many common earth materials span over large resistivity value spectrums which overlap at several points, there are uncertainties on how well the interpretation of the results reflects reality. Adding variables like degree of weathering, fractures, water content, etc., the overlaps increase even more. Drilling reports were used in determining which material resistivity value could correspond to.

Comparison of the two methods are made harder by the fact that no information of the layout directions are found for the VES, and the field surveys were done during different seasons. The first layer is generally the same on both VES and ERT, however for the second and third layer there are notable difference in the interpreted thickness.

The subsurface of the district Mogincual is best described as a highly 3D environment with vertical and lateral variations. Therefore, the interpretation with VES is not accurate. ERT surveying handles lateral variation better, and the results are more comprehensive and intuitive. The lack of reliable reference data for the region and the complex geology makes interpretation more difficult.

Several of the dry boreholes are placed above or just at the edge of high resistive units. It is likely that if an ERT survey had been made instead of VES such a placement could have been avoided due to more comprehensive information on the 3D character of the geology. There are some positive boreholes placed on these units. The resistivity values suggest fractured zone that is not resolved by the ERT. A better yield could have been reached if the drilling point selection had been based on ERT.

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