THE APPLICATION OF GEO-ELECTRICAL RESISTIVITY DATA TO GROUNDWATER MODELLING IN HARDROCK TERRAINE – AN INTEGRATED APPROACH

MAURICE ODONDI K'OROWE

A Thesis submitted in fulfilment for the Degree of Doctor of Philosophy in Physics in the Jomo Kenyatta University of Agriculture and Technology

2009

ABSTRACT

This thesis presents the application of geo-electrical data in the field of hydrogeology. In this regard, two distinct applications of geo-electrical techniques have been carried out. One is to determine a theoretical relationship between geo-electrical data and hydraulic parameters by modifying the theories developed in laboratories by Bernabe and Revil (1995) and applying the bond shrinkage process of pore network structures described by Wong *et al.*, (1984). The petrophysical relationship thus established, have been tested with data from a typically hard rock terrain found in the Jangaon sub-watershed, Andhra pradesh, India. Secondly a site-specific relationship between geo-electrical data and an aquifer process namely; natural recharge has been developed and referred to as a natural recharge model for the Jangaon sub-watershed. In order to evaluate the coherence of the geo-electrically derived hydraulic parameters and process, these data have been integrated into a groundwater flow simulation model. To modify the Bernabe and Revil (1995) model, the theories explaining the flow characteristics of a material's pore structure have been modified into a field scale relationship between transmissivity and apparent formation factor of the aquifer materials and a relationship expressed as; $\ln T = \ln \frac{B a_c \delta g}{A\mu} - \frac{m_k}{m_\phi} F_a$. This theoretical relationship was applied to data from Jangaon sub-watershed. The transmissivity values were obtained from pumping tests done on the boreholes of the area. Formation factors were obtained form geo-electrical data from the borehole sites. The relationship ln $T=9.9-2.5\ln F_a$ which shows that the theoretical relationship explains the relationship between geo-electrical and hydrogeological data For a site-specific geo-electric recharge model to be developed, two methods were integrated. The first method involves using surface electrical resistivity sounding data to

evaluate the resistivity of topsoil layers within the top 3 meters at each site. The second procedure is to determine natural recharge by using the Tritium tagging technique, where the flow of tritiated water within a soil profile is monitored and natural recharge at each injection site is estimated. Consequently, a correlation analysis between the two data sets was carried out with the result that natural recharge correlate very well with 'Composite layer resistivity' to produce a geo-electrical recharge model of the form $R=3.1\rho_t-73.71$.The geo-electrically derived hydrogeological parameters and processes were used as input parameters into a groundwater flow simulation model. A transient groundwater flow simulation for a time period of one hydrologic cycle was carried out. The simulation period was divided into two stress periods, representing the rainy season and the dry season. At the end of the simulation period, simulated groundwater heads were compared with observed hydraulic heads. The model errors from residual hydraulic heads are less than 10% at all the observation boreholes. Scatter plots of simulated heads versus observed heads at the end of simulation period have a weighted variance of 8.89, indicative of goodness fit