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A comparative study of the groundwater potential in hard rock areas of Rajapuram and Balal, Kasaragod, Kerala

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ABSTRACT
Groundwater exploration in hard rock terrain due to the restricted movement/occurrence of water, remains a challenging task. Resistivity of rock formation gives an indication of groundwater occurrence with an established inverse relationship. Resistivity surveys carried out in Rajapuram and Balal areas of Kasaragod district show contrasting results whereas the former is totally devoid of groundwater reserves while the latter has good potential. In Rajapuram, where the surface is covered with thick laterite, the resistivity values vary from 1795 ohm-m to 621 ohm-m from surface to depth of 100m.The interpretation of resistivity data using inverse slope method shows that there are three layers/formations below the surface. They are (1) Laterite cover at the top with a resistivity of 1000 ohm-m (0-30m) followed by (2) Less fractured rock with a resistivity of 400 ohm-m (30-60m) and (3) Massive rock with resistivity of 746 ohm-m (60-80m). Here, all the formations are dry and this site cannot be reccommended for bore well. In Balal area, where surface is covered with soil, the resistivity value ranges between 133 ohm-m to 253 ohm-m. The results of resistivity data shows three layers/formations. They are : (1) soil cover with resistivity of 118 ohm-m (0-15m) at top followed by (2) Less fractured rock with resistivity of 400 ohm-m (15-35m) and (3) Highly fractured rock with resistivity of 143 ohm-m which contains water at a depth of 35m to 50m. The site is reccommended for bore well with total depth of 50m and casing of 15m.Exploratory drilling confirms a discharge of 3 litres per second.

INTRODUCTION

Water constitutes one of the sensitive environmental parameters of the hydrological processes. Water resources development in hard rock terrain in many parts of Kerala State poses a key issue in the management strategy. (Mohamed Aslam et. al, 2010). Studies relating to groundwater exploration have evoked much interest and clearly indicates its relevance and importance in day to day life. There are many techniques/methods to explore the groundwater . Electrical resistivity method is most widely accepted and used in ground water exploration. Electric currents are being passed into the ground through electrodes and resistivity of rock formations are measured. Groundwater, due to various dissolved salts, is very conductive and enables electric current to flow into it. Electrical resistivity methods assumed considerable importance in the field of groundwater exploration because of its low cost, easy operation and its capacity to identify between fresh and saline water zones and are therefore widely employed throughout the world. (Pal & Majumdar 2001; Majumdar & Pal 2005; Narayanpethkar, Vasanthi & Mallick 2006).The resistivity methods can be employed successfully to estimate the thickness and electrical nature of the formation which provides useful information regarding the groundwater potentialities (Griffith & King 1965; Parasins 1966 and Balakrishna1980). As a part of ground survey, geoelectric resistivity studies have wide applications in hydrogeological and related field investigations (Ilkisik et al., 1997; Monteiro Santos, Andrade & Mendes 1997; Raju & Reddy 1998; Yadav & Abolfazli 1998; Mohammed-Aslam & Balasubrahmanyam 2002). The resistivities of different formations/layers can be identified by plotting the data by inverse slope method (Ballukraya, Shakthivadivel & Baraton 1981).

STUDY AREA

The study area forms part of Kasaragod District of Kerala State (Fig.1) and is bounded by latitudes 12° 25' 18" & 12° 30' 25" N and longitudes 75° 14' 43" & 75° 20' 30" E and falls in Survey of India

Toposheet no: 48 P/7. The area is about 50 km from Kasaragod and 25km from Kanhangad town. The area forms part of the Western ghat and consists of hills, valleys and lateritic plateaus covered with thick vegetation. The area is subjected to a tropical climate and the annual rainfall is around 3000mm. Dry weather starts from February and ends in May. The SW monsoon starts from June and continues till September, and NE monsoon is witnessed in October and November.

GEOLOGY OF THE AREA

The northern part of Kerala comprises the southwestern part of Dharwar craton together with north western portion of South Indian high grade terrain and is characterized by rare association of rocks belonging to granite greenstone as well as granulite terrains (Drury 1964). The rock types of the area are charnockites, gneisses, laterites, amphibolites, quartzites, schist, anorthosite, granite, gabbro, diorite, syenite and granophyres. Along the coastal tract, tertiary sedimentary formations also occur as minor units. Charnockite and gneisses constitute the predominant rocks of the area and these are cut across by schist belts. Laterites occur as cappings over charnockites and gneisses. In many places, Charnockites are highy jointed and fractured and acts as a good aquifer at a depth of 50 to 100 m with yield of 1 liter per second to 4 liter per second of water.

MATERIALS AND METHODS

The methodology used is electrical resistivity survey by vertical electrical sounding (VES) using Schlumberger method. The resistivity of rock

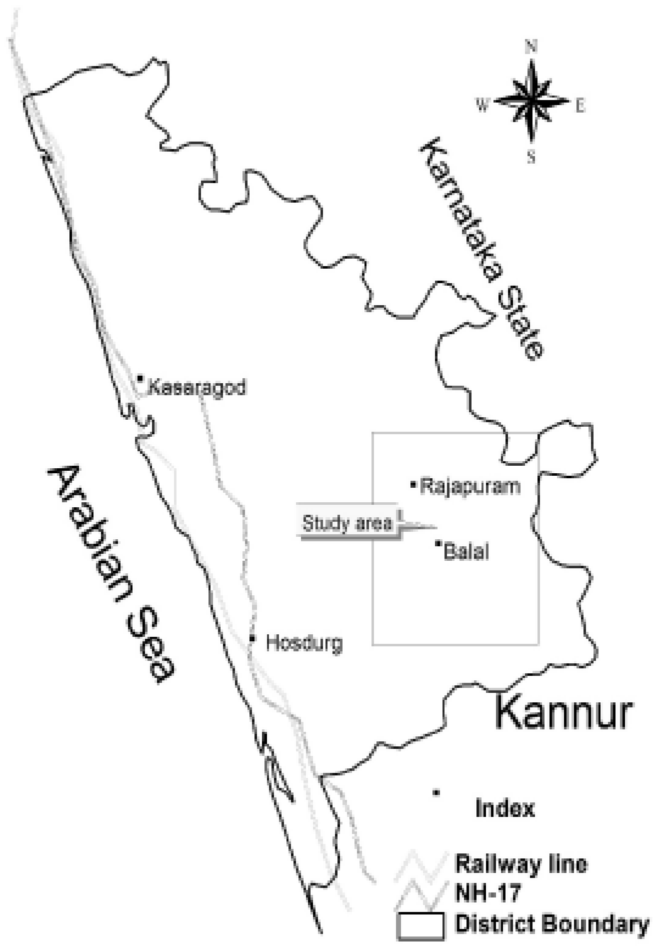

Figure 1. Location Map.

formations below the earth's surface can be determined by passing an electric current between two fixed poles/electrodes on the surface. As the electrode spacing increases, the penetration of current also increases .The penetration of current below the surface is proportional to half of the distance between two current electrodes. The resistivity value decreases with fractures, joints, water content etc. of the formation. The instrument used is Resistivity meter. In resistivity meter, DC voltage input is used (180 v). The resistance reading can be noted from the instrument and resistivity can be obtained by multiplying it with geometrical factor (K) using Schlumberger formula, $\rho a = K \Delta V$ where, ρa = apparent

I

resistivity, ΔV= potential difference and I= current. Resistance (R) = Potential difference/Current ($\Delta V/I$) and apparent resistivity (ρa) = KR. The rseisitvity data are plotted in a graph paper with electrode spacing (AB/2) in X axis and electrode spacing/resistivity (AB/2/KR) in Y axis (Inverse slope method). The points thus obtained are connected by straight lines with maximum number of points in a line. Each line represents a layer and resistivity of that layer can be determined by the formula, R= Difference between electrode spacing between the end points of the line in X axis/(difference between electrode spacing/resistivity at the end points in Y axis).The resistivity can be compared with resistivity values of geologic

Table 1. Resistivity of Geologic Formations.

Formation	**Resistivity (Ohm- m)**
Fractured rock with saline water	0.1 to 0.2
Clay, silt and sand	<15
Fine and med.sand	15-30
Medium-coarse sand	30-60
Highly fractured rock with water	60-100
Fractured rock with water	100-200
Less fractured rock	200-300
Massive rock	>300
Laterites	>2000

Table 2. Comparison between resistivity and yield.

Resistivity (Ω m)	**Yield (liter per second)**
<100	VERY GOOD (3 to 4 liter per second)
100-150	GOOD (2 to 3 liter per second)
150-200	FAIR (1 to 2 liter per second)
200-300	POOR (< 1 liter per second)
>300	NIL

formations (Table 1) and nature and yield (Table 2) of the formation can also be determined.

RESULTS AND DISCUSSION

Resistivity surveys carried out in Balal & Rajapuram areas for exploration of groundwater shows that Rajpuram is a dry area whereas Balal has high water potential. The details are discussed below as case studies.

Case Study-I: Rajapuram

Lithologically Rajapuram area consists of charnockites and gneisses but in many places they are concealed by laterites on the surface. Topographically, the area is plain.Lateritisation is predominant in this area due to tropical climatic conditions. Laterites due to porous in nature, are good conductor of groundwater. Laterites are followed by lithomarge and clay in the weathering profile. But rarely laterites ends abruptly to hard rock without clay. Due to high porosity, clays hold good amount of groundwater and are responsible for perched water table in lateritic terrains. Hence they are ideal site for ground water for open wells. But for borewells, this relation is not applicable because it is the hard rock fracture, that determines the occurrence of groundwater. In Rajapuram the hard rock is massive with less fracture upto 55m and without fracture below 55m that is evidenced by constant resistivity reading. Hence the area is dry for groundwater prospects because of compactness/massive nature of bed rock.

In Rajapuram, the apparent resistivity (?a) values decreases from 1795 ohm-m to 621.5 ohm-m from surface to a depth of 100m (Table 3).The high resistivity value at the surface upto a depth of 30m clearly indicates a highly resistant thick laterite cover followed by clay. From 30m to 55m, the ?a value slowly decreases from 1177 ohm-m to 625 ohm-m suggestive of less fractured bed rock. From 55m to 100m, the ?a value is not varying much indicative of massive rock without any fracture.

A hard rock without fracture or pores and dry sand without water are very resistive with ρ_a of 1000 ohm-m- and a porous or a fractured rock bearing water have ?a values of 10ohm-m to 250 ohm-m (Bernard 2003). The weathered and fractured rocks present a good resistivity contrast with compact basement crystalline, and the structures, such as joint, fault, dyke, etc., in a geological terrain impose marked anomalies on the resistivity profiles (Majumdar, Majumdar & Mukherjee 2000).

Table 3. Resistivity data at Rajapuram.

AB/2(Current electrode spacing)	MN/2 (Potential electrode spacing)	K (Geometric factor)	R (Resistance)	KR (Apparent ρ_a)	(AB/2)/KR
10	2	75.43	23.8	1795	0.005
15	2	173.6	9.5	1649	0.009
20	2	311.1	4.48	1393	0.014
25	5	487.9	2.49	1214	0.020
30	5	275	4.28	1177	0.025
35	5	377.1	2.68	988	0.035
40	5	495	1.62	801	0.049
45	5	628	1.15	722	0.062
50	10	777.8	0.9	700	0.071
55	10	459.65	1.36	625.1	0.088
60	10	550	1.12	616	0.097
65	10	648.2	0.965	625.5	0.103
70	10	754.2	0.839	632.8	0.11
75	15	868.2	0.735	638.1	0.117
80	15	646.9	1.03	666.3	0.12
85	15	733.3	0.905	663.6	0.128
90	15	825	0.79	651.7	0.138
95	15	921.9	0.152	624.5	0.152
100	20	1024	0.6	621.5	0.16

The resistivity data plotted using inverse slope method shows that there are 3 layers below the surface.(Fig.2). They are (1) Thick laterite cover with apparent resistivity (?a) of 1000 ohm-m up to a depth of 30m. (2) Less fractured bed rock with ?a of 400 ohm-m from 30 m to a depth of 60m and (3) Massive bed rock with ?a of 746 ohm-m from 60 m to a depth of 100m.Here all the formations are devoid of water and hence the area is not recommended for borewell drilling.

Case Study-II: Balal

Lithologically, Balal area consists of charnockites and gneisses. Here lateritisation is less compared to Rajapuram area because here the topography is undulatory with hillocks and valleys and forms part of Western Ghats. The weathering profile consists of only soils (upto 12m).The overburden is less compared to Rajapuram area due to less weathering in the area. The bed rock here is fractured throughout which is evidenced by low resistivity reading and contains groundwater below 35m.Balal area is a high water potential zone due to the highly fractured bed rocks that holds groundwater in sufficient amounts.

In Balal, the apparent resistivity (?a) value ranges from 265.78 ohm-m to 133.25 ohm-m from surface to a depth of 100m (Table 4).The resistivity value increases from surface to a depth of 50m from 133.33 ohm-m to 265 ohm-m and then decreases to 210.7 ohm-m at 100m.The slight increase of resistivity value at the surface shows that the formations are made of soil, clay, lithomarge etc. in the descending order. The decrease in ρa value from 265 ohm-m to 210 ohm-m further below indicates that the formation is made of highly fractured rock.

Plotting of resistivity data shows that there are three layers below the surface (Fig3).They are (1) Soil cover with ?a of 118 ohm-m upto a depth of 15m (2) Less fractured bed rock with ρa of 400 ohm-m from 15 m to a depth of 35m and (3) Highly fractured rock with ?a of 143 ohm-m from 35m to a depth of 50m.

Here the formation with a apparent resistivity of 143 ohm-m indicates presence of groundwater and the site is recommended for borewell with total depth of 50m and a casing of 15m. Drilling results confirms a discharge of 3 litres per second. Here, the resistivity of groundwater containing formation is very high. Possibility is that the water quality is very good with less dissolved salts that is responsible for conductivity.

Table 4. Resistivity data at Balal.

AB/2(Current electrode spacing)	MN/2 (Potential electrode spacing)	K (Geometric factor)	R (Resistance)	KR (Apparent Resistivity, ρ_a)	(AB/2)/KR
10	2	75.43	1.76	133.25	0.0754
15	2	173.6	0.95	164.82	0.910
20	2	311.1	0.60	187.37	0.1067
25	5	487.9	1.16	219.13	0.1140
30	5	275	0.84	233.06	0.1287
35	5	377.1	0.64	241.39	0.1450
40	5	495	0.445	220.52	0.1813
45	5	628	0.342	215.28	0.2090
50	10	777.8	0.705	265.78	0.1881
55	10	459.65	0.552	253.98	0.2165
60	10	550	0.438	240.9	0.249
65	10	648.2	0.366	237.24	0.2739
70	10	754.2	0.304	229.65	0.304
75	15	868.2	0.276	239.83	0.312
80	15	646.9	0.232	230.05	0.347
85	15	733.3	0.207	232.10	0.366
90	15	825	0.187	235.07	0.382
95	15	921.9	0.152	212.98	0.446
100	20	1024	0.135	210.7	0.474

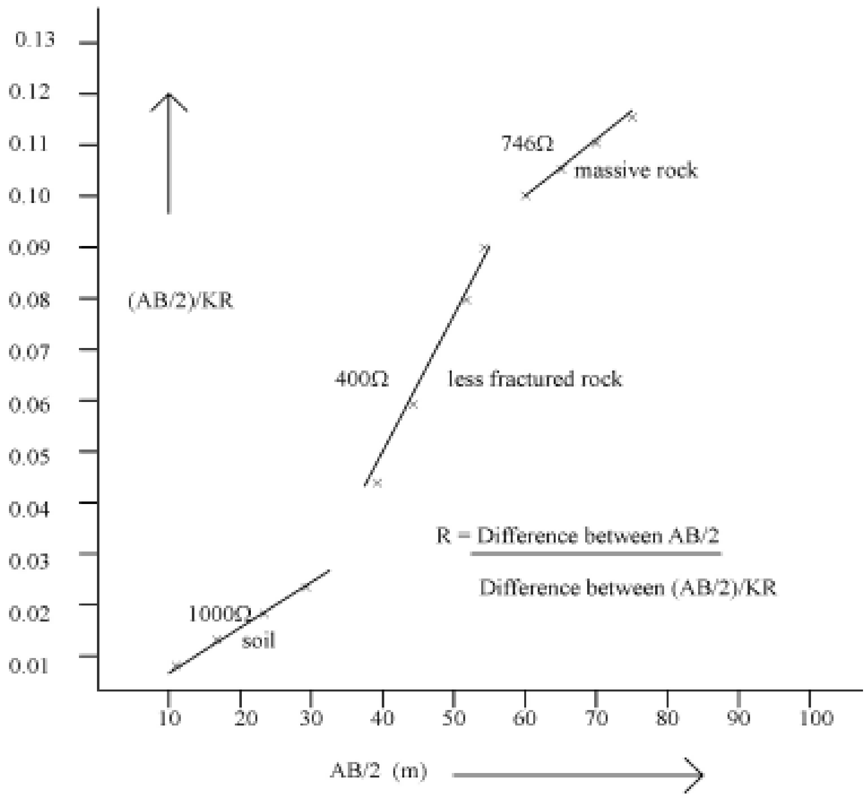

Figure 2. Resistivity plotting at Rajapuram.

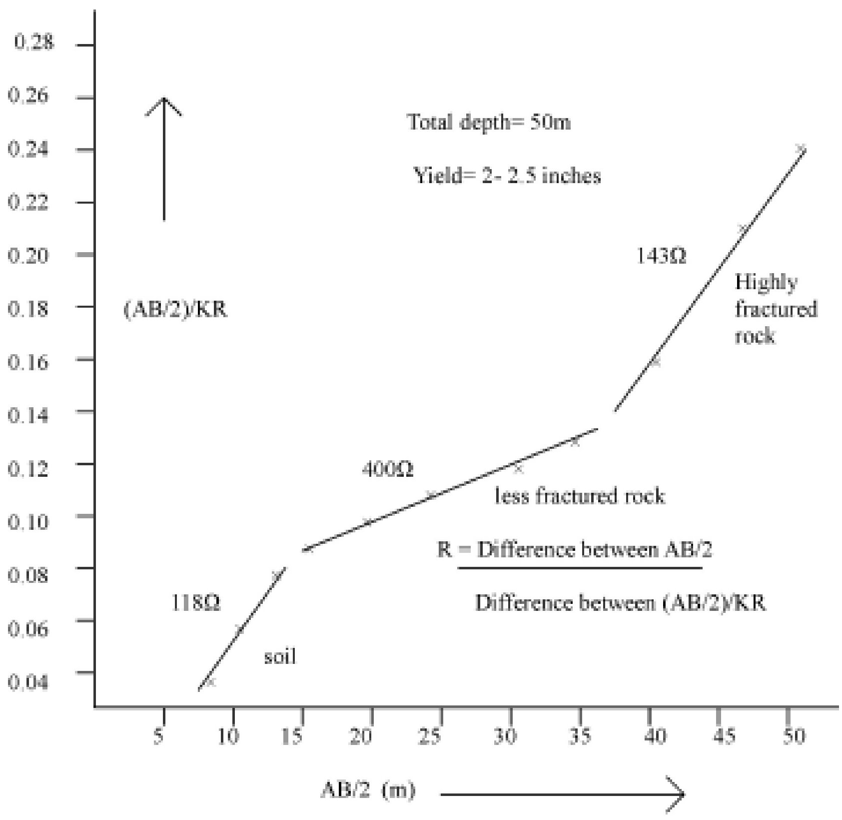

Figure 3. Resistivity plotting at BalaL.

CONCLUSIONS

The electrical resistivity surveys have proven successful in demarcating water resources of potential zones and barren zones in the study area. The resistivity values in Balal area varies from 133 ohm-m to 265 ohm-m and is having a water bearing formation with yield of 3 liter per second. Groundwater occur here in fractures, joints, fissures and weathered zones of massive crystalline rocks. In laterite terrain of Rajapuram area, the resistivity values ranging from 621.5 ohm-m to 1795 ohm-m and is not having water bearing formation because of massive bedrock without any fracture zone. A reliable procedure for the assessment of dynamic water resources potential is necessary to delineate the water potential zones in the area.

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