Success and Failed Stories in Identification of Groundwater Potential Zones in Hard Rock Terrain

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***Abstract*—identifying a good site for groundwater exploration in hard rock terrain is a challenging task. In hard rocks, groundwater occurs in secondary porosity developed due to weathering, fracturing, faulting, etc., which is highly variable within short distance and contributing to near-surface inhomogeneity, , sometimes within few meters and even within the same geological formations. In the Indian context, the situation becomes more precarious due to negligible primary porosity and low permeability of host rocks restricting groundwater storage as well as movement. Further, low rainfall, high evaporation and run-off limit recharge to the groundwater systems. Out of many geophysical methods like Seismic methods, Electromagnetic methods, Magnetic method, Gravity method etc., resistivity method is familiar to identify the ground water potential zones in view of resistivity variations of rocks with presence or absence of water. The 2D Electrical Resistivity Imaging (ERI) survey was conducted in the granitic and basaltic terrain for better understanding of the aquifer layers/groundwater potential zones and the structural differences which are reasons for success and failure of wells situated at few meters distance. The ERI profiles are taken at shankarpally, Shabad, Pargi, kammeta, pudur by using the ABEM tetrameter SAS 1000 with three cables, each cable containing 16 electrodes with an interval of 5m. The locations of these Imaging survey are covering the two formations namely granites and basalts. From these profiles it is observed that in both the terrains low yield of wells is either due to highly weathered material of the aquifer or due to basement characteristics. Similarly high yields are either due to contact zone or fractured zone**

***Index Terms*— Groundwater, hard rock, resistivity imaging survey.**

I. INTRODUCTION

During the last few decades in India creation of surface reservoirs and the associated irrigation canal networks has formed the backbone of our water management strategy. Where the canal network could not reach, ground water has been heavily exploited for irrigation. But 75% of the total area of the Indian subcontinent is occupied with hard rocks (crystalline rocks) such as granites, gneisses, basalt and indurated pre-cambrian sediments. The area covered under hard rock region includes Karnataka, parts of Andhra Pradesh, Telanagana, Tamilnadu, Madhya Pradesh and Maharashtra (Krishnan,1975). The hard rock areas of the country face special problems due to void space being localized to regions of fractures and fissures resulting in limited groundwater potential.

Major portion of the Telanagna state is hard rock and semiarid. Due to insufficient surface water, groundwater has been essential element in meeting domestic, agricultural and industrial needs. The study area rangareddy district of Telangana state has no surface water resources for agriculture. They are mainly depending on well irrigation. This area comprising rocks of granites, gensisses, basalts and consolidated sedimentary rocks which is traversed by numerous dolerite dykes and veins of quartz, feldspar, pegmatitie and epidote. Lineaments control weathering and fracturing (venkatreddy and Raju,1997). Two water bearing zones namely weathered zone and water bearing joints and fractures can be generally identified in this hard rock area (narasimhan,1990; Briz-Kishore,1993; Ranganath,1982). Fractures may transmit large quantities of water; in other areas they may be nearly impervious. Because of the complex distribution fractures in almost every type of rock, no single method can unambiguously map fractures and their capacity for fluid movement. The need there is to develop more efficient and reliable methods for locating zones of fractures and fissures and estimating their water yielding potential both under natural as well as stressed condition. In this paper the 2D Electrical Resistivity Imaging (ERI) survey was conducted in the granitic and basaltic terrain for better understanding of the aquifer layers/groundwater potential zones and the structural differences which are reasons for success and failure of wells situated at few meters distance. The ERI profiles are taken at Shankarpally, Shabad, Pargi, Kammeta, Pudur by using the ABEM terrameter SAS 1000 with three cables, each cable containing 16 electrodes with an interval of 5m. The locations of these Imaging survey are covering the two formations namely granites and basalts.

II. THEORY

The electrical properties of the subsurface vary with the ground material, the presence and saturation level of fluids, and the presence of buried objects. Electrical techniques seek to describe the distribution of these properties as a function of depth and horizontal distance. The most commonly used electrical technique is Electrical Resistivity Imaging (or Electrical Resistivity Tomography, ERT). Measurements of ground resistance are made by introducing an electric current into the subsurface via two metal stakes (current electrodes) planted into the ground. The current passing through the ground sets up a distribution of electrical potential in the subsurface. The difference in electrical potential between two additional electrodes (potential electrodes) is measured as a voltage. Using Ohm's law, this voltage can be converted into a resistance reading for the ground between the two potential electrodes. To build a cross-sectional image of ground resistance, a string of connected electrodes are deployed along a straight line with an inter-electrode spacing. Once a measurement of ground resistance has been determined for one set of four electrodes, the next set of four electrodes is automatically selected and a second measurement of resistance is made. This process is repeated until the end of the line is reached. The line is then re-surveyed with an inter-electrode spacing of 2 , 3 , 4 , etc. Each increase in inter-electrode spacing increases the effective depth of the survey. The measured resistance values are converted to value of apparent resistivity, (in ohm-metres) which can then be used to model the true subsurface resistivity distribution

III. RESULT AND DISCUSSION

Investigations in Granitic Terrain

In this kind of terrain usually VES data could recognise the weathered and fractured country rocks and failed to recognise deeper and very thin fractures situated at depths more than 40 m and sharp contrast between two layers. (Venkateswara Rao et al., 2009). The 2D Resistivity imaging could able to throw some light in finding the structural differences which could explain the success and failure of well in short distances.

Shankarpally success well

Fig.1 shows the distribution of electrical resistivity along the profile. The figure shows low resistivity zone of 7.33 to 19.4 ohm-m. distributed at the top of the image is interpreted as moist clayey soil. Very low resistivity region of 1.5 to 6.5 ohm-m is interpreted as clay is at the right side of the image And very high resistivity zones of 953 to 2523 ohm-m are interpreted as bedrock can be observed at left bottom of the image and top right in the image at 40-41electrodes. Below the success well, there is a layered earth with increasing resistivity from a low resistivity to high resistivity. High yield obtained at a depth of 30 m. Near this depth the resistivity values are about 360 ohm-m. Below this well, hard rock material touched from 35 m depth onwards.

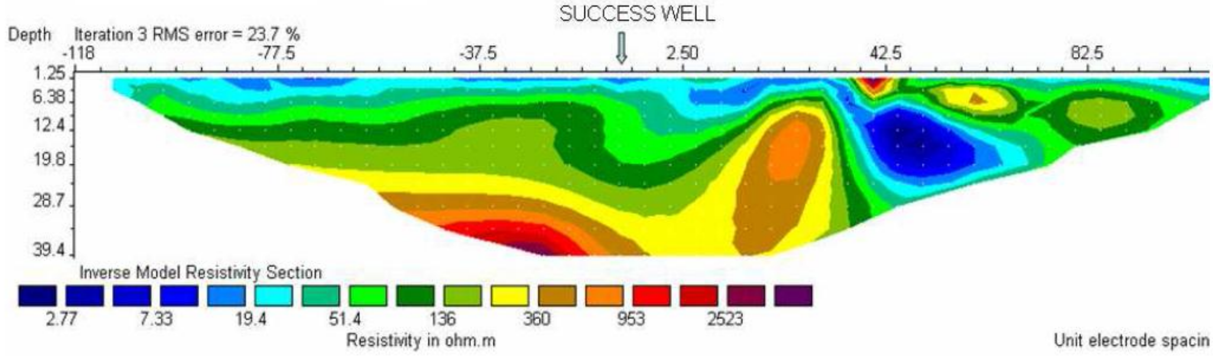

Fig.1 Distribution of Electrical Resistivity Values along Success Well at Shankarpally

Shankarpally failed well

Fig. 2 shows the distribution of electrical resistivity values along the profile. The figure shows low resistivity region of 9.16 to 23.4 ohm-m in the central part of the figure and distributed to the left bottom part. A very high resistivity region of 400 ohm-m to 2562 ohm-m is interpreted as the hard rock at middle part and bottom of the image where failed well has been penetrated.The resistivity values below the failed well are very low in the top of the image upto the depth of 6.38 m and high resistivity values obtained from 12.4 m till the entire depth of the well. Due to high resistivity zone which is interpreted as basement, this well is failed and due to lack of any fractured environment this well was failed.

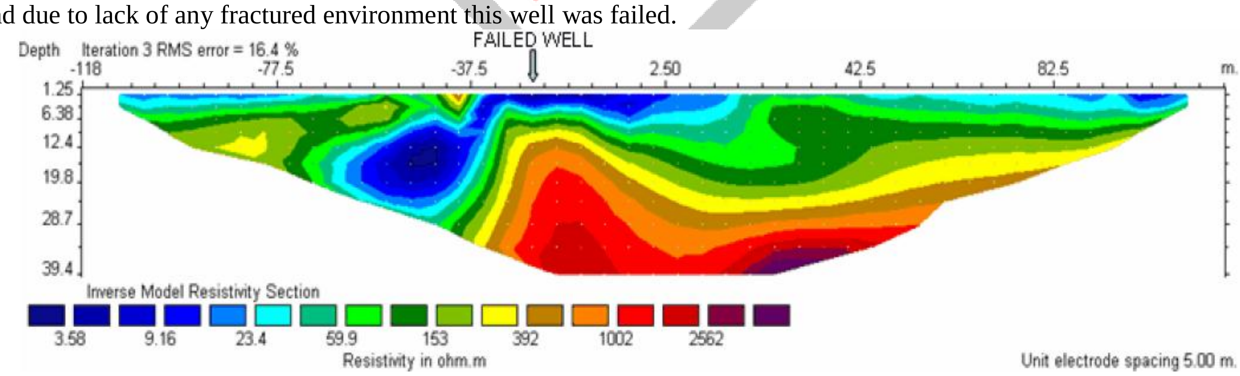

Fig.2 Distribution of Electrical Resistivity Values along Failed Well at Shankarpally

Shabad failed and success wells

This profile has chosen such that failed well and success wells, come under same profile. The profile taken in the field is 'roll-along'. The horizontal range of investigation is naturally increases by doing 'roll-along' process in the field. Therefore, a 315 m long profile is carried out. Failed well is located at 21st electrode and success well is located between 34-35 electrodes. Fig. 3 shows the distribution of electrical resistivity along the survey line. Field observation has indicated that the high resistive hard rock zone of 404 to 896 ohm-m has appeared at the 17th electrode, and between 32 and 33 electrodes in the image. And this hard zone also appeared at the 48-49 electrodes in the right side of the image. The low resistivity zone is highly weathered zone of 4.45

to 9.44 ohm-m can be observed at right side and left side in the image. The layered earth below the failed well has very less resistivity values varying from 4.45 to 89.9 ohm-m and encountered complete highly weathered material lead to the failure of the well. Below the success well, the layered earth has resistivity values of 89.9 to 190 ohm-m and gradually increasing from 24 m depth. This well fell in contact zone and it has good fractured zone from 28.7 m depth. This well has good yield of water at this depth.

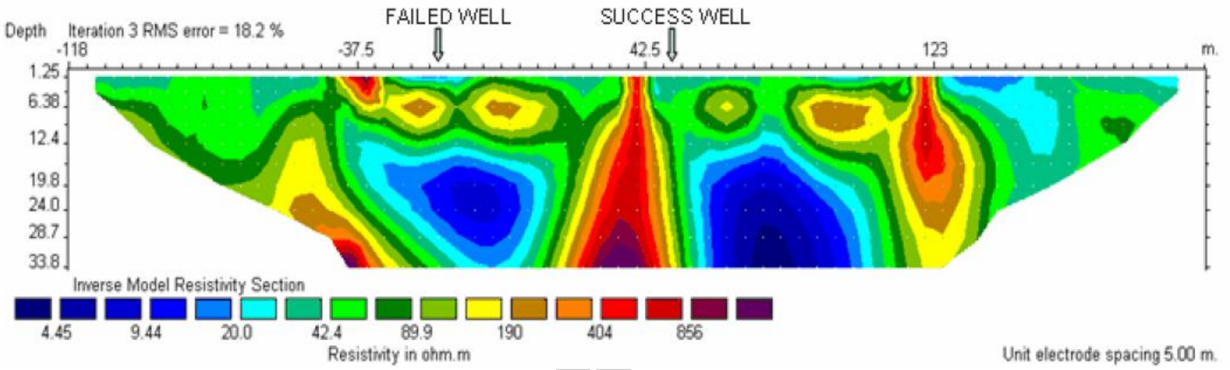

Fig.3 Distribution of Electrical Resistivity Values along Success and Faied Well at Shabad

Investigations in Basaltic Terrain

The Basaltic terrain in the study area usually covered with more weathered, fractured and jointed basaltic terrain. The hard basalt is appeared as sheet rock on the surface. At the Vikarabad, Pargi some times the weathering is intense consequently laterite is to be formed on the surface itself. Well yields also found to be varied greatly with in few meters of distance at both these places. It is very hard to interpret all these hydrogeologic observations in the interpreted 1D VES data. Therefore at these sites 2D Resistivity technique is applied to track the fracture system behavior at Pargi, Kammeta and Pudur which are formed with basaltic rocks.

Pargi success well

Fig. 4 shows the electrical resistivity distribution along the profile. A low resistivity clay zone of 3.95 to 8.20 ohm-m can be observed on the top of the image and left side of the profile. A layered earth below the success well has resistivity values of 153 to 662 ohm-m. The high yield obtained at this location is at 100 ft. Near this depth at 18-25 m, the resistivity values are 318-370 ohm-m. This well fell in good fractured zone of an aquifer having the resistivity values of 318-370 ohmm and has thickness of about 10 m.

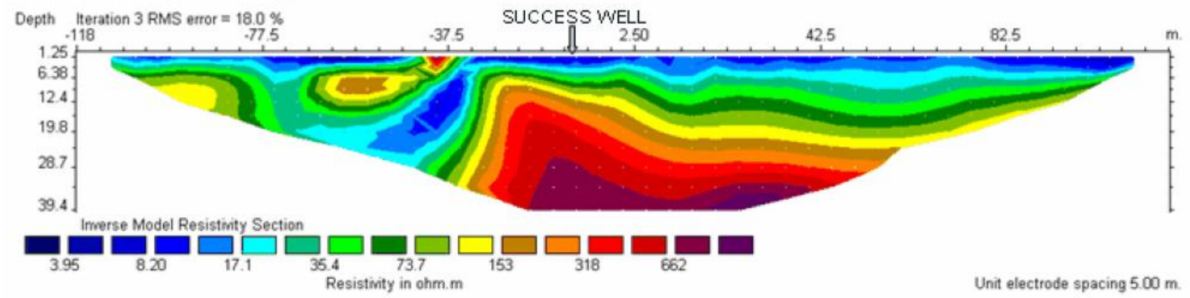

Fig.4 Distribution of Electrical Resistivity Values along Success Well at pargi

Pargi failed well

Fig. 5 shows the distribution of electrical resistivity along the profile. Low resistivity clay zone of 4.58 ohm-m can be observed in the top of the image line. The figure shows a very low resistivity zone of 0.182 to 0.913 ohm-m in the right hand side of the image. And this figure also exhibits a very high resistivity zone of 580-14614 ohm-m in the left bottom and right bottom of the image which is interpreted as bedrock. The failed well is located between 19-20 electrodes. Under this failed well, the resistivity values are unevenly varying from very low 4.58 to very high 2911 ohm-m resistivity values. Hence the well has encountered a very high weathered zone followed by basement. At this location, there is no obvious sign of a fractured zone. So, this well is failed.

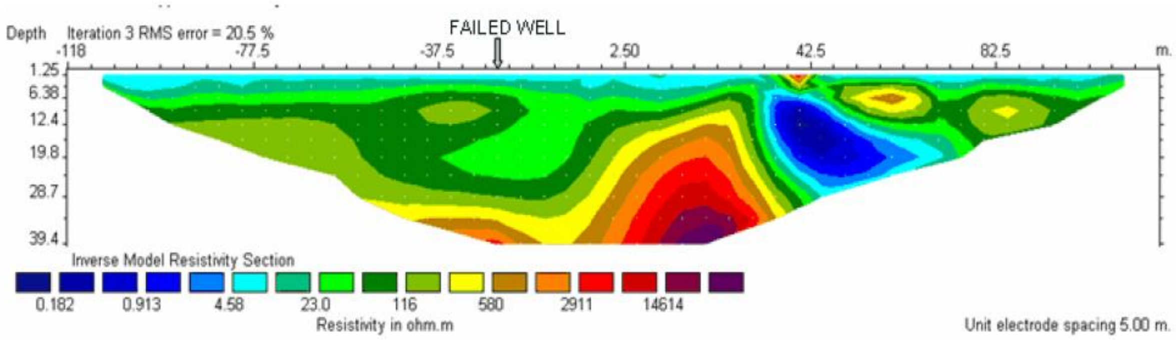

Fig.5 Distribution of Electrical Resistivity Values along Failed Well at Pargi

Kametta success well

Fig. 6 shows the distribution of electrical resistivity values along the profile. Figure shows a very low resistivity regions of 0.889 to 4.74 ohm-m distributed along the profile line. Figure also shows the zone which has resistivity values of 58.5 to 312 ohm-m is at the bottom left of the image and some places in the top left of the image. At deeper depths, the resistivity values are of the order of 312 ohm-m. High yield is obtained at deeper depths only. But these yields are good enough for hand pump supplies and not significantly enough for bore well supplies.

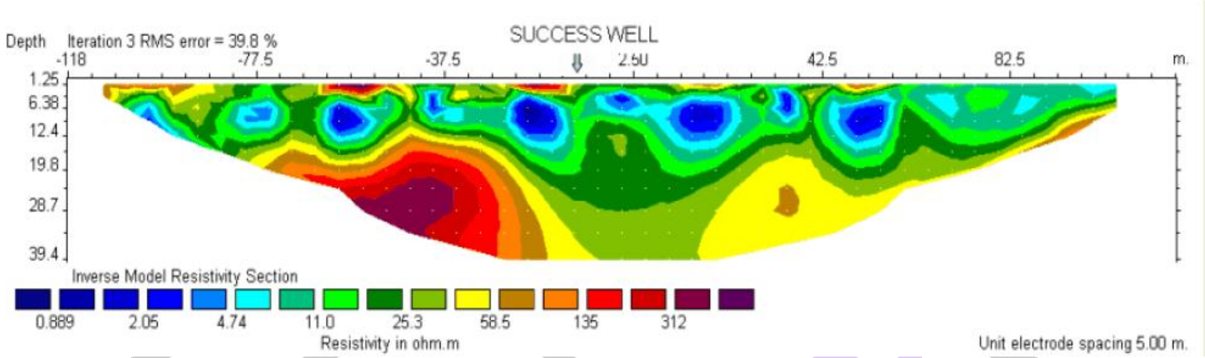

Fig.6 Distribution of Electrical Resistivity Values along Success Well at Kammeta

Kammeta failed well

Fig. 7 shows the distribution of electrical resistivity values along the profile. Figure shows a very low resistivity regions of 2.36 to 3.99 ohm-m distributed along the image line below. The soil zones have resistivity values of 32.4 to 92.2 ohm-m distributed on the top of the image profile. And, left side bottom and right side bottom of the image profile contains semi weathered pockets. The failed well has low resistivity values right from the top except soil layer. Because of low resistivity values below this well, the zone is interpreted as highly weathered layer. Hence the well was failed.

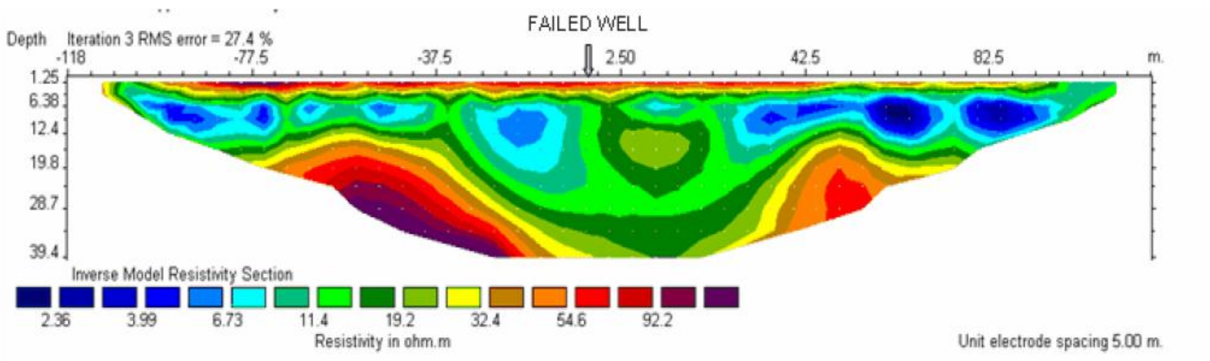

Fig.7 Distribution of Electrical Resistivity Values along Failed Well at Kammeta

Pudur failed and success wells

A 315 m electrical resistivity survey line was carried out at pudur. Fig.8 shows the distribution of electrical resistivity values along the profile. The failed well and success well are taken in the same profile. This profile is 'roll along'. A very low resistivity regions of 0.423 to 2.85 ohm-m is interpreted as clay zones are distributed in the middle of the image line. Below the failed well, the earth has very low resistivity values ranging from 49.8 ohm-m at the top to 0.423 ohm-m indicating the soil. With this very low resistivity values, this well is failed. The layered earth below the success well has resistivity values of 300 to 350 ohm-m in the deeper depths. At this depth of about 200 ft, high yield was obtained. This well fell in fractured zone in deeper depths. Therefore, this well is success.

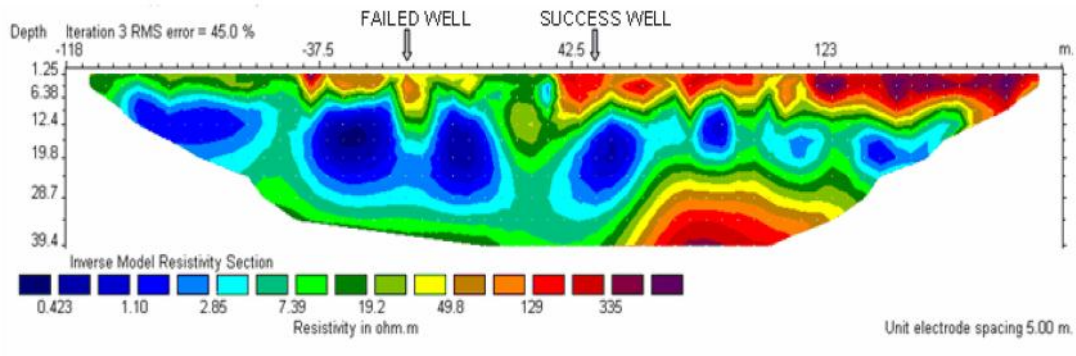

Fig.8 Distribution of Electrical Resistivity Values along Success and Faied Well at Pudur

IV. CONLUSION

Parameters of all the success and failed wells in both granitic and basaltic terrains were summarized from Table 1 to Table 2. From these tables it can be observe that the resistivity range of success wells in the granitic terrain is 170 ohm-m to 360 ohm-m (Table 2). While the same for failed wells in the granitic terrain has two ranges (Table 2) one is in the lower resistivity range of less than 90 ohm-m which is due to highly weathered formation, the other one is in the range of greater than 300 ohm-m which is due to basement characteristics. Well depths are mostly below 40 m for both success and failed wells.

Similarly for Basaltic terrain the resisitivity range for success wells is 300 ohm-m to 370 ohm-m (Table 3). While the same is for failed wells has two ranges (Table 4). One is in the lower resistivity range of less than 120 ohm-m representing highly weathered formation; the other is in the range of greater than 500 ohm-m representing basement characteristics. In both the terrains low yield of wells is either due to highly weathered material of the aquifer or due to basement characteristics. Similarly high yields are either due to contact zone or fractured zone (Siva Prasad, 2010).

Table 1. Parameters of success wells in granitic terrain

Name	High yield obtain at depth (m)	Resistivity values of the aquifer (ohm-m)	Total depth of wells (m)	Remarks
Shankarpally	30-40	200-360	35-39.4	Contact zone
Shabad	22	170-250	22-29	Fractured zone

Table 2. Parameters of failed wells in granitic terrain

Name	Resistivity values of the aquifer (ohm-m)	Total depth of wells (m)	Remarks
Shankarpally	300-1002	11.5-39.4	Dyke
Shabad	4.45-89.9	1.25-33.8	Highly weathered

Table 3. Parameters of success wells in Basaltic terrain

Name	High yield obtain at depth (m)	Resistivity values of the aquifer (ohm-m)	Total depth of wells (m)	Remarks
Pargi	33	318-370	18-25	Fractured zone
Kammeta	Deeper depths	Morthan 312	Above 39.4	Contact zone
Puduru	65	300-350	Above 39.4	Fractured zone

Table 4. Parameters of failed wells in Basaltic terrain

Name	Resistivity values of the aquifer (ohm-m)	Total depth of wells (m)	Remarks
Pargi	4.58-116	1.25-34	Highly weathered basement

	500-2911	36-39.4	
Kammeta	55-32.4	1.25-39.5	Highly weathered
Puduru	49.8-0.423	1.25-39.4	Soil,weathered

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