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Integration of high resolution satellite data and electrical resistivity technique for ground water exploration and exploitation over parts of Mahbubnagar district, Andhra Pradesh, India

P.Chandrasekhar
National Remote Sensing Centre (NRSC), ISRO / DOS, Govt. of India,
Hyderabad – 500 625
E.mail: chandrasekhar_p@nrsc.gov.in

ABSTRACT
Interpretation of high resolution satellite data had revealed the presence of two major regional lineaments, which are fracture controlled, in an area of about 300 acres of land in parts of Mahbubnagar district of Andhra Pradesh state. These lineaments were successfully identified and accurately traced in the semi-accessible field area. Along these two lineaments, seven possible recharge locations were identified on ground based on the in-field hydrogeological and geomorphological evidences. Vertical Electrical Sounding (VES) surveys were conducted over them and collected the electrical resistivity data. This data was analyzed, processed and interpreted. Various subsurface geological formations, in the form of different layers, were inferred along with depths, thicknesses and resistivities. Favorable locations for possible occurrence of ground water resources were pinpointed along with their depths and recommended for drilling new bore wells. Subsequently all the recommended wells were drilled, which had proved the occurrence of good quantities of water, precisely as per the recommendations of point locations on ground and depths. Discharge yield tests were also conducted with V-Notch chamber continuously for 24 hrs, for each of the wells and the yields of bore wells were also estimated. They were 154.33, 153.27, 160.05 and 74.92 Litres Per Minute (LPM) respectively for the recommended bore wells. Three of the above can be declared as 'production wells' as per CGWB and PHEDs guidelines and the other one appears to be a seasonal source, because of the low yield. However, this well also can be made a permanent source by recharging the existing bund (check dam) in the northern side central portion of the study area. The above wells drilled based on this study can serve the requirement of about 2000 persons a day by running the above bore wells only for a period of 2 ½ hours a day, on an average, as per the prescribed standards of 40 Litres Per Capita per Day (LPCD) for human beings livelihood. Thus the utility of satellite data in conjunction with VES for pinpointing the sites for drilling new bore wells is successfully demonstrated in reality on ground in this result oriented study, which is cost and time effective too.

INTRODUCTION

Most of the rural population and about 30% of urban population of our country depend on ground water for meeting drinking water and domestic requirements. Ground water is also required for irrigation, infrastructure, horticulture, floriculture, etc. The demand for identification of new potential zones of ground water is steadily increasing with the increase in population as well as with declining ground water levels. The distribution of ground water is not uniform in all the parts of a region because of the variations in the rainfall and the geological conditions. Increasing agricultural & industrial activities, vagaries in monsoon, over exploitation of ground water, recharge problems, etc. have also resulted in collapse of the water bearing structures and drying up of the wells in many parts making the ground water a scarce commodity (NRSC Technical report 2008) even for drinking water needs. This has necessitated the invention of new cost & time effective ways and the integration of different technologies for the exploration and exploitation of ground water resources. The utility of satellite imagery for mapping the regional geological structures useful for ground water exploration has been emphasized by various workers (Dinesh Kumar, Gopinath & Seralathan 2007; Rao, Bhattacharya & Reddy 1996; Reddy, Vinod Kumar & Seshadri 1996; Salama, et. al., 1994, Semere Solomon & Woldai Ghebreab 2008). This is possible because of the synoptic coverage provided by the satellite imagery which is a difficult task in conventional ground surveys due to scanty rock exposures, soil cover, lack of continuous observations etc. (NRSC Technical report, 2008). Different types of primary and secondary geological structures can be interpreted from satellite imagery by studying the landforms, slope asymmetry, outcrop pattern, drainage pattern and individual stream / river courses etc. Lineaments representing the faults, fractures, shear zones, etc. are the most obvious structural features important for ground water exploration that can be interpreted by the satellite imagery based on the image characters and geological evidences (NRSC Technical report 2008 & Remote Sensing Applications, NRSC 2009). They appear as linear to curvilinear lines on the satellite imagery and are often marked by the presence of moisture, alignment of vegetation, straight stream / river courses, alignment of ponds / tanks etc. In hard rock areas, geological structures exercise definite control on the aquifer characteristics of different rock types, as the structurally weak planes act as conduits for movement and occurrence of ground water, thereby introducing an element of directional variation in hydraulic conductivity. The geological structures that can be identified on satellite imagery can be divided into two categories: (i) primary structures – associated with specific rock types and (ii) secondary structures – which cut, deform and otherwise affect the rock units themselves (NRSC Technical report, 2008). On the other hand, the role of Geophysical techniques, especially Vertical Electrical Sounding (VES) methods is well established in ground water exploration over the decades, as these techniques play a vital role in understanding the qualitative and quantitative nature of the subsurface in-homogeneities with reference to water-bearing formations. These methods are extremely useful to investigate the nature of subsurface formations by studying the variations in the electrical properties of the crustal layers because of the possibility of very good resistivity contrasts among different subsurface lithological units, controlled depth of investigation, low cost of instrumentation, easy operation, etc (Ramanujachary & Balakrishna 1985). Thus a judicious combination of high resolution satellite data for the interpretation of regional fractures and electrical resistivity data for pinpointing the locations for drilling new bore wells, was adapted and successfully utilized in the present work and is presented in this paper.

STUDY AREA

The study area is about 300 acres of land abutting National Highway No. 7 of Hyderabad leading to Mahbubnagar district, A.P. and located about 60 km away from Hyderabad. There is an existing infrastructure of only about 60 acres of land, presently, in the above. This area is acting as a good run off zone for neighboring agricultural fields and the soil is made up of granitic pediplain. Topographically NE zone is elevated and there is nearly a 25 m elevation drop over a length of 1.3 km in the N – S direction & 35 m elevation drop from NE to SW of the area. The area is dotted with shrubs (more dense in the centre) and also comprises of a few high mounds / rock out crops and forms part of Peninsular Gneissic Complex (PGC) consisting of massive granites and gneisses. Few outcrops of granites are exposed in the central part of the area.

METHODOLOGY

Lineaments are interpreted on the satellite data as anomalous features and linear alignment of streams, water bodies or vegetation. (NRSC Technical report 2008). High resolution satellite data on 1:2000 scale (Fig.1) was interpreted for regional geology and the structural set up of the study area. Two prominent lineaments that are passing through the study area, one in the northwestern portion and the other in the southeastern portion, were interpreted (Fig.1) based on the analysis of image elements such as tone, texture, association etc. and geotechnical elements such as drainage, water bodies etc. Both of these were in the NE - SW direction and are almost parallel to each other. These are also confirmed on ground and are identified as fracture controlled deeper semi-confined aquifers, with the help of satellite image and the topographic map of the area. Along these two fractures, two check dams (one along each of the above) were also interpreted (Fig.1). Along these fracture zones, which are supposed to host good quantities of ground water, seven possible recharge locations (Fig.1), were selected based on the hydrogeological and geomorphological evidences on ground. Three of them were along the southeastern lineament and four along the northwestern lineament. Vertical Electrical Sounding (VES) surveys were conducted over the above seven points, named as VES locations 1, 2, 3, 4, 5, 6 & 7 (VES 1-7) as shown in Fig.1, selected by narrowing down the possible

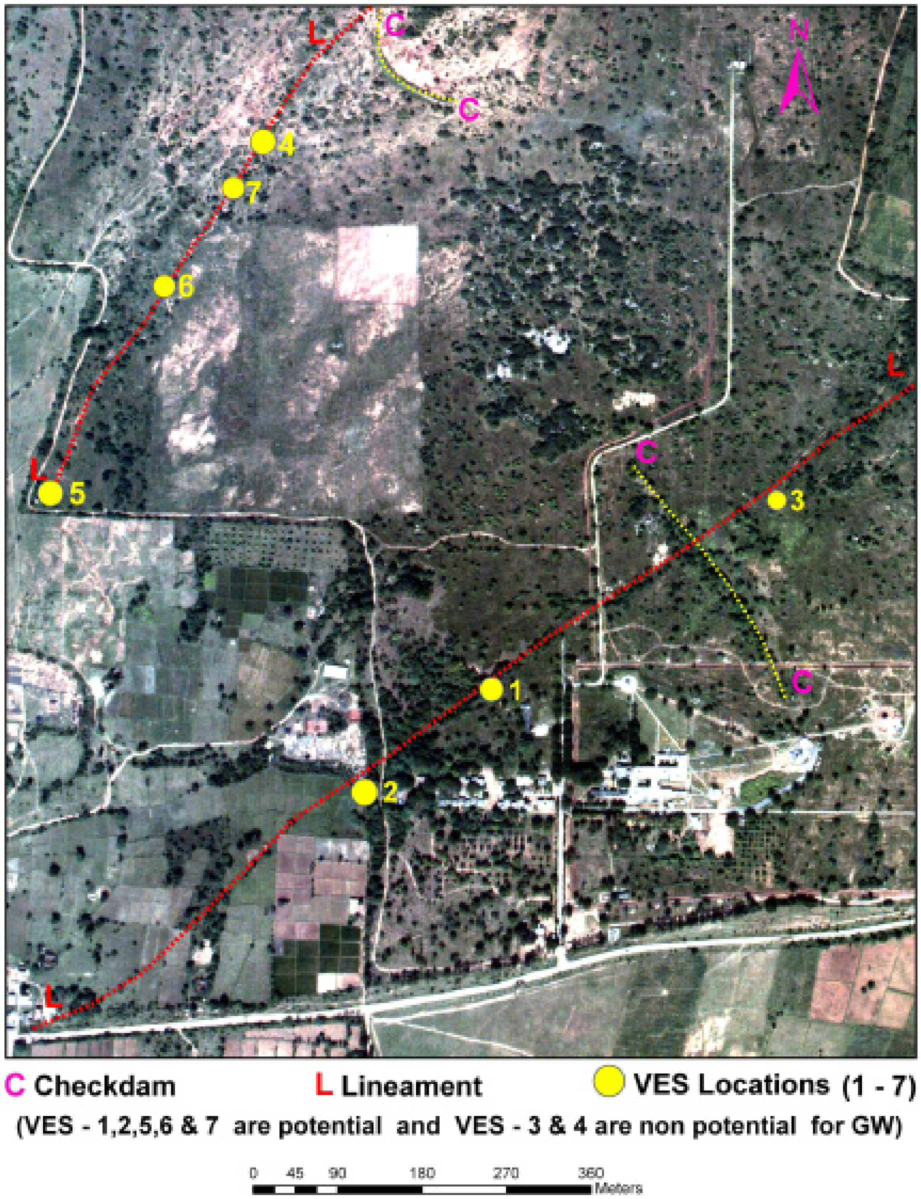

Figure 1. High resolution satellite image with interpretation and VES locations.

potential locations based on remote sensing interpretation and in-field hydrogeological & geomorphological evidences. Electrical resistivity data was collected along traverses, which are planned, as far as possible, in a perpendicular direction to the fractures in order to cut across different formations. Schumberger electrode configuration (Milton B. Dobrin 1984) was used for collection of the data and the spread length used was based on the neighbourhood hydrogeological conditions. The half separation of current electrodes (A & B) and the potential electrodes (M & N) from the reference point i.e, AB/2 and MN/2 that were used are as follows: AB/2 (in meters) were 3, 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84, 90, 100, 110, 120, 130, 140, 150, 160, 180, 200, 220, 240, 260, 280, 300, 320, 340, 360, 380 and 400 and MN/2 (in meters) were 1, 1, 1, 1, 5, 5, 5, 5, 5, 5, 5, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 30, 30, 30, 30, 30, 30, 30, 60, 60, 60, 60, 60 and 60 respectively. However, at crossover points i.e, when AB/2 is 18, 60, 150, 280 meters, etc. repeated values were taken with next MN/2 also in order to obtain better control over data. The total spread length used is 800 metres approximately, i.e., 400 m on either side of the reference point at the centre. The depth

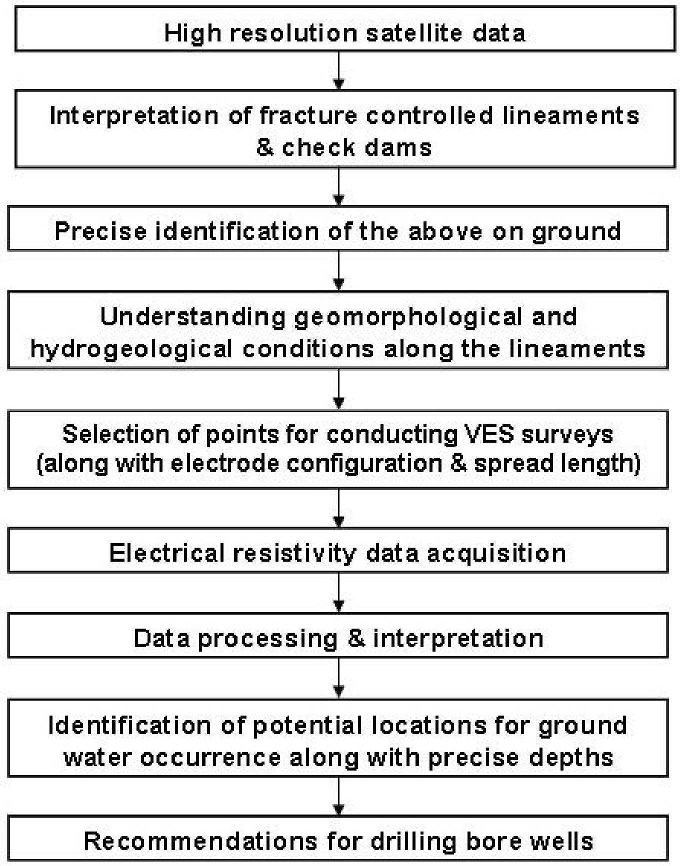

Figure 2. Methodology Flowchart.

of investigation would be approximately 1/3rd of the total spread length i.e., 270 m. The electrical resistivity data was then processed and interpreted using 'inverse slope technique' and various subsurface layers with true resistivities and thicknesses were delineated. The "longitudinal conductance" (S), which is the ratio of half the current electrodes spacing (AB/2) and apparent resistivity (ρa) (or $S=AB/2/\rho a$), was computed for each of the soundings. This was plotted against AB/2. The random points were deleted and the signal to noise (S / N) ratio was improved. The smoother variations were then joined linearly and inverse slopes were computed. Finally, the graphs showing the nature of the subsurface formations were constructed, for each of the VESs, by means of true resistivities and thicknesses considering the possible hydrogeological conditions. The methodology followed is shown in Fig.2. The formations indicated in green and red colors are the potential and the non-potential zones (Figs 3-7), respectively. VES Nos. 1, 2, 5, 6 & 7 (Fig.1) are recommended for drilling bore wells up to the recommended depths, as shown in Figs. 3-7 respectively.

RESULTS, VALIDATION & CONCLUSIONS

VES 1 is recommended for drilling a bore well up to a depth of approximately 175 -185 m, however, there is a possibility of getting a seasonal / temporary water column at a depth of approximately 50 – 60 m also (Fig.3). VES 2 is recommended for drilling a bore well up to a depth of approximately 110 - 130 m, however, there is a possibility of getting a seasonal / temporary water column at a depth of approximately 55 - 65 m also (Fig.4). VES 3 and VES 4 are totally non-potential for ground water, as the subsurface contains only harder rocks with increasingly higher resistivities. Hence VES 3 and 4 are not recommended for drilling purpose. VESs 5, 6 and 7 are recommended for drilling bore wells up to depths of approximately 65 - 80 m, 45 - 55 m and 200 - 210 m, respectively (Figs 5, 6 & 7). All the above five recommended points were subsequently drilled and obtained good quantities of water in four out of five wells drilled, exactly within the recommended depths. Discharge yield tests were also conducted with V-Notch chamber continuously for 24 hrs for each of these wells and the yields of the

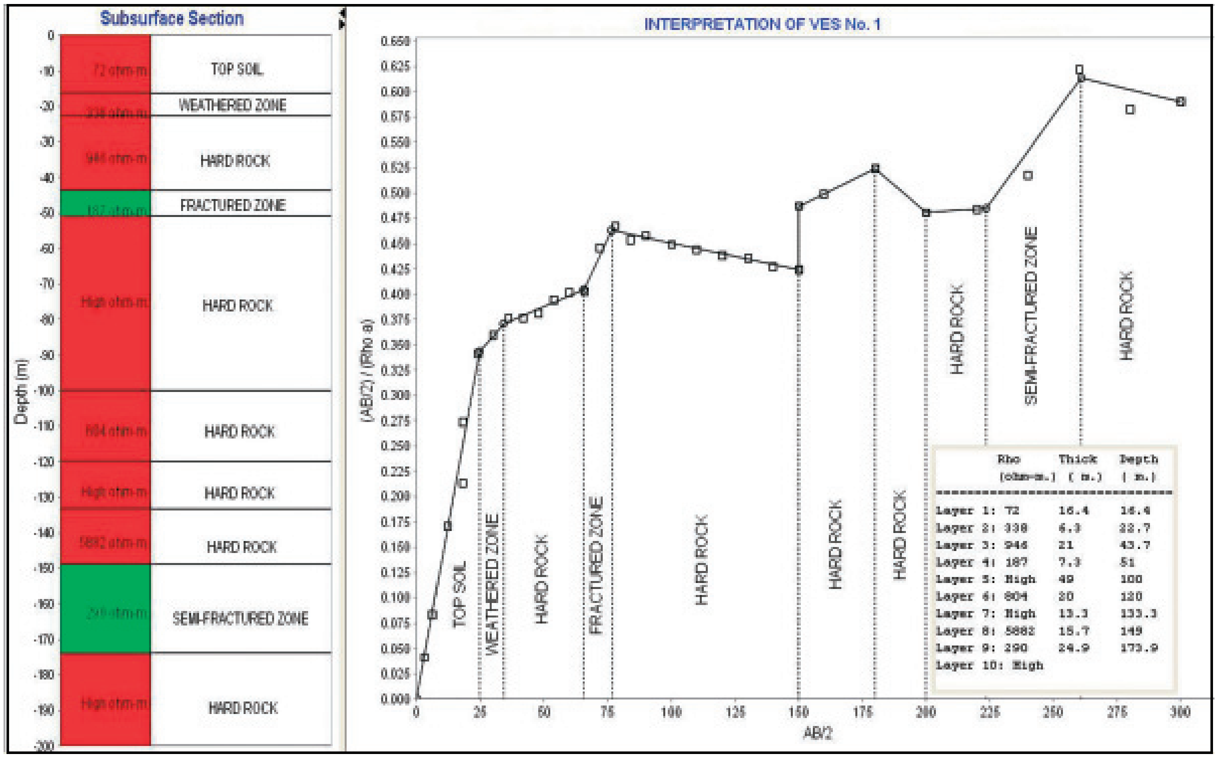

Figure 3. Interpretation of electrical resistivity data for VES 1.

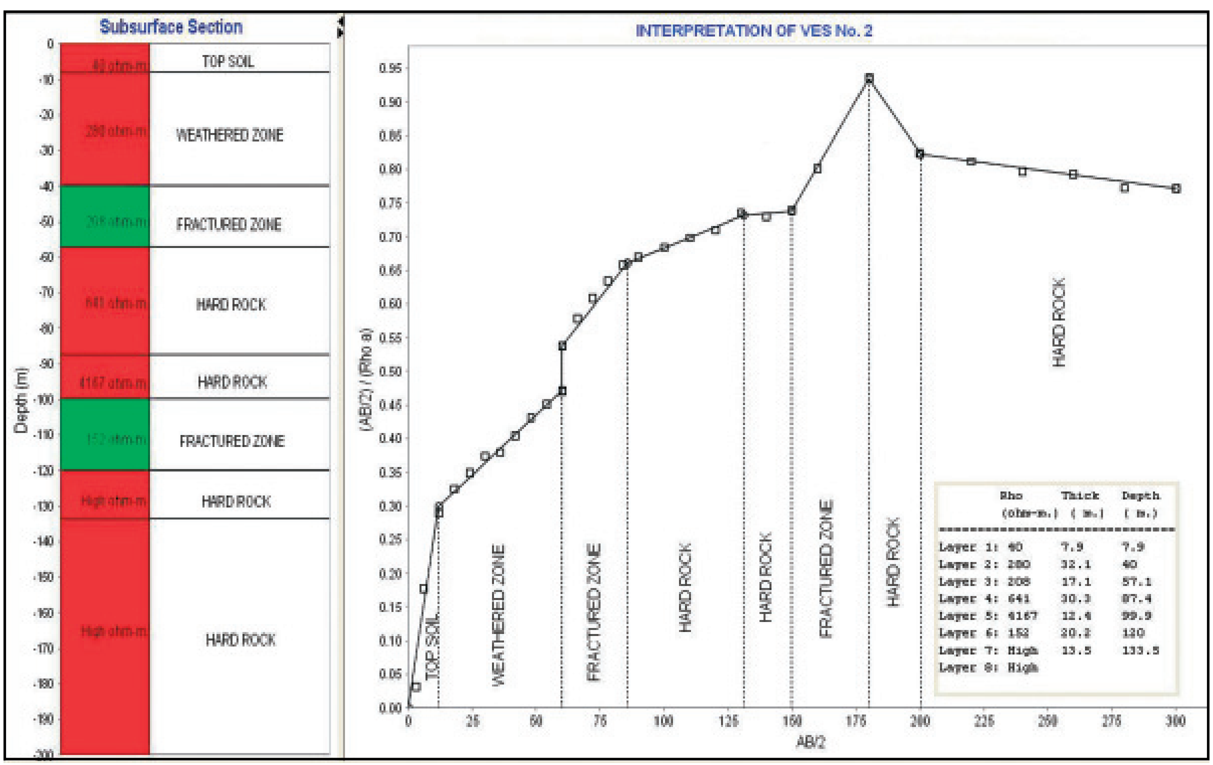

Figure 4. Interpretation of electrical resistivity data for VES 2.

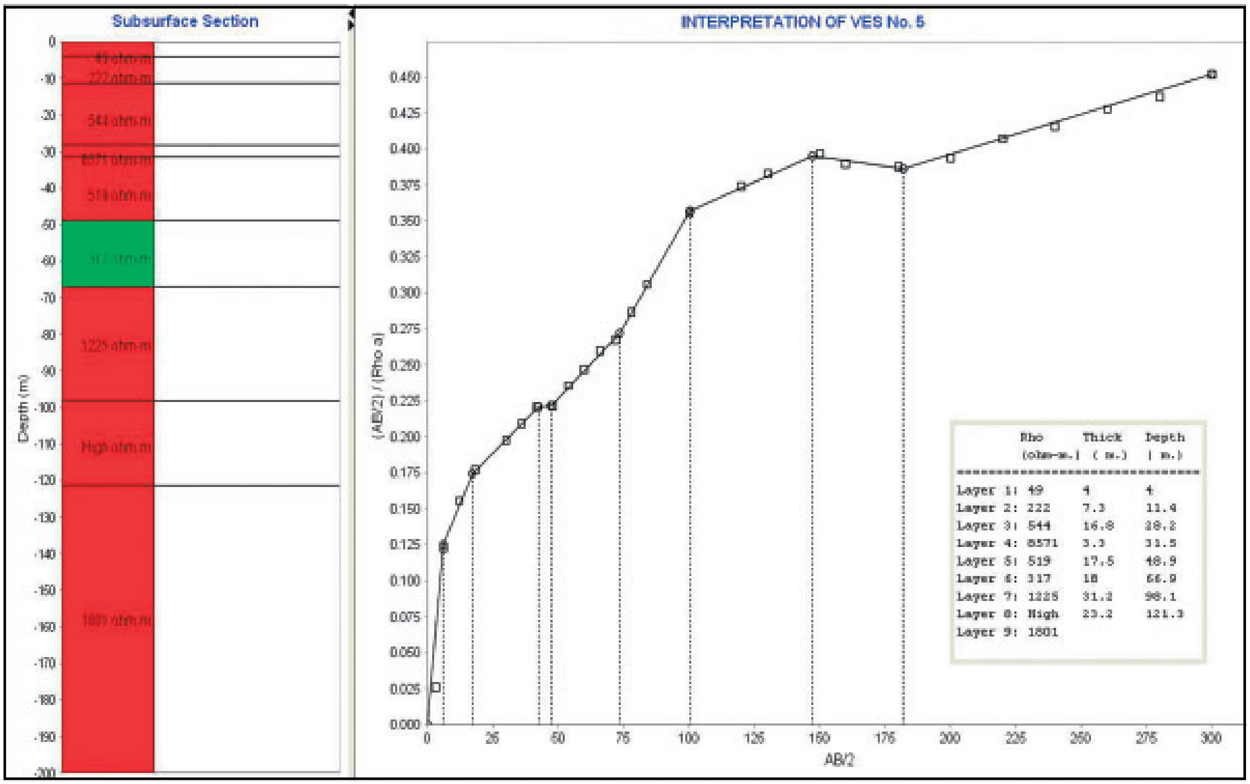

Figure 5. Interpretation of electrical resistivity data for VES 5.

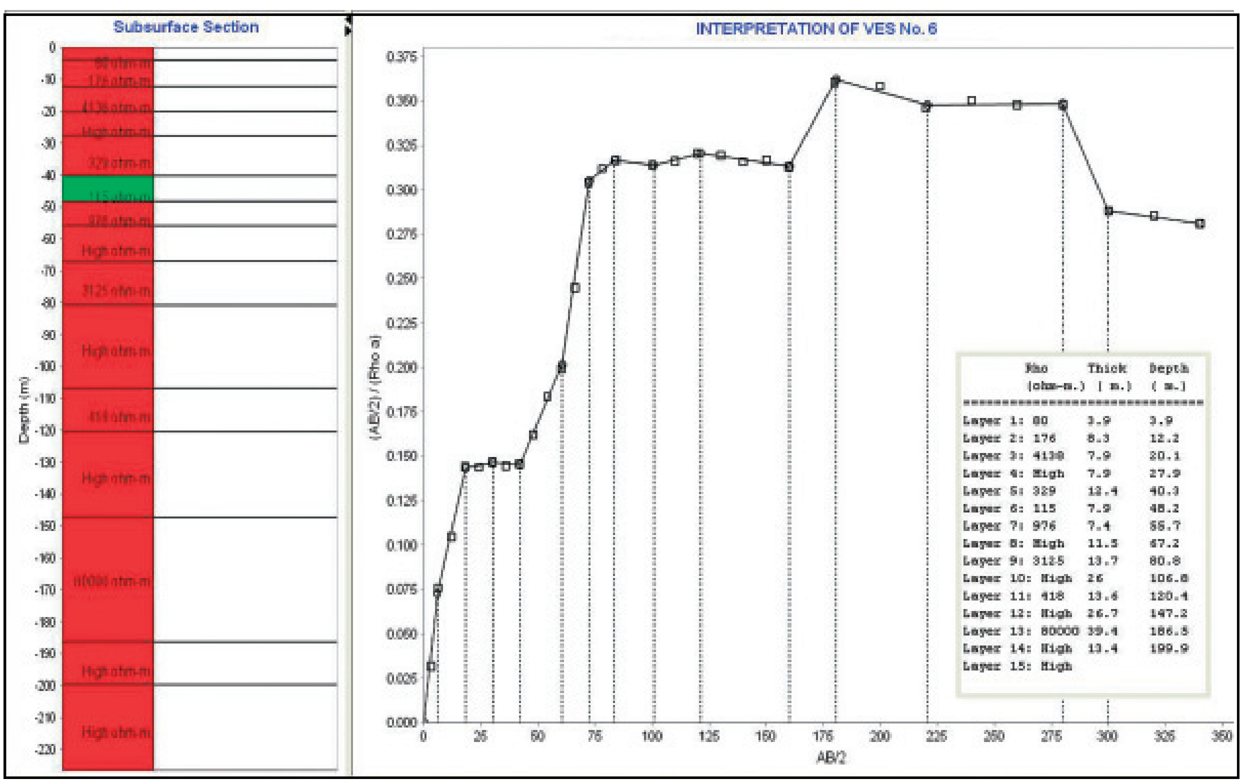

Figure 6. Interpretation of electrical resistivity data for VES 6.

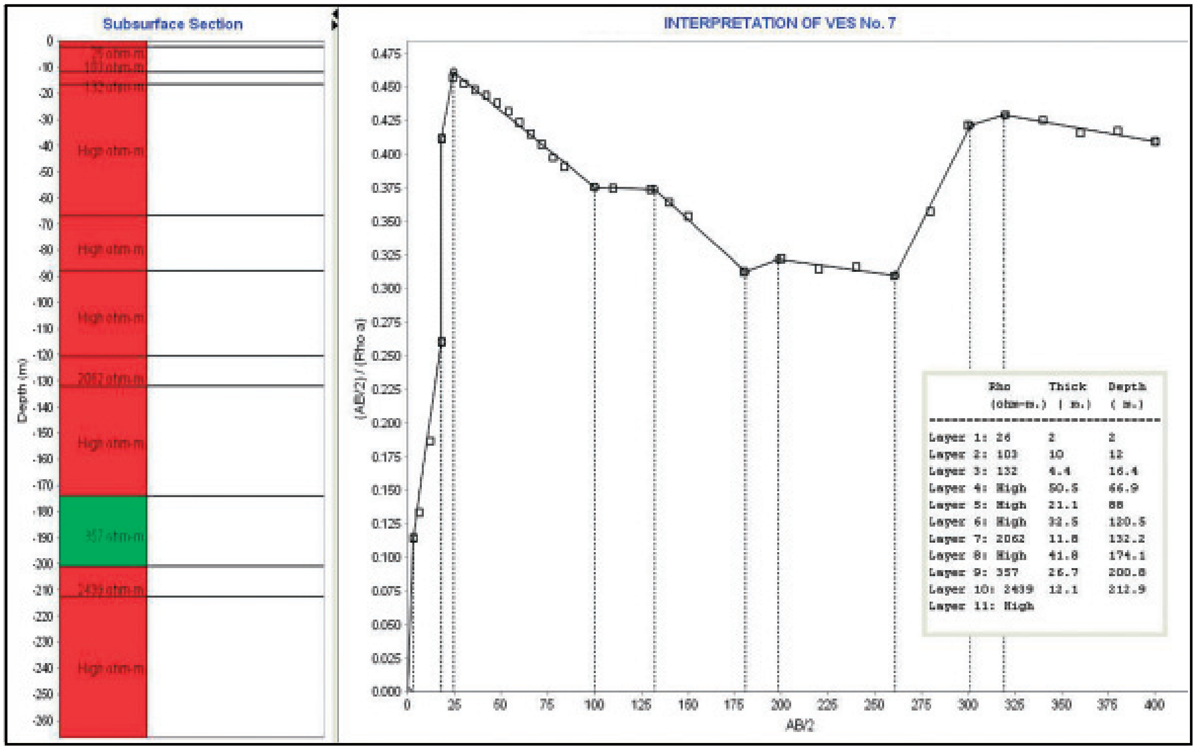

Figure 7. Interpretation of electrical resistivity data for VES 7.

bore wells were also estimated. They were 154.33, 153.27, 160.05 and 74.92 Litres Per Minute (LPM) for the bore well nos. 1, 2, 5 & 7 respectively. As per PHEDs and CGWB guidelines, if a bore well is yielding 2.5 Litres Per Second (LPS) or more it is declared as a 'production well'. Accordingly, the yields in LPS of the bore wells drilled for VES nos. 1, 2, 5 & 7 are 2.57, 2.55, 2.67 & 1.25 respectively (Technical report of CMD, NRSC 2009) indicating three of them are production wells and the other one, a seasonal source. Though presently bore well no.7, that is VES 7 (Fig.1), appears to be a seasonal source, because of the low yield, it can also be made a permanent source by recharging the existing bund in the northern side central portion (Fig.1). The above wells drilled based on this study can serve the requirement of about 2000 persons a day by running the above bore wells only for a period of 2 ½ hours a day, on an average, as per the prescribed standards of requirement of 40 Litres Per Capita per Day (LPCD) for human beings livelihood. While drilling the bore wells, it was favorably observed that after touching water at a particular depth, yield increased systematically with increasing depths and maintained stability. The existing two bunds (check dams) across the two streams (Fig.1) should be de-silted for acting as recharge areas for augmenting the ground water resources of the area i.e., for sustainability of the bore wells. Instead of randomly conducting electrical profiling and sounding in the present study, a novel cost and time effective approach of integration of high resolution satellite data (coupled with ground geomorphological and hydrogeological conditions) and VES surveys has been adapted and successfully proved on ground, in reality, for ground water exploration and exploitation.

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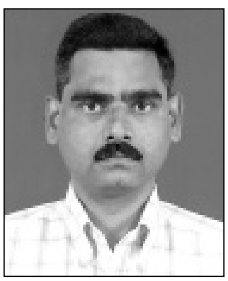

P.Chandrasekhar has obtained his M.Sc. (Tech) in Geophysics from Andhra University, Visakhapatnam and was a recipient of UGC merit scholarship. He joined NRSC in the year 1990 and, since then, has been working in various projects aimed for regional geological mapping, oil & gas, mineral and ground water exploration sponsored by ONGC, DGH, GSI, MoRD (Govt. of India) etc. utilizing Geophysical, Geological and Remote Sensing data and carried out integrated studies for natural resources exploration. He had visited ITC, The Netherlands during 1997, in response to their invitation & funding and worked for digital compilations of Aeromagnetic data flown with different flight parameters & flight seasons. He was the recipient of ISRO Merit award-2007 for his contribution as "In-charge", Digital Data Quality of Rajiv Gandhi National Drinking Water Mission (RGNDWM) project sponsored by MoRD, Govt. of India. Presently he is working as Scientist "SE" in Geosciences Division, RS & GIS – AA, NRSC.