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Research Article

VERTICAL ELECTRICAL SOUNDING FOR GROUNDWATER EXPLORATION FOR PART OF VISAKHAPATNAM URBAN AREA, ANDHRA PRADESH, INDIA

Kiran Jalem[1]*., Venkateswara Rao V[2] and Rambabu K[3]

[1]Centre for Land Resource Management, Central University of Jharkhand, Ranchi
[2]Department of Geo-Engineering, Andhra University, Visakhapatnam
[3]Department of Geophysics, Andhra University, Visakhapatnam

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ABSTRACT

An attempt made to identify the subsurface lithology by using electrical method for micro watershed of Visakhapatnam Urban Area. The study area extends from 17 47' 02" N to 17 48' 38" N latitudes and 83 11' 51" E to 83 14' 45" E longitudes, covering an aerial extent of 9.18 km2. Total of 30 vertical electrical sounding data acquired in the watershed region using the Schlumberger configuration. The collected data were analyzed using both quantitative and qualitative interpretation and generated 3 to 4 subsurface layers and Pseudo cross sections with the help of IPI2W in Software. The apparent resistivity of the study area varies from 2.93Ωm to 24848Ωm at VES-26, VES-22 revealing HA-type curve respectively. Geophysical studies revealed that the deeper aquifers are present in southwest part of the study area where the total thickness of the aquifer zone extends to 80 metre depth. The interpretation exposed that watershed area indicates mostly H-type curves leading to second layer low resistivity which also has the possibility of groundwater.

INTRODUCTION

Water-related problems are increasingly recognized as one of the most immediate and serious environmental threats to humankind. Water use has more than tripled globally since 1950, and one out of every six persons does not have regular access to safe drinking water. Lack of access to a safe water supply and sanitation affects the health of 1.2 billion people annually (WHO and UNICEF 2000).

The complex and various interrelations between activities on the territory of the watershed cause that any considerable change of affectation of the land can have impacts on the management and the availability of the water in the basin; the production of goods, services and the prosperity of the general population (Lasalmil and Boulal 2003). High amounts of impervious cover have been associated with stream warming, habitat alteration, and decreased aquatic integrity in urban areas (Karr 1991; May *et al*. 1997; Schueler 1995; Shaver *et al*. 1994). In highly developed areas, options for improving storm water management exist, but are more limited and less likely to result in high quality water (Schueler 2008). Several studies indicate that streamside forests offer significant protective effect (Deacon *et al*. 2005);

Historically, zoning has been used to establish limits on building density and to separate uses believed to be inherently incompatible (Arendt 1997). Watershed-based zoning, in contrast, uses watershed and sub-watershed boundaries as the basis for making land use decisions. Typically, zoning objectives focus on maintaining or reducing impervious cover in sensitive sub-watersheds and redirecting development to sub-watersheds that are better able to absorb their influence (Caraco *et al*. 1998).

The impact of human activities including urbanization, land use changes, groundwater contamination and over exploitation etc. requires protection of these valuable resources. Techniques to adequately assess these impacts requires the methods for quantifying the recharge, geophysical characteristics of the aquifers and modeling the contamination transport, within the watershed, at different temporal and spatial scales. GIS modeling of flow characteristics contribute to the understanding, quantification and transport processes in complex hydrogeological systems and used in practical approaches to assess the water quality, protection methods,

Corresponding author:* **Kiran Jalem
Centre for Land Resource Management, Central University of Jharkhand, Ranchi

solutions to contamination problems. To meet the growing challenges on these resources, an integrated water resources management at micro level is needed.

METHODOLOGY

The field procedure used Vertical Electrical Sounding (VES) using schlumberger array which carried out at thirty (30) VES stations. The orientation of the profiles were maintained in regular directions of north-south and north west-south east, with the current electrode spacing of 1/2AB=100M. The Schlumberger array consists of four (4) collinear electrodes. The outer two electrodes are current source electrode and the inner two electrodes are potential (receiver) electrodes (Figure 1). The potential electrodes are installed at the center of electrode array with a small separation, typically less than one fifth of the spacing between the current electrodes. The current electrodes are increased to a greater separation during the survey while the potential electrodes remain in the same position until the observed voltage become too small to measure. The instrument used for this survey is the ABEM terrameter (SAS 300) which is the modern instrument in which the resistance readings at every VES point were automatically display on the digital read out screen and were jotted down in the book provided during the survey.

The advantages of the Schlumberger array are fewer electrodes need to be moved to each sounding and the cable length for the potential electrode is shorter. Schlumberger sounding generally have better resolution, greater probing depth, and less time-consuming field deployment then the wenner array. The disadvantages are that long current electrode cable is required, the recording instrument needs to be very sensitive, and the array may be difficult or confusing to coordinate amongst the field crew (Keller, 1966).

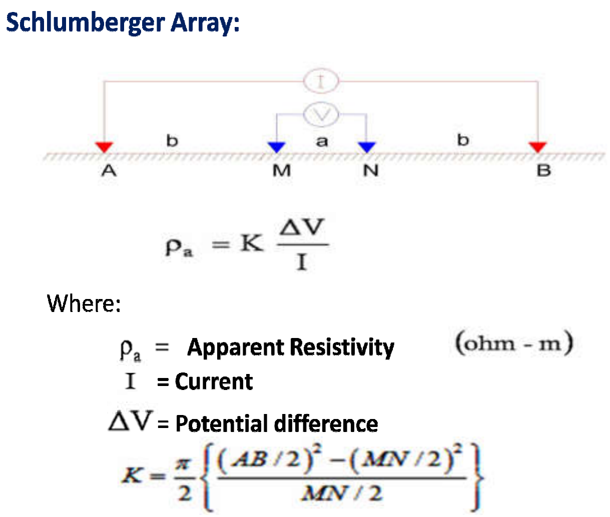


Figure 1 Schlumberger array and apparent resistivity diagram (Keller, 1966)

Study Area

The study is aimed at identifying the complex system of surface runoff in a semi urban system, between 17^0 47' 02" N to 17^0 48' 38" N latitudes and 83^0 11' 51" E to 83^0 14' 45" E longitudes, covering an aerial extent of 9.18 km^2. It is a part of Survey of India (SOI) Toposheets-65 O/1 SE (Figure 4a) of 1:25,000 scale and is within the administrative boundaries of Greater Visakhapatnam Municipal Corporation (GVMC) of Visakhapatnam, Andhra Pradesh (Figure 2). It includes the tanks existing at Sujathanagar, Laxmipuram and Chinamushidiwada. Because of rapid urbanization there is an urgent need to protect these valuable water resources. A brief description of these tanks is given below and the sub-watershed boundaries for these tanks are shown in Figure 4b.

Sujathanagar tank: The tank (Figure 3a) is located in the midst of the highly urbanized area called Sujathanagar and is at the latitude 17^0 48" 08" N and 83^0 12" 52" E longitude. Entire Ayacut area under this tank is completely developed into well planned colonies. Tank bed area is about 8.0 hectares and there are indications that the tank bed being occupied by the unauthorized colonies. There is large catchment to this tank originating from the west face of the Kambalakonda forest.

Chinamushidiwada tank: The tank (Figure 3b) is located to the west of Chinamushidiwada village at 17^0 48' 10" N latitude and 83^0 11' 57" E longitude. All around the tank the land is under urban use for residential layouts. Tank bed area is about 5.1 hectares and is fed from its catchment as well excess water from krishnarayapuram tank.

Laxmipuram tank: The tank (Figure 3c) is located at the latitude 17^0 47' 40" N and longitude 83^0 11' 59" E and the nearest village is Laxmipuram, which is a part of GVMC. Tank bed area is about 20.4 hectares and is a medium irrigation tank under which about 500 acres of paddy being cultivated every year. Some part of the Ayacut is converted into urban land and still the remaining area being irrigated. In another 4 to 5 years the entire ayacut area will be converted into urban land use. Hence there is a need to convert this tank into urban water storage tank, the storage of which becomes a good dependable source to the residents in the Laxmipuram and Chinamusidiwada area.

Due to the rapid urbanization and un-precedent growth of the city in the past two decades, most of the storm water drains are encroached by slum-dwellers (Figure 5a and b), as well as modern apartments, thereby causing obstructions to the free flow of stream and narrow-down the width furthermore.

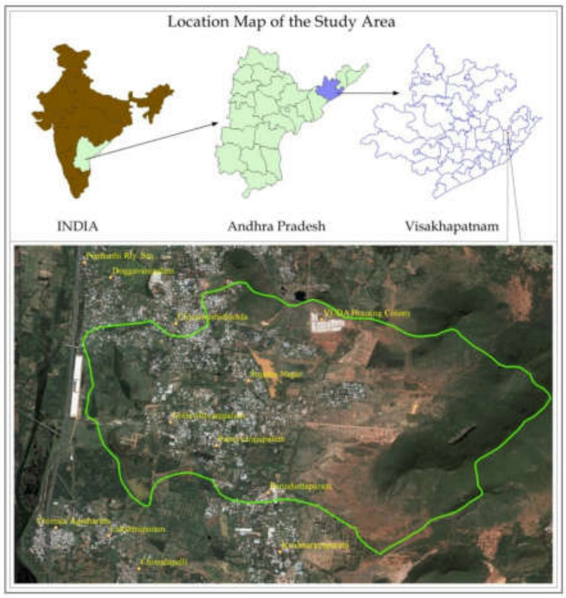


Figure 2 Location map of Study Area

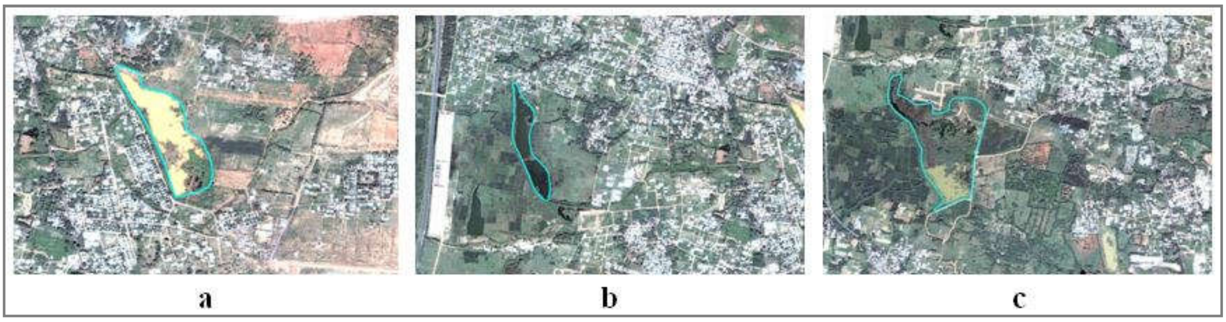
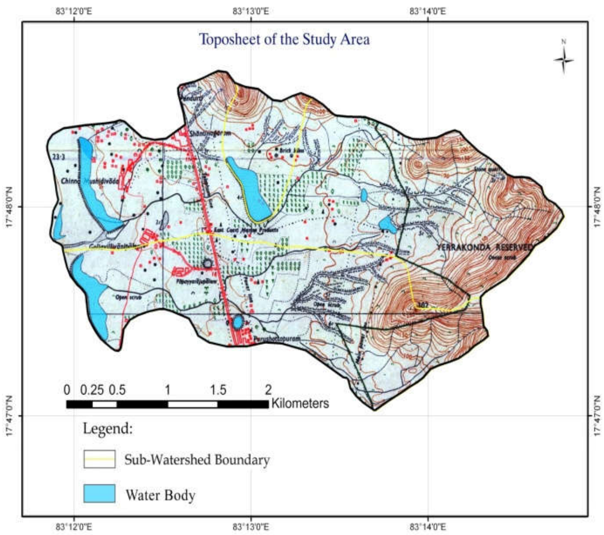
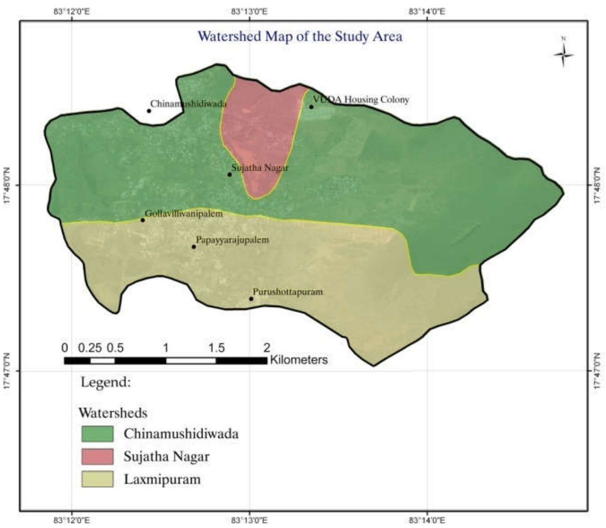


Figure 3 Satellite Image of Sujathanagar tank (a), Chinamushidiwada tank (b) and Laxmipuram tank (c).



(a)



(b)

Figure 4 Toposheet of Study Area (a) and Subwatershed boundaries (b).

The nearby residents are habituated to throw the debris and other wastages into the drains due to lack of proper demarcation and fencing of storm water drains. This has resulted in silting of drains and reducing its the carrying capacity (Figure 5c). Cattle pollution is found to be predominant in the study area (Figure 5d).

During heavy rains the problem gets complicated due to stagnant conditions and the low lying areas are severely affected.

On the other hand the illegal occupants, surrounding the tank area, are damaging the retaining structures (tank bund, weirs, spill ways etc.) to prevent water logging in their premises (Figures 5e, f and g).

As fast developments are expected in near future it is utmost important for regularisation of storm water drains and demarcation of lands for storm water drain networks before the city grows haphazardly. Presently in peripheral areas of the city, like our study area, the drains pass through undeveloped areas with growth of vegetation all along drains. Most of the geddas are not properly trained and defined with side walls and as such there is every need to train them by constructing RCC drains in the well developed areas and stone masonry trapezoidal drains in peripheral areas, which are likely to grow in near future. At few stretches, the geddas are encroached. These need to be widened for smooth flow of storm runoff without affecting day to day life and also minimizing damages to properties and loss of human life during heavy rains. Few of the following exhibits indicate the existing condition of geddas near Sujathanagar area (Figure 5h) and Laxmipuram (Figure 5i), needs the remodeling of the same.

RESULT AND DISCUSSION

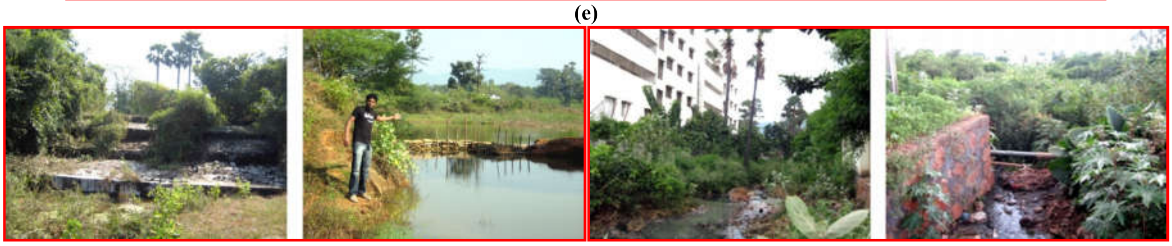
The Vertical Electrical Sounding modeling carried out at thirty (30) VES stations was used to derive the geo-electric sections of various profile; which indicate the existence of mostly four geologic layers in the study area in each VES point where the survey was carried out. This comprised the top soil, weathered rock, fractured rock, hard fractured rock and hard rocks. In order to have an illustration of subsurface lithology, vertical cross sections are prepared by selecting the soundings in a linear direction as shown in Figure 6. VES lithological data is plotted in a linear direction choosing four traverses along A-A', B-B', C-C', and DD' are shown in Figure 7 to Figure 10.

Subsurface lithological vertical cross section along the traverse A-A'

The figure 6 represents lithological section A-A' which traverses through Vertical Electrical Sounding (VES) recorded stations 28, 27,11 and 4 respectively, extending from Rajayyapetta to Simhapuri Colony falling in the lower portion of the study area. In the location 28 of Rajayyapetta, elevation with respect to Mean Sea Level (MSL) recorded for weathered rock and fractured rock is 17.64 m. In the location 27 near Chinnamushidiwada Tank, elevation with respect to Mean Sea Level (MSL) recorded for weathered rock is 7.28 m and beyond 7.28 m depth is hard rock.

(a) **(b)** **(c)** **(d)**

(e)



(f) **(g)** **(h)** **(i)**

Figure 5 Occupations observed in the Sujathanagar tank bed area (a) (b), Debris around the Sujathanagar tank (c) and cattle pollution in Chinamushidiwada tank (d), A panoramic view of Sujathanagar tank, showing the damaged weir (e), Vegetation growth across the weir (f) and breaching along Laxmipuram tank bund (g), Existing geddas with silt (h) and vegetation (i).

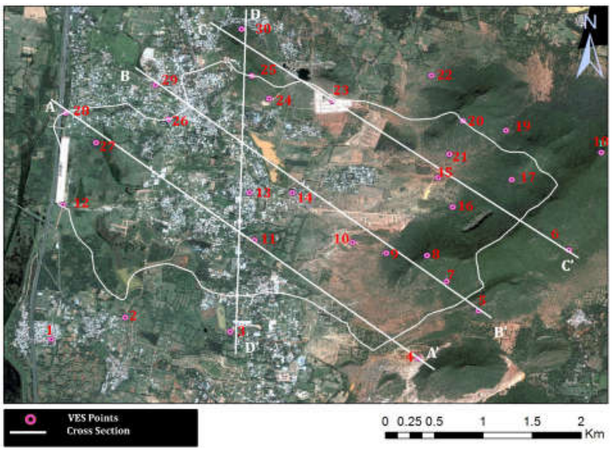


Figure 6 Traverse along the VES locations A, B, C and D

The location 11, which is half a kilometre away from Vellimeraka, where the elevation recorded with respect to Mean Sea Level (MSL) for weathered rock is 14.97 m and beyond 7.28m depth, is hard rock. The recording station 4 which is 760 metres away from Simhapuri Colony in northeast direction recorded elevation with respect to Mean Sea Level (MSL) for weathered rock is 76.43 m, and 52.93 m is the elevation recorded for fractured rock and beyond fracture rock is hard rock. It is observed that the section A-A' having good layer thickness of weathered and fractured rock indicating an excellent ground water potential zone along the traverse A-A'.

Along the cross section A-A', the area represented in blue in the figure 7 is weathered rock extending from VES location 27 to 11 and this area identified as potential aquifer zone.

The green and yellow color in the figure represents Fracture and Hard fracture rock respectively. The red color having high apparent resistivity in the figure is hard rock.

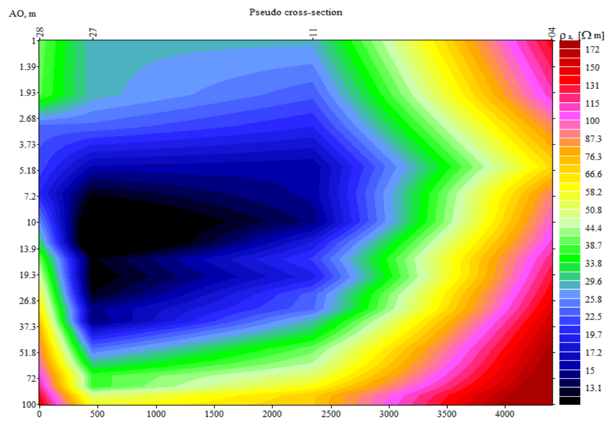


Figure 7 Subsurface lithological vertical cross section along the traverse A-A'

Subsurface lithological vertical cross section along the traverse B-B'

Lithological section B-B' which traverses through VES recorded stations 29, 26, 13, 14, 10 and 9 respectively, extending from Pendurthi Police Station area to Yerrakonda hill falling in the middle portion of the study area. In the location 29 of Pendurthi PS, elevation with respect to Mean Sea Level (MSL) recorded for weathered rock is 22.31 m, beyond weatherd rock is hard rock. In the location 26 of Chanakya Nagar, elevation with respect to MSL recorded for weathered rock is -25.1 m, and beyond is hard fractured rock. The location 13 of Sujatha Nagar, recorded elevation with respect to MSL for weathered rock as 23.01 m, and after 23.01

metre is fractured rock. The recording station 14 of Sujatha Nagar, recorded elevation with respect to MSL for weathered rock as 40.87 m, and -20.83 m is the elevation recorded for fractured rock and beyond is hard rock. The recording station 10 of Yerrakonda hill, recorded elevation with respect to MSL for weathered rock as 37.25 m,. The recording station 9 of Yerrakonda hill, recorded elevation with respect to MSL for weathered rock as 69.33 m, and after 69.33 is hard fractured rock.

Along the cross section B-B', the area represented in blue in the figure 8 is weathered rock extending from VES location 29 to 14 and this area identified as potential aquifer zone. The green and yellow color in the figure represents Fracture and Hard fracture rock respectively. The red color having high apparent resistivity in the figure is hard rock. The VES location 10 and 9 are in the foothill region of yerrakonda hill, hence the area has low aquifer potential.

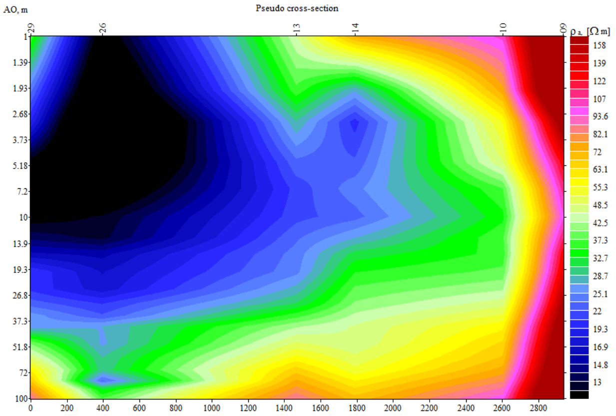


Figure 8 Subsurface lithological vertical cross section along the traverse B-B'

Subsurface lithological vertical cross section along the traverse C-C'

The figure 4.44 represents lithological section C-C' which traverses through VES recorded stations 30, 25, 24, 23, 15, 16 and 6 respectively, extending from Penduruthi Hill to Yerrakonda Hill falling in the upper portion of the study area. In the location 30 of Penduruthi Hill, elevation with respect to MSL recorded as 78.74 m for weathered and72.36 recorded for fractured.

In the location 25 of Penduruthi Hill, 198.89 m elevation with respect to MSL recorded for weathered and fractured rock respectively. The location 24 of Penduruthi Hill, where the elevation recorded with respect to Mean Sea Level 66.43 m for weathered and 44.23 m is the elevation recoded for fractured rock. The location 23 of Penduruthi Hill, where the elevation recorded with respect to Mean Sea Level 67.83 m for weathered and 54.61 m is the elevation recoded for fractured rock. The location 15 of Yerrakonda Hill, where the elevation recorded with respect to Mean Sea Level is 71.34 m for weathered and fractured rock. The recording station 16 Yerrakonda Hill which as recorded elevation with respect to Mean Sea Level for weathered rock is 84.6 m, and 40.8 m is the elevation recorded for fractured rock. The recording station 6 Yerrakonda Hill which as recorded elevation with respect to Mean Sea Level for weathered and fractured rock as recorded 117.48 m. It is observed that the section C-C' having relatively poor layer thickness of weathered and fractured rock indicating a weak ground water potential zone for recharge along the traverse C-C'.

Along the cross section C-C', the area represented in blue in the figure 9 is weathered rock extending from VES location 24 to 16 and this area identified as potential aquifer zone but if comparing to other cross section, the area is not high potential. The green and yellow color in the figure represents Fracture and Hard fracture rock respectively. The red color having high apparent resistivity in the figure is hard rock.

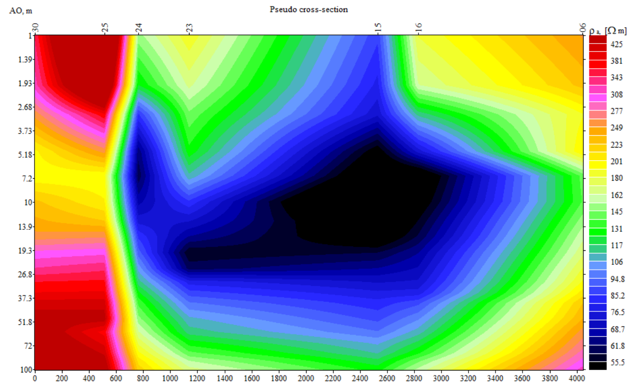


Figure 9 Subsurface lithological vertical cross section along the traverse C-C'

Subsurface lithological vertical cross section along the traverse D-D'

The figure 4.45 represents lithological section D-D' which traverses through VES recorded stations 30, 25, 24, , 13, 14, 11 and 3 respectively, extending from Penduruthi Hill to Yerrakonda Hill falling in the upper portion of the study area. In the location 30 of Penduruthi Hill, elevation with respect to MSL recorded as 78.74 m for weathered and72.36 recorded for fractured. In the location 25 of Penduruthi Hill, 198.89 m elevation with respect to MSL recorded for weathered and fractured rock respectively. The location 24 of Penduruthi Hill, where the elevation recorded with respect to Mean Sea Level 66.43 m for weathered and 44.23 m is the elevation recoded for fractured rock.The location 13 of Sujatha Nagar, recorded elevation with respect to MSL for weathered rock as 23.01 m, and after 23.01 metre is Fractured rock. The recording station 14 of Sujatha Nagar, recorded elevation with respect to MSL for weathered rock as 40.87 m, and -20.83 m is the elevation recorded for fractured rock and beyond is hard rock. The location 11, which is half a kilometre away from Vellimeraka, where the elevation recorded with respect to Mean Sea Level (MSL) for weathered rock is 14.97 m and beyond 7.28 m depth, is hard rock. The location 3 of Penduruthi Hill, where the elevation recorded with respect to Mean Sea Level 21.40 m for weathered and beyond hard rock. It is observed that the section D-D' having good layer thickness of weathered and fractured rock indicating an good ground water potential zone for recharge along the traverse D-D'.

Along the cross section D-D', the area represented in blue in the figure 10 is weathered rock extending from VES location 13 to 03 and this area identified as potential aquifer zone but if comparing to other cross section, the area is high potential aquifer zone. The green and yellow color in the figure represents Fracture and Hard fracture rock respectively. The red color having high apparent resistivity in the figure is hard rock.

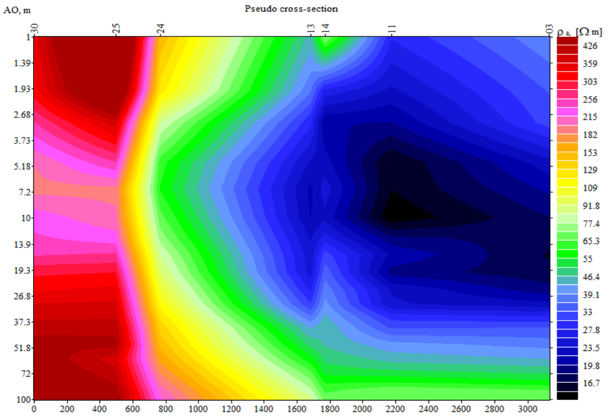


Figure 10 Subsurface lithological vertical cross section along the traverse D-D'

From all the vertical cross sections, it is clear that the thickness of the water bearing formations i.e., weathered and fractured rock zones has increased from the foot hill regions to the low lying areas of the study area. Over the hill slopes and hill ridges, hard rock is present immediately below the top soil. Even though there is some fractured rock zones noticed over the hill slopes, these may not contain aquifer system but may guide the rainwater to percolate from the top soils into the aquifer system down below.

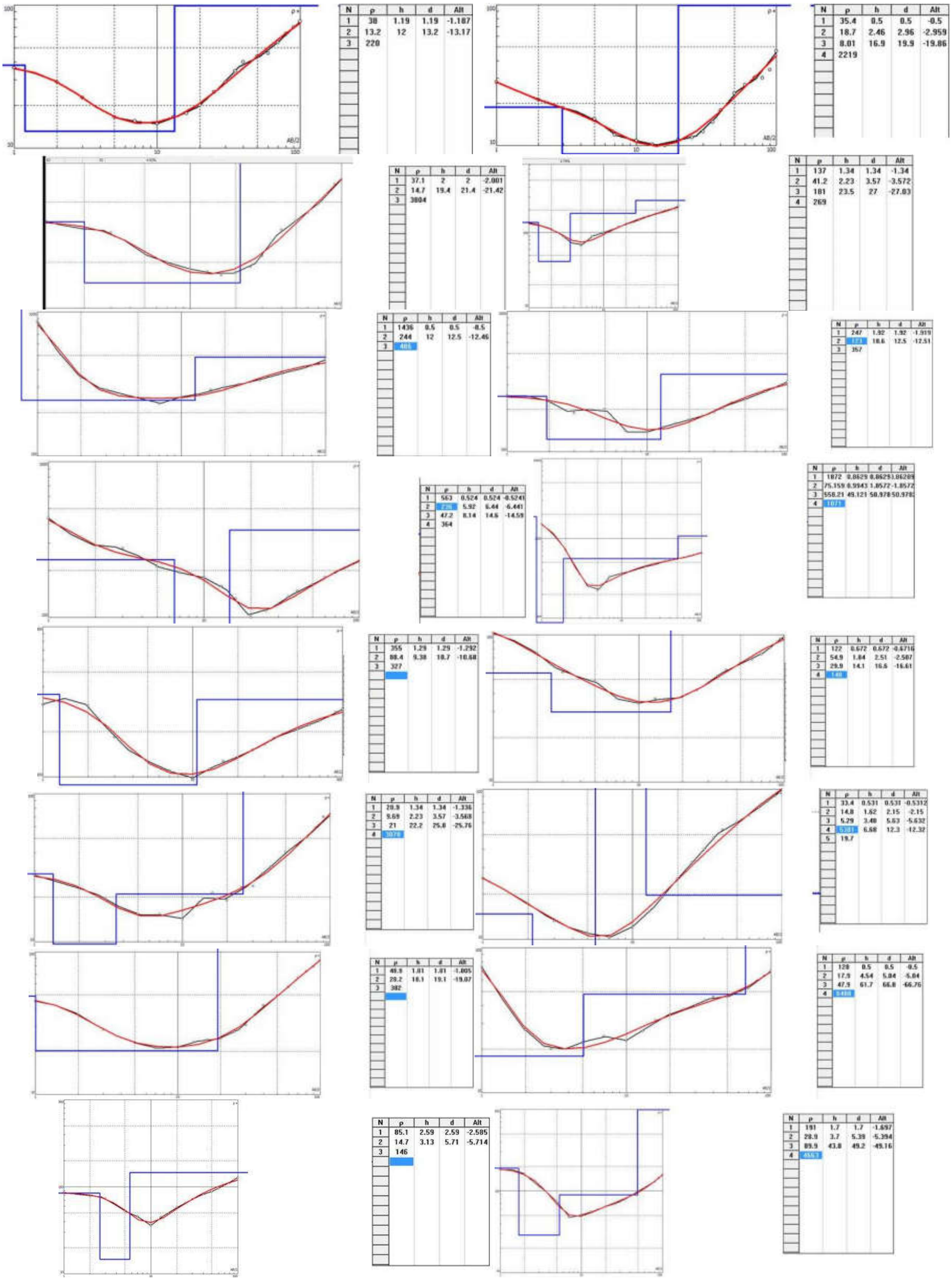
Table 1, below illustrates the results of the fieldwork that was carried out during the Vertical Electrical Sounding experiment for exploring Groundwater for Part of Visakhapatnam Urban Area, Andhra Pradesh, India.

VES No	Type of Curve	Resistivity Ω-m	Thickness (Meter)	Depth (meter)	Lithological Units
1	H	38	1.19	1.19	Red Loamy Soil
		13.2	12	13.20	Weathered Rock
		220	-	-	Fractured Rock
2	QH	35.4	0.5	0.50	Red Loamy Soil
		18.7	2.46	2.96	Gravel
		8.01	16.9	19.90	Weathered Rock
		2219	-	-	Hard Rock
3	H	37.1	2	2.00	Red Loamy Soil
		14.7	19.4	21.40	Weathered Rock
		3804	-	-	Hard Rock
4	HA	137	1.34	1.34	Gravel & Boulder
		41.2	2.23	3.57	Weathered Rock
		181	23.5	27.07	Fractured Rock
		269	-	-	Hard Fractured Rock
5	H	1436	0.5	0.50	Gravel & Boulder
		244	12	12.50	Fractured Rock
		486	-	-	Hard Fractured Rock
6	H	247	1.92	1.92	Gravel & Boulder
		123	10.6	12.52	Weathered Rock
		357	-	-	Hard Fractured Rock
7	QH	563	0.524	0.52	Gravel & Builder
		236	5.92	6.44	Gravel
		47.2	8.14	14.58	Weathered Rock
		364	-	-	Hard Fractured Rock
8	HA	1872	0.8629	0.86	Gravel & Boulder
		75.159	0.9943	1.86	Gravel
		558.21	49.121	50.98	Hard Fractured Rock
		1071	-	-	Hard Rock
9	H	355	1.29	1.29	Gravel & Boulder
		88.4	9.38	10.67	Weathered Rock
		327	-	-	Hard Fractured Rock
10	QH	122	0.672	0.67	Gravel & Boulder
		54.9	1.84	2.51	Gravel
		29.9	14.1	16.61	Weathered Rock
		148	-	-	Fractured Rock

Table 1 Continues

VES No	Type of Curve	Resistivity Ω-m	Thickness (Meter)	Depth (meter)	Lithological Units
11	HA	28.9	1.34	1.34	Red Loamy Soil
		9.69	2.23	3.57	Clay
		21	22.2	25.77	Weathered Rock
		3070	∞	-	Hard Rock
		27.7	0.91	0.91	Red Loamy Soil
12	QHK	895	7.89	8.6	Weathered Rock
		2926	∞	-	Hard Rock
		48.9	1.01	1.01	Red Loamy Soil
13	H	20.2	18.1	19.11	Weathered Rock
		382	∞	-	Fractured Rock
14	HA	128	0.5	0.50	Gravel & Boulder
		17.9	4.54	5.04	Weathered Rock
		47.9	61.7	66.74	Fractured Rock
		6480	∞	-	Hard Rock
15	H	85.1	2.59	2.59	Gravel & Boulder
		14.7	3.13	5.72	Weathered Rock
		146	∞	-	Fractured Rock
16	HA	191	1.7	1.70	Gravel & Boulder
		28.9	3.7	5.40	Weathered Rock
		89.9	43.8	49.20	Fractured Rock
		4663	∞	-	Hard Rock
17	HKH	816	1.02	1.02	Gravel & Boulder
		44.4	1.25	2.27	Weathered Rock
		1280	2.3	4.57	Boulder
		119	7.68	12.25	Fractured Rock
		722	∞	-	Hard Fractured Rock
18	HK	1677	1.81	1.81	Gravel & Boulder
		661	11.5	13.3	Fractured Rock
		1356	∞	-	Hard Fractured Rock
19	H	468	1.99	1.99	Gravel & Boulder
		53.7	2.38	4.37	Fractured Rock
		1168	∞	-	Hard Fractured Rock
20	H	2138	0.961	0.96	Gravel & Boulder
		436	7.84	8.80	Fractured Rock
		1442	∞	-	Hard Fractured Rock
21	HA	249	1.34	1.34	Gravel & Boulder
		71.1	2.23	3.57	Fractured Rock
		363	21.9	25.47	Hard Fractured Rock
		629	-	-	Hard Rock
22	HA	203	1.58	1.58	Gravel & Boulder
		47.9	2.29	3.87	Weathered Rock
		216	35.5	39.37	Fractured Rock
		24848	-	-	Hard Rock
23	QH	203	0.744	0.74	Gravel & Boulder
		136	4.41	5.15	Hard Fractured Rock
		28.8	8.81	13.96	Fractured Rock
		318	-	-	Hard Fractured Rock
24	HA	162	1.34	1.34	Gravel & Boulder
		30.3	2.23	3.57	Weathered Rock
		117	22.2	25.77	Fractured Rock
		435	-	-	Hard Fractured Rock
25	H	1046	1.11	1.11	Boulder
		162	6.07	7.18	Fractured Rock
		498	-	-	Hard Fractured Rock
26	HA	12.3	0.938	0.94	Red Loamy Soil
		2.93	1.36	2.30	Clay
		27.1	63.6	65.90	Weathered Rock
		1164	-	-	Hard Fractured Rock
27	H	3.01	2.04	2.04	Clay
		7.82	15.2	17.24	Weathered Rock
		11377	-	-	Hard Rock
28	H	47.9	1.2	1.20	Gravel
		13.4	4.46	5.66	Weathered Rock
		229	-	-	Fractured Rock
29	QHA	46.3	0.5	0.50	Red Loamy Soil
		23.6	1.53	2.03	Gravel
		4.1	2.2	4.23	Clay
		25.3	16.1	20.33	Weathered Rock
		14887	-	-	Hard Rock
30	H	370	1.26	1.26	Gravel & Weathered
		161	6.38	7.64	Fractured Rock
		608	-	-	Hard Fractured Rock

However, the hill slopes are useful to retain rainwater for some time and release it into the aquifer system existing down below the foot hill region. Therefore this zone is considered to be suitable for constructing harvesting structures, like contour trenches. The geometric factor, K, were determine for all the electrode spacing using the relation; $K = \pi (L^2/2b - b/2)$, for Schlumberger configuration in which MN=2b and AB/2=L. The results obtained were multiplied with the resistance values to obtain the apparent resistivity, ρa values. By the use of IPI2win software the result of apparent resistivity and electrode spacing was plotted in a log-log scale to obtain VES sounding curve. Below are the sounding curves and their models for all 30 VES locations.



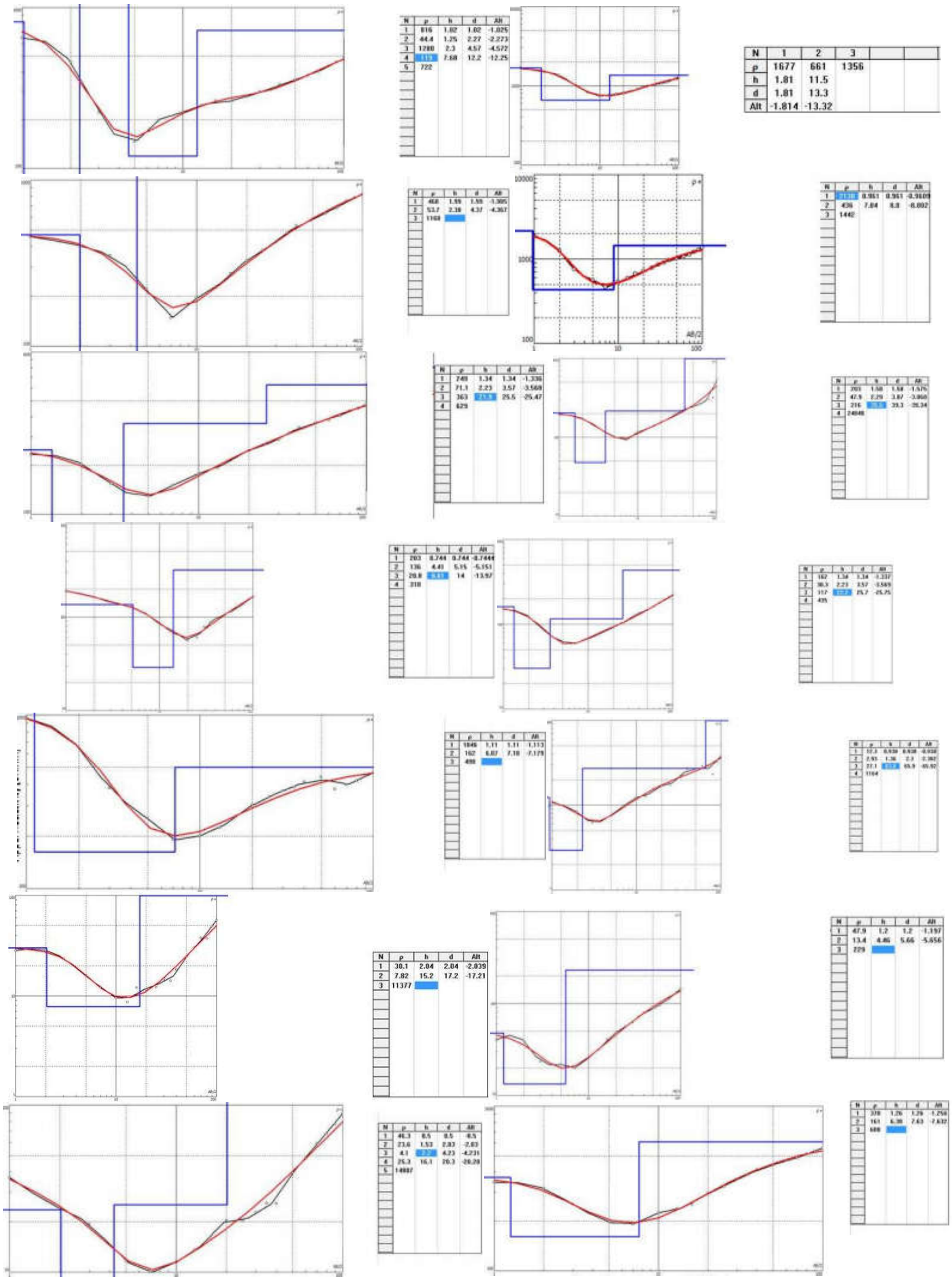


Figure 11 Graphs of apparent resistivity (Ωm) against Electrode spacing (m) for all 30 VES Locations.
Where N is the number of layers; P is the apparent resistivity; h is the thickness and d is the depth to interface of each layer.

Where N is the number of layers; P is the apparent resistivity; h is the thickness and d is the depth to interface of each layer.

CONCLUSION

Borehole Lithological Information in and around the study area

The borehole lithological information is collected from various locations in and around the study area. Total four borehole investigations were conducted at VUDA Colony, Laxmipuram, Drivers Colony and Sujatha Nagar respectively.

Borehole in VUDA Colony is done for Vishakha urban development authority revield four layes, first layer extending from ground to 10 metre below revealed Gravel and Boulder, second layer extending till 50 metre reviel weatherd rock, third layer extending from 50 to 80 metre below reveled fractured rock and last layed which beyond 80 metre depth is hard rock. Borehole in Laxmipuram is done for Rural Water Supply Scheme of Panchayathiraj (RWSP) Vishakhapatnam, revield four layes, first layer extending from ground to 3 metre below revealed soil, second layer extending till 30 metre reviel weatherd rock, third layer extending from 30 to 90 metre below reveled fractured rock and last layed which beyond 90 metre depth is hard rock.

Table 2 Lithological information of Borehole Stations

Borehole Stations	Location	Depth(m)	Lithological Units
1	VUDA Colony (VUDA)	0 to 10	Gravel& Boulder
		10 to 50	Weathered Rock
		50 to 80	Fractured Rock
		> 80	Hard Rock
2	Laxmipuram (RWSP Scheme, VSP)	0 to 3	Soil
		3 to 30	Weathered Rock
		30 to 90	Fractured Rock
		> 90	Hard Rock
3	Drivers Colony (N. Nookaraju House Purpose)	0 to 0.5	Soil
		0.5 to 15	Gravel
		15 to 50	Fractured Rock
		> 50	Hard Rock
4	Sujatha Nagar (BHPV-VSP)	0 to 2	Soil
		2 to 20	Weathered Rock
		20 to 80	Fractured Rock
		> 80	Hard Rock

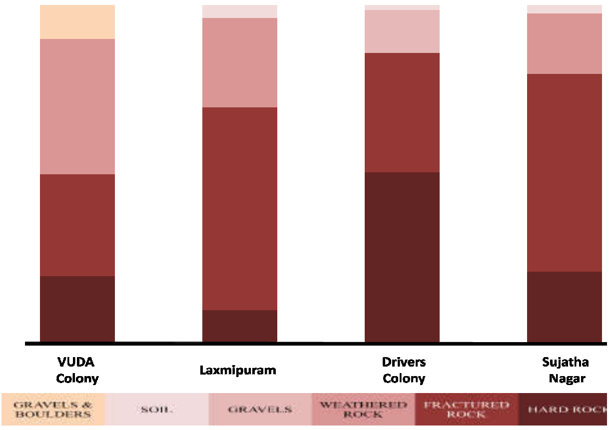


Figure 12 Borelog Profile of four locations

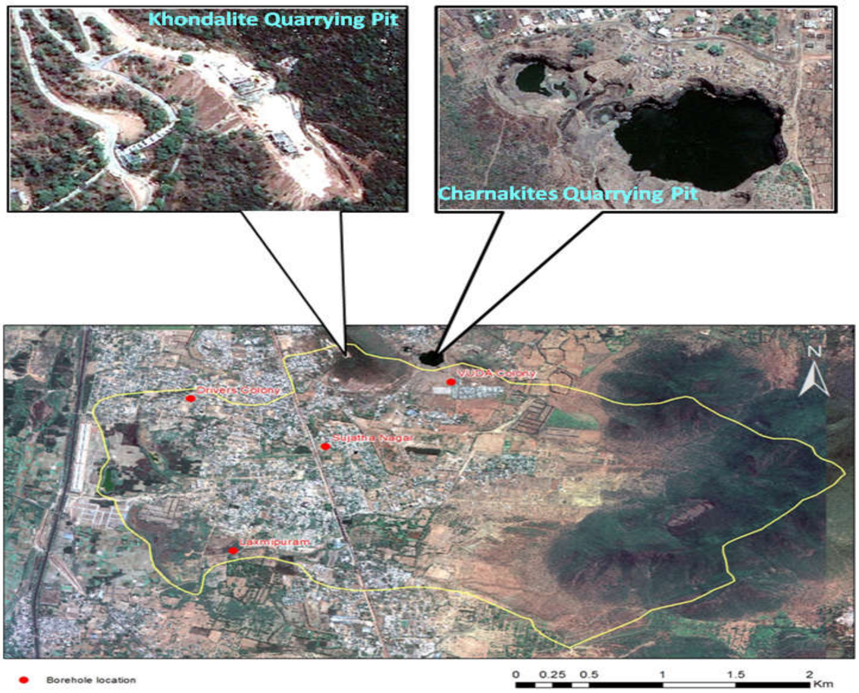


Figure 13 a Showing Locations of Boreholes and Quarrying pits

Figure 13 b Lithological information from Quarrying Pits/Rock Outcrops of Validation Data Points

Borehole data collected from local inhabitant Mr N. Nookaraju for household purpose, revield four layes, first layer extending from ground to 0.5 metre below revealed soil, second layer extending till 15 metre revealed gravel, third layer extending from 15 to 50 metre below reveled fractured rock and last layed which beyond 50 metre depth is hard rock. Borehole data from Sujatha Nagar is done for Bharat Heavy Plates & Vessels (BHPV) Vishakhapatnam, revield four layes, first layer extending from ground to 2 metre below revealed soil, second layer extending till 20 metre reviel weatherd rock, third layer extending from 80 to 90 metre below revealed fractured rock and last layed which beyond 80 metre depth is hard rock. The collected borehole data is given below in the table 2. The bore hole data were analysed with VES data nearest to the location of borewell and identified that the VES data is almost similar to borewell data. The result is strongly proven that VES data are more accurate and it is a essential tool for identifying ground water.

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