J. Ind. Geophys. Union ( November 2017 )
**v.21, no.6, pp: 465-473**

# Delineation of groundwater potential zones using geo-electrical surveys in SSW part of Yeleru river basin, East Godavari District, Andhra Pradesh

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**ABSTRACT**

Data of 40 Vertical Electrical Resistivity soundings covering an area of about 144 square kms located in SSW part of Yeleru river basin, East Godavari district provided by Andhra Pradesh state Ground Water department was analyzed to delineate potential sources of ground water, its extent and depth of water table. The study revealed mainly a three layer subsurface with top layer consisting of clay/lateritic gravel, followed by the sandstones. The general geology of the study area is Rajahmundry sandstone. Saturated sandstone with a resistivity range of 10-50 Ωm extending to a maximum depth of approximately 135 m forms the major aquifer, while layers with less than 10 Ωm may be possibly due to high clay content and hence poor aquifers. The fence diagrams and geoelectric sections reveal potential aquifers in the northern part of the region dominated by a thickness of 21-50m with a small patch showing a thickness above 50m and clay dominated zones in the southern part of the region, which are unevenly distributed. Thus, the study provides vital clues on the distribution and thickness of the aquifer, which helps to decide the type of well to be built (dug well, bore well) in future groundwater exploration/ exploitation programs.

**Key words:** Yeleru river basin, Vertical Electrical Soundings, Groundwater potential zones, Fence diagram, geo electric sections.

## INTRODUCTION

Yeleru River is one of the major streams in East Godavari district. The basin area covers different geological formations like Flood plains, Rajahmundry sandstones, Tirupati sandstones, Charnockites and Migmatite group of rocks including Deccan traps. The present study is confined to the Rajahmundry sandstone formations in the basin area. This study area located between 17.00$^0$ to 17.13$^0$ N latitudes and 82.00$^0$ to 82.17$^0$ E longitudes spread over an area of 144.224sq.km (Figure 1) covers the villages around Peddapuram mandal, which is an irrigation command area. The major crops in the area are Tapioca, Rice and Sugar cane (Groundwater Brochure, 2013). The topography of the area varies from 33 to 81m above mean sea level. The average annual rainfall of the district is about 1280 mm (East Godavari district web portal), of which more than half contributed by South-West monsoon. Figure 2 shows the total annual rainfall during six years (2009-2014). This chart also indicates total maximum rainfall of 1909 mm during the year 2010 (much above annual average of 1280 mm), which decreased from 2012 onwards touching a low of 632 mm in 2014. This has resulted in decline in groundwater levels in all the three study blocks with maximum difference in Ramesampeta from 5.29m in the year 2013 to 12.62m in 2014. Due to the heavy demand of water for irrigation, people looked for deeper groundwater to meet their requirements.

Among all the geophysical methods the resistivity techniques especially the Vertical Electrical Sounding (VES) method is widely used for investigating subsurface layer parameters and groundwater potential (Jagadeswara Rao, 2003; Hardianshah and Abdul Rahim, 2013). This method was found suitable for hydro-geological surveys in sedimentary rocks (Kelly and Stanislav, 1993; Hadi, 2009). In sedimentary rocks, the resistivities of the interstitial fluid are probably more important than that of the host rock. Resistivity for sandy material is about 100Ωm and decreases with increasing clay content to about 40Ωm and the values decrease further to 1-10Ωm for those more typical of clay (Reynolds, 1987a; Majumdar and Das, 2011). In the present study, a detailed investigation has been made to identify the ground water potential zones in the study area using electrical resistivity sounding data.

### Hydrogeology of the Study Area:

Groundwater in the study area occurs under phreatic and semi confined conditions and the hydro geological regime of the area is influenced by the Yeleru River. There are three observation wells, which have been monitored for six years from 2009 to 2014 during both pre monsoon and post monsoon. These three open wells show depths of water level of 24m at Peddapuram, 16m at Ramesampeta and 8m at Katravulapalli. As the infiltration rate is high in sandstone formations, the depth to water level has been

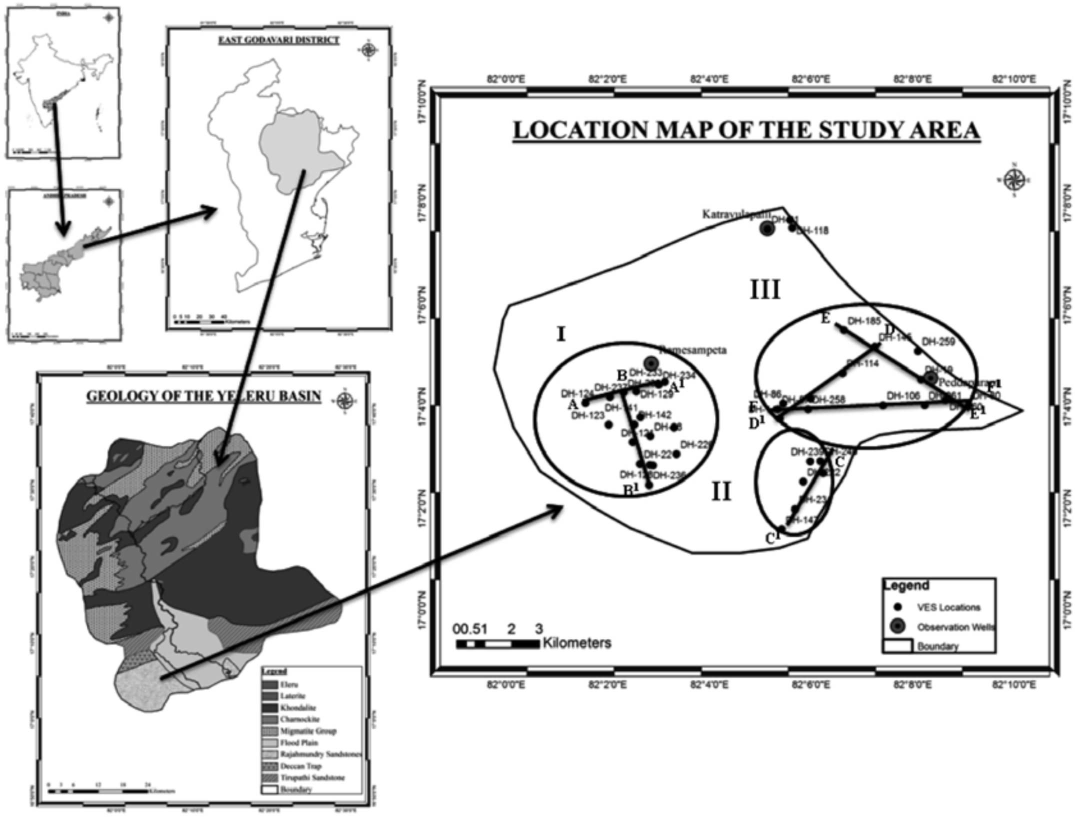


**Figure 1.** Location map of the study area.

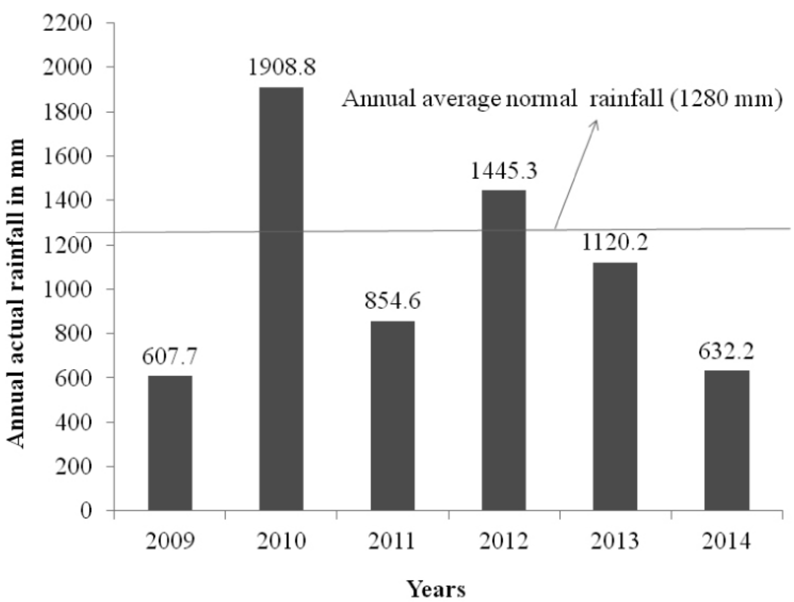


**Figure 2.** Actual annual rainfall of the district (2009-2014).

raising abruptly during post monsoon in all wells (Figure 3). Very Shallow water levels were clearly observed during post monsoon of 2010, 2012 and 2013 wherein the water levels in these three years were much deeper during pre-monsoon.

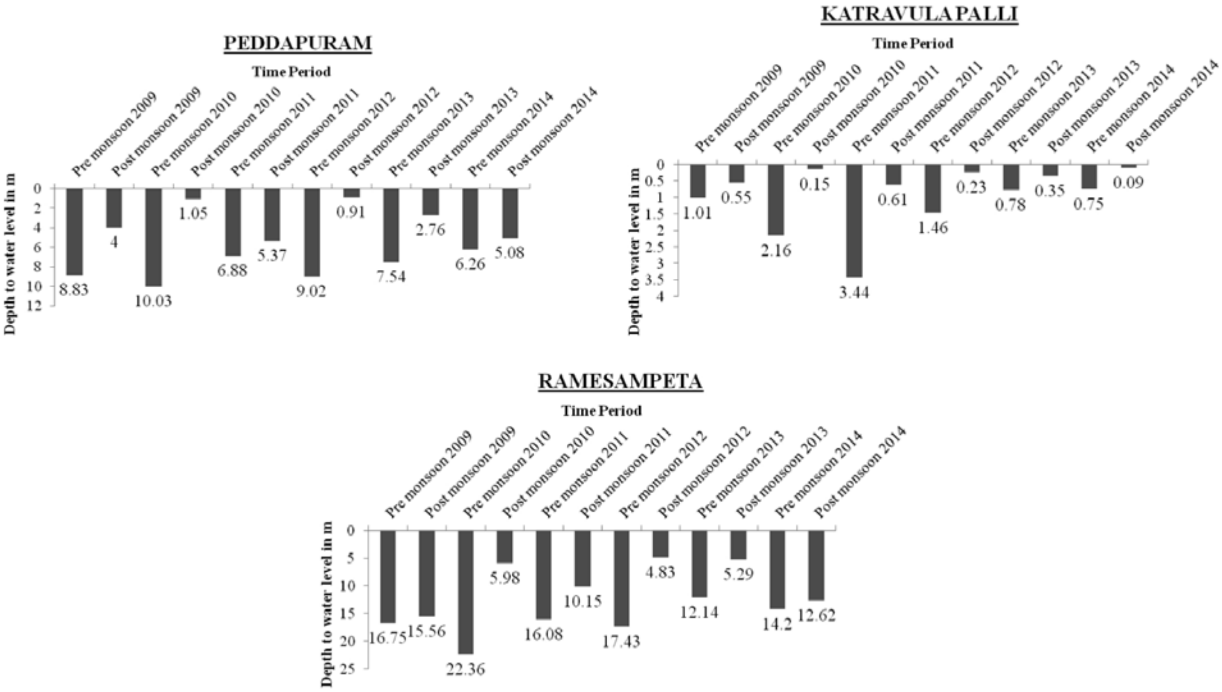


**Figure 3.** Depth to water levels in dug wells during the period 2009-2014 (Pre and Post monsoons) at three locations Peddapuram, Katravulapalli and Ramesampeta.

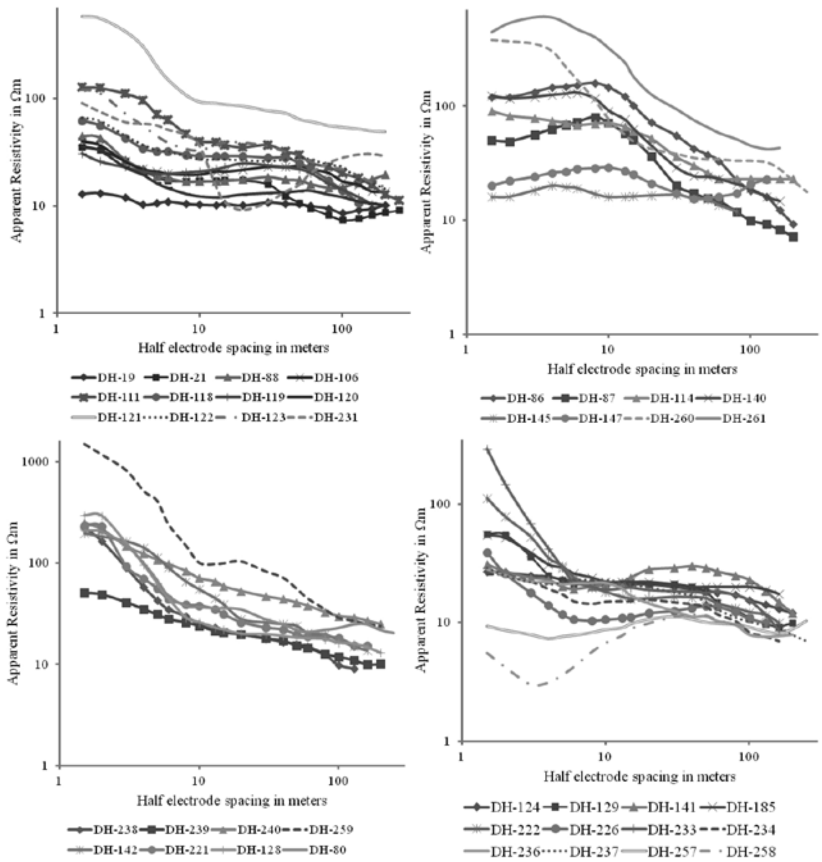


**Figure 4.** Vertical Electrical Sounding curves (40 nos.) of the study area.

**Table 1.** Interpreted Results of the vertical electrical soundings.

| Code | Longitude | Latitude | Elevation | Resistivity (Ωm) | | | | | Thickness (m) | | | | Total Thickness(m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1st Layer | 2nd Layer | 3rd Layer | 4th Layer | 5th Layer | 1st Layer | 2nd Layer | 3rd Layer | 4th Layer | |
| DH-19 | 82.136 | 17.0757 | 41 | 17.7 | 10.2 | 4.6 | 18.9 | | 0.9 | 50.8 | 31.9 | | 83.6 |
| DH-80 | 82.1517 | 17.0674 | 41 | 279.5 | 34.3 | 8 | 71.6 | 12.1 | 1.4 | 19.7 | 14.9 | 30.6 | 66.6 |
| DH-86 | 82.0908 | 17.0678 | 54 | 102.9 | 249.8 | 42.3 | 8.4 | | 1.5 | 3.7 | 36.5 | | 41.7 |
| DH-87 | 82.089 | 17.066 | 56 | 66.1 | 204.2 | 41.2 | 8.2 | | 0.6 | 5.2 | 37.2 | | 43 |
| DH-88 | 82.0473 | 17.0571 | 60 | 72 | 16 | 25 | 8 | 30 | 1 | 10 | 15 | 30 | 56 |
| DH-106 | 82.1235 | 17.0673 | 53 | 55 | 19 | 26 | 10 | | 1 | 10 | 40 | | 51 |
| DH-111 | 82.104 | 17.045 | 40 | 142.2 | 34.1 | 10.9 | | | 2.1 | 41.8 | | | 43.9 |
| DH-114 | 82.1103 | 17.0778 | 45 | 89.3 | 70.4 | 20.5 | 39.4 | | 1 | 10.5 | 111.6 | | 123.1 |
| DH-120 | 82.0471 | 17.0477 | 58 | 39.9 | 11.1 | 15.3 | 8.7 | | 1.5 | 11.7 | 39.4 | | 52.6 |
| DH-121 | 82.0414 | 17.0551 | 65 | 645.8 | 80.3 | 46.6 | | | 1.8 | 26.7 | | | 28.5 |
| DH-122 | 82.055 | 17.06 | 66 | 76.4 | 26.5 | 7 | | | 1.3 | 77.8 | | | 79.1 |
| DH-123 | 82.0336 | 17.0609 | 64 | 147 | 26 | 100 | 24 | 13 | 1.4 | 5.5 | 4 | 45 | 55.9 |
| DH-124 | 82.026 | 17.068 | 72 | 27 | 20 | 11 | | | 2 | 42 | | | 44 |
| DH-128 | 82.0482 | 17.0476 | 56 | 470 | 38.5 | 19 | 9.1 | | 1.2 | 3 | 75.4 | | 79.6 |
| DH-129 | 82.0427 | 17.0717 | 77 | 142 | 21.2 | 4 | 20 | | 0.8 | 37.4 | 44.9 | | 83.1 |
| DH-140 | 82.0897 | 17.0628 | 54 | 82 | 261.1 | 26.7 | 12.1 | | 1 | 2.3 | 39.8 | | 43.1 |
| DH-141 | 82.044 | 17.0634 | 67 | 30 | 13 | 35 | 7 | | 1.5 | 3 | 50 | | 54.5 |
| DH-142 | 82.042 | 17.061 | 67 | 200 | 50 | 23 | 10 | | 2 | 8 | 60 | | 70 |
| DH-145 | 82.1208 | 17.0865 | 45 | 12 | 35 | 10 | 25 | 10 | 1 | 1.5 | 5.5 | 15 | 23 |
| DH-147 | 82.0903 | 17.0266 | 33 | 21.8 | 32.4 | 6.3 | 40.9 | | 2 | 14.1 | 21 | | 37.1 |
| DH-185 | 82.1107 | 17.0919 | 53 | 83 | 23 | 20 | 10 | | 1 | 12 | 123 | | 136 |
| DH-221 | 82.0438 | 17.0481 | 63 | 411.2 | 39.1 | 18.6 | 7 | | 1 | 10.4 | 120.8 | | 132.2 |
| DH-222 | 82.0974 | 17.0422 | 46 | 128.8 | 17.1 | 9 | | | 1.2 | 46.5 | | | 47.7 |
| DH-226 | 82.0558 | 17.0513 | 60 | 57.5 | 9.3 | 13.9 | 7 | | 1 | 5.6 | 60.6 | | 67.2 |
| DH-231 | 82.0947 | 17.0332 | 35 | 151.5 | 61.1 | 3.8 | 102.3 | 15.1 | 0.5 | 5.1 | 11.4 | 50.9 | 67.9 |
| DH-233 | 82.052 | 17.075 | 77 | 396.9 | 19.3 | 2.5 | | | 0.9 | 88.7 | | | 89.6 |
| DH-234 | 82.05 | 17.074 | 77 | 27.6 | 14.5 | 4.9 | | | 1.5 | 54.7 | | | 56.2 |
| DH-236 | 82.0469 | 17.0412 | 61 | 38.5 | 21.4 | 9.7 | 6.8 | | 0.5 | 9.3 | 44.3 | | 54.1 |
| DH-237 | 82.034 | 17.07 | 80 | 48.7 | 21.7 | 14.4 | 6.9 | | 0.5 | 15.1 | 26.6 | | 42.2 |
| DH-238 | 82.0385 | 17.0714 | 81 | 368.9 | 40.3 | 16.8 | 5 | | 0.9 | 3.8 | 45.3 | | 50 |
| DH-239 | 82.0997 | 17.0489 | 43 | 60 | 22 | 10 | | | 1.5 | 20 | | | 21.5 |
| DH-240 | 82.103 | 17.049 | 41 | 251.7 | 62.8 | 26.7 | | | 1.6 | 17.7 | | | 19.3 |
| DH-257 | 82.0999 | 17.0695 | 42 | 9.3 | 6.6 | 13.7 | 6.2 | 29.6 | 1.4 | 4 | 21 | 103.1 | 129.5 |
| DH-258 | 82.099 | 17.066 | 43 | 8.4 | 1.7 | 16.9 | 4.8 | | 0.8 | 1.7 | 28.1 | | 30.6 |
| DH-259 | 82.135 | 17.085 | 35 | 1547.3 | 99.3 | 23.1 | | | 1.7 | 22.5 | | | 24.2 |
| DH-260 | 82.144 | 17.069 | 46 | 377.5 | 36.3 | 4.9 | | | 2.9 | 114.1 | | | 117 |
| DH-261 | 82.1372 | 17.0673 | 55 | 391.9 | 727.9 | 95.8 | 39.8 | | 0.8 | 3.3 | 19.7 | | 23.8 |
| DH-21 | 82.0857 | 17.125 | 44 | 47.2 | 16.6 | 5.4 | 20 | | 1 | 24 | 84.7 | | 109.7 |
| DH-118 | 82.0938 | 17.1255 | 42 | 79.6 | 29.3 | 6.8 | | | 1 | 38.5 | | | 39.5 |
| DH-119 | 82.093 | 17.128 | 39 | 30 | 18 | 32 | 8.5 | | 1 | 6 | 23 | | 30 |

**Table 2.** Resistivity ranges of Sandstones.

| S.No. | Resistivity in Ωm | Formation |
|---|---|---|
| 1. | <10 | Saturated Clay |
| 2. | 10-50 | Unconsolidated/Saturated Sandstones |
| 3. | 51-250 | Top soil/Dry sands/Consolidated sandstones |
| 4. | 251-1550 | Lateritic gravel |

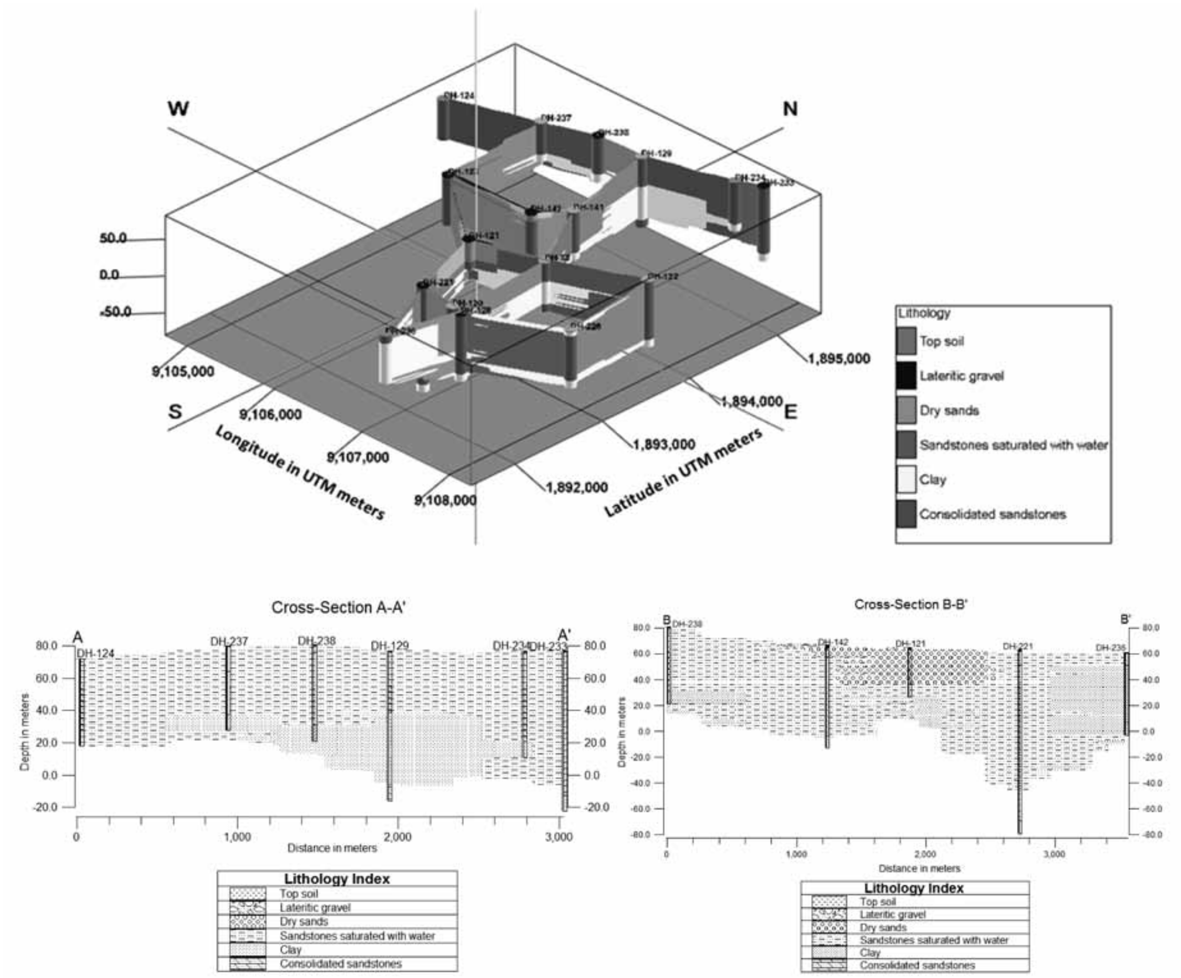


**Figure 5.** Top figure is the fence diagram for region-I, Bottom two figures are the lithologies along the geo-electric section AA` and BB` of Figure 1.

## METHODOLOGY

Electrical resistivity data of 40 Vertical Electrical Soundings (VES) using Schlumberger array with maximum of half-current electrode spacing varying between 100-250 m are initially interpreted with theoretical curves prepared by Orellana and Mooney (1966) for having preliminary understanding of the true resistivities and thicknesses of the subsurface layers of different composition. The shapes of the curves indicate 3-5 layer subsurface patterns corresponding to Q, HK, KH, QH, KQ, QQ, HKH, QHK, HKQ and KHK (Figure 4). These curves have been interpreted with the inversion technique using RESIST program (Vander Velpen and Sporry, 1993) based on the criteria of flexibility and user friendliness to process the data with Wenner, Schlumberger and Dipole-Dipole arrays. The results obtained from partial curve matching technique were given as inputs for RESIST program. The inversion of the resistivity data is based on the Marquardt-Levenberg technique. The layers resistivity and thicknesses of all the

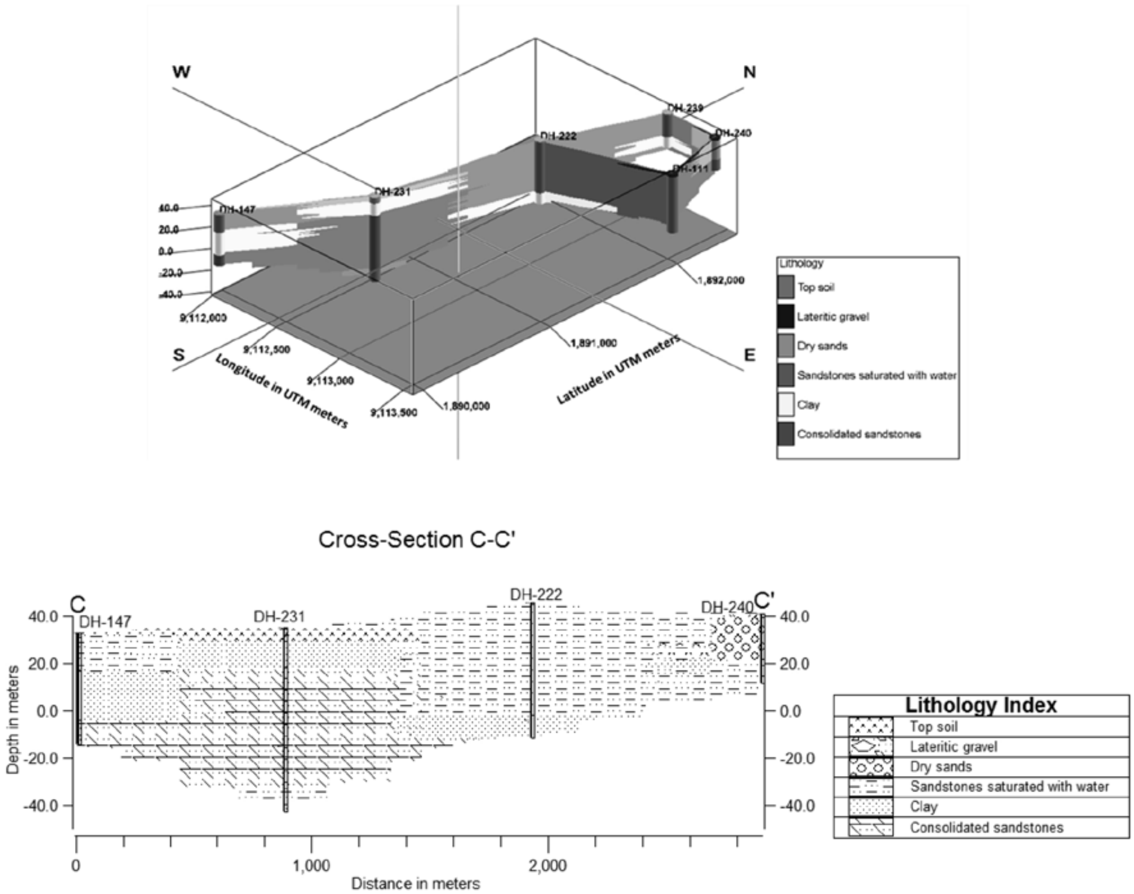


**Figure 6.** Top figure is the fence diagram for region-II, Bottom figure is the lithology along the geo-electric section CC` of Figure 1.

sounding curves determined with RESIST program are given in table-1.

## Sub Surface Lithology:

Based on the interpreted resistivity values, geology of the area and lithology of the three observation wells, the subsurface lithology is classified broadly into clay, consolidated and unconsolidated sandstones and gravel (Reynolds, 1997; Hasan et al., 2013). The resistivity ranges of these formations are shown in table 2. In some pockets of the study area, dry sand is observed in the top layer. Most of the curves initially show descending trend with an exception of a very few curves with a high second layer resistivity. Such a trend could probably be due to dry sandy/lateritic gravel layer followed by a steep fall in the third layer resistivity (~41-42Ωm) with a larger thickness of approximately 36-37m (DH86 and DH87), which could be a potential zone of groundwater. The top layer consists of sand/sandy loam/dry soils/lateritic gravel with a thickness of 0.5 to 2.9m with an average thickness of 1.7m underlain by saturated sandstones at many places. In addition to this, clay formations (very low resistive less than 10 Ωm) were identified at a few locations in deeper layers. Sounding data inferred the thickness of saturated sandstones varying between 10 – 135m (maximum at DH-185).

The study area is divided into three regions (I, II & III in Figure 1) and fence diagrams have been generated based on the lithology of the observation wells and resistivity values (table 2) for each region separately, for better view of the lithology. Fence diagrams for regions-I, II and III are drawn based on 17, 6 and 14 soundings, respectively. For each region, soundings located along straight lines are connected for drawing geoelectric sections (AA`, BB`, CC`, DD`, EE`, FF`), based on the resistivity values. All these fence diagrams and sections are shown in Figures 5, 6 and 7.

Discussion of Region-I: Fence diagram for this region (top of Figure 5) covering an area of about 17.4 square km is drawn on the basis of layer resistivities and thicknesses of 17 VES data. By looking at this figure, one can easily infer that bed rock is not reached at any of the sounding points in spite of the sounding spread extending to 250m (AB/2). Saturated sands of Rajahmundry sandstones, which form a major aquifer (resistivity range 10-50 Ωm) occupy maximum area of the region and extend to a maximum depth of 50m below

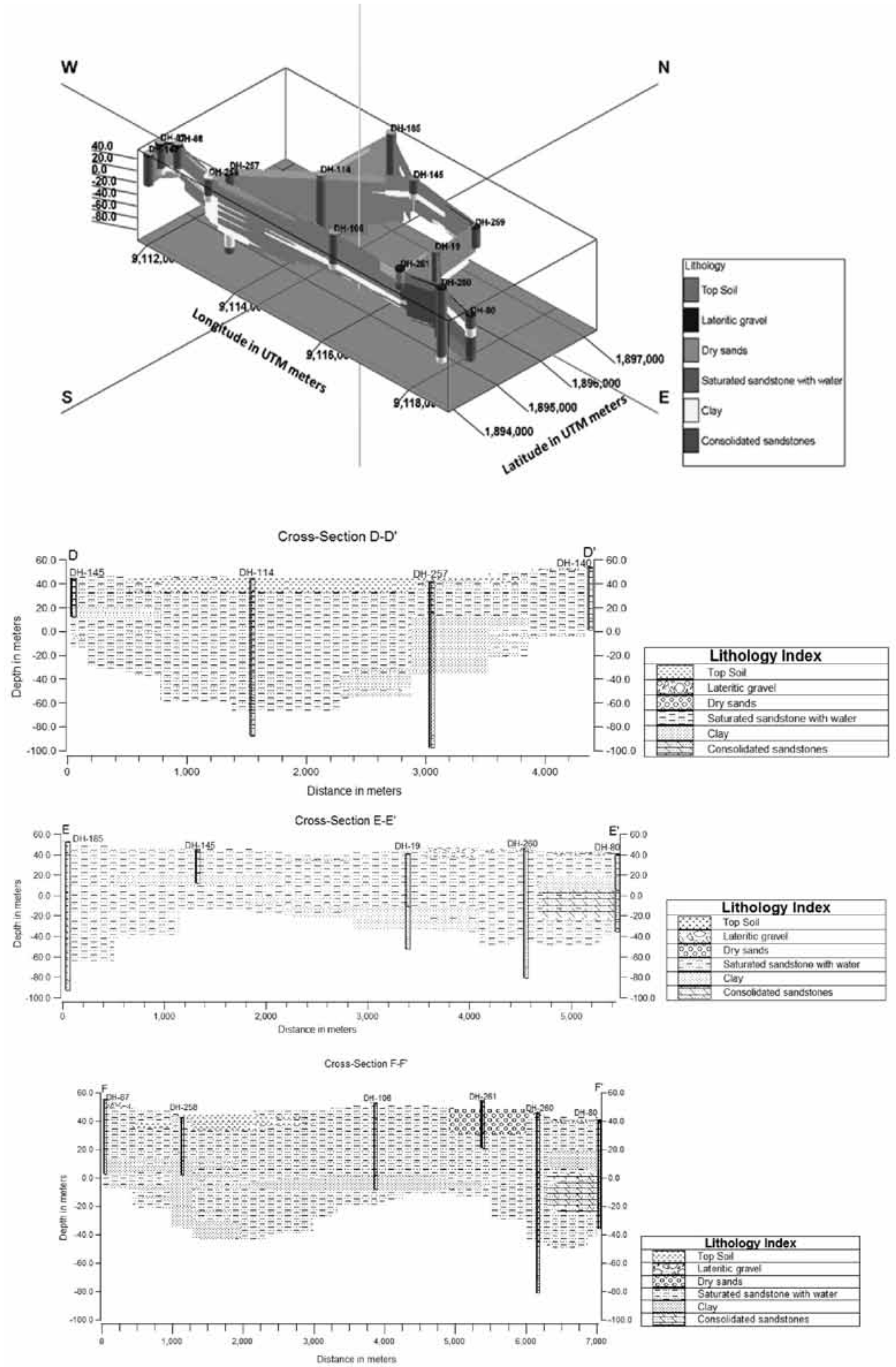


**Figure 7.** Top figure is the fence diagram for region-III, Bottom three figures are the lithologies along the geo-electric section DD`, EE` and FF` of Figure 1.

mean sea level (DH-221). Open well dug at Ramesampeta in this region up to a depth of 16m also shows sandstone.

Bottom diagrams of Figure 5 are lithological sections along profiles AA′ and BB′ of region-I (Figure 1).

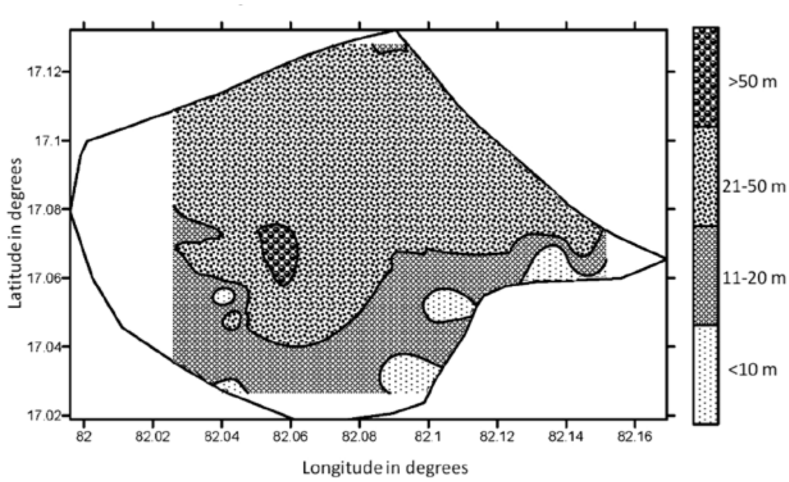


**Figure 8.** Spatial distribution of the saturated sandstone (10-50 Ωm) of varying thicknesses.

Section AA`: The topography of this section varies between 72 and 77m above mean sea level (amsl) along W-E direction. Two major formations viz. saturated sandstones followed by saturated clay have been inferred along this section. The thickness of the clay zone ( <10 Ωm ) varies in the range of 10–50m, found at depth of 40m below ground level (bgl) with 10m thickness at a distance of 600m from A (West) and increasing towards A`(East) with maximum thickness at distance of 2 km from A. Above this zone, saturated sand (10-50 Ωm) is encountered with an average thickness of approximately 30-40m, over a length of 3km along AA`.

Section BB`: The length of this section is 3.6km and runs along N-S direction with surface topography decreasing from 80 m amsl on the northern side (B) and 60m amsl on the southern side (B`). Saturated sandstone is inferred at most of the locations with few locations revealing dry sand as top layer at 2 km from B (DH121) and clay zone with a thickness of 50m at a depth of 10 m bgl located on southern most part of the section (DH236). The thickness of aquifer (saturated sandstone) is about 60m extending to a distance of about 1 km (DH142) towards south from B (DH238). The depth to this aquifer is approximately 1 m bgl.

Discussion of Region-II: The fence diagram of this region (top of Figure 6) covering an area of about 5.34 square km is based on the resistivity and thickness values of the different layers of the subsurface from 6 VES data. It can be inferred from this fence diagram that two thirds of the fence area is occupied by saturated sandstones, while one third is covered by consolidated sandstones (high resistive).

Section CC`: This section of 2.9 km (bottom of Figure 6) revealed aquifer (saturated sandstone) along a length of about 800-900m having thickness of 30- 40m. This unconfined aquifer is located from a distance of 1.4 km from the point C (DH147) and at the sounding point DH222. The region occupied by consolidated sandstones and clay (from Point C to approximately 1.4 km) in some parts of this section is not suitable for ground water exploitation.

Discussion of Region-III: 14 electrical resistivity soundings (VES) were carried out in this region covering an area of about 31.91 square km. The maximum surface elevation from the mean sea level is approximately 50m. The subsurface lithology is depicted in the fence diagram (Figure 7 top) based on the lithology of the well near DH19 (Peddapuram). Entire region is covered by saturated sandstones as can easily be observed from the fence diagram, with an exception at few locations where clay and consolidated sandstones are revealed.

Section DD`: The length of this section (bottom of Figure 7) is about 4.3 km. Dominant formation along this section is saturated sandstone covering the entire length of the section with the exception at DH257, where the thickness of this formation is very less. This is underlain by a thick clay zone. The sandstone (saturated) is a good aquifer with thickness varying from 20m at DH257 to a maximum thickness of 90m at DH114 along length of approximately 2.8 km from D along this section.

Section EE`: The distance between E and E` is 5.3 km (bottom of Figure 7). Most of the region is characterized by saturated sandstones, with an average thickness of around 40m. At few locations, clay deposits (10-20m thick) embedded into this formation (DH145, DH19 and DH80). Clay zone of 20m underlain by the same thickness of consolidated sandstones (high resistive) is observed in between the sounding locations DH260 and DH80, extending over a length of 800 m at a depth of 20 m bgl.

Section FF`: This sections runs to about 7.0 km in the W-E direction in which saturated sandstones with an average thickness of 50m over a length of 6.0 km are the