

Application of Geoelectrical Resistivity Technique for Groundwater Exploration in Lower Ponnaiyar Sub-Watershed, Tamilnadu, India

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Abstract. Geoelectrical Resistivity survey was carried out in Lower Ponnaiyar Sub-watershed, to intercept the sub-surface lithology and groundwater prospective zones. Twenty Vertical Electrical Sounding (VES) of the Schlumberger configuration were performed with an AB/2 separation 100 m. The acquired geoelectric data were interpreted with curve matching and computer iteration using Inverse Slope software. The results showed the presence of six geoelectric layers comprising Alluvium, Sand, Silt, Clay, Clayey sand and Hard Rock. The investigations also revealed the range of resistivity values from - 40 to 400 Ω m, while the depth of aquifer ranged between 6 and 100 m. The prospective for the occurrence of groundwater in the Lower Ponnaiyar watershed was categorized as high, good, moderate and low by interpreting the sub-surface geophysical studies. The groundwater recharge structures like percolation pond, check dam have to be constructed in the moderate and low zones of groundwater potential so as to augment the groundwater resources.

Keywords: *Groundwater potential, Geoelectric resistivity survey, VES, Recharge structures*

1. Introduction

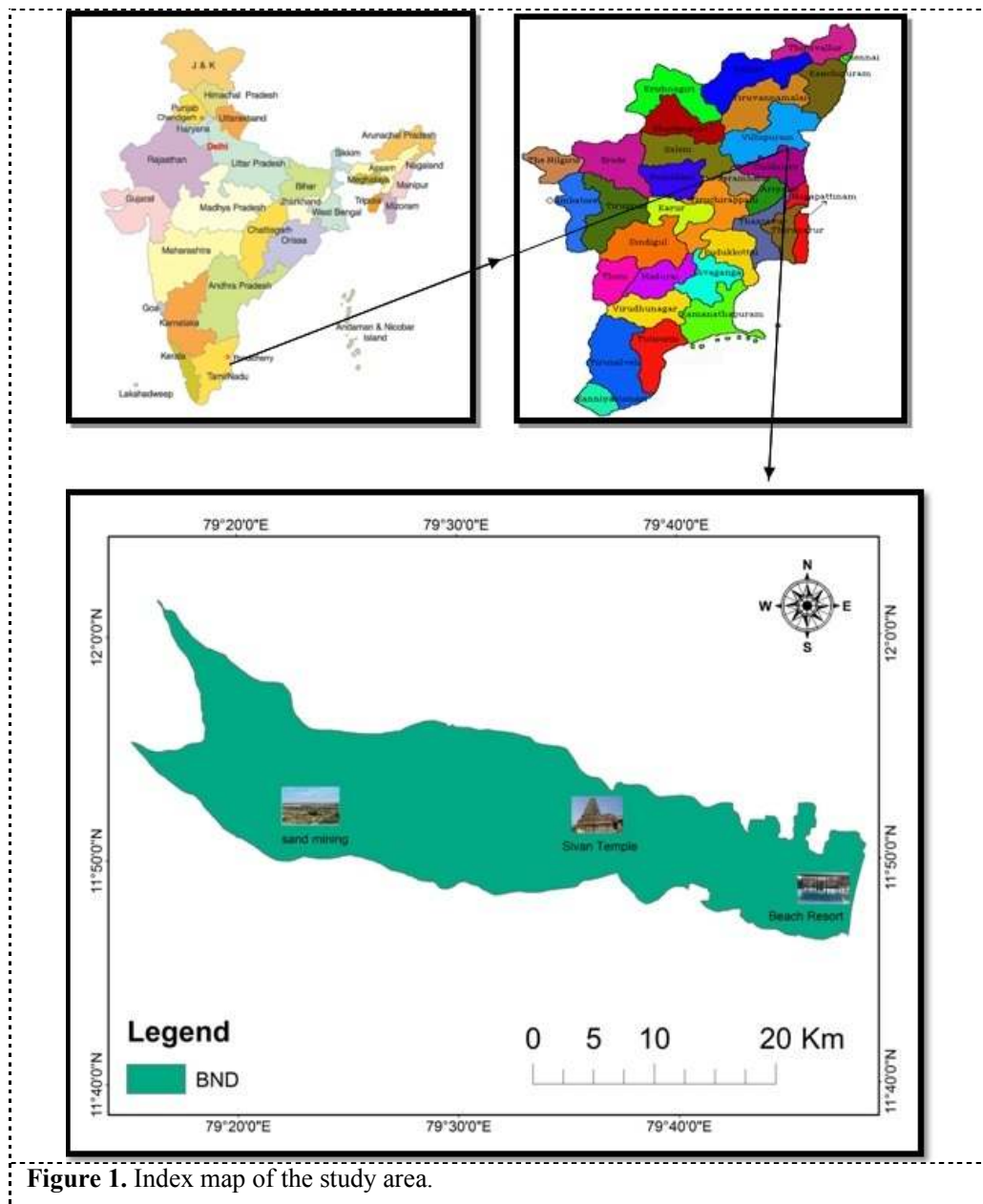
Geophysical methods can be used to measure the physical properties of the subsurface, specifically related to the position of water and its quality, and the position and properties of geological units. Essentially, the geophysical methods comprise of measurement and interpretation of signals from or induced physical phenomena generated as a result of the spatial changes in one or more physical properties of sub-terrain formation. The various physical properties, currently used in different geophysical techniques for groundwater exploration are electrical conductivity, magnetic susceptibility, density, gravity, elasticity, dielectric constant and radioactivity [9]. In this study, one of the geophysical methods, namely the electrical resistivity technique has been employed to delineate the subsurface lithology and assessment of groundwater potential of the watershed.

2. Study area

The study area lies in between 79° 15' 13" and 79° 48' 28" E longitudes and 11° 50' 18" and 11° 55' 18" N latitudes with a total area of extent of 598.162 km² (Figure.1). It includes five taluks namely Tirukoilur, Ulundurpettai, Villupuram, Panruti and Cuddalore with a general elevation of 81.25 m above MSL sloping from West to East. The river Ponnaiyar is almost dry throughout the year. Water flows during the monsoon season only in Tamilnadu. However, this water flow raises the groundwater



table throughout the river basin and feeds numerous reservoirs /tanks. The maximum rainfall recorded is 1851 mm (1996-97), while the minimum is 548 mm (1989-90). The maximum temperature may rise up to 40 °C and decrease during winter season up to 27 °C. The winter water level ranges from 2.50 to 5.00 m and the summer water level ranges from 3 to 7 m. The Index map of the Lower Ponnaiyar Sub-Watershed is presented in Figure 1.

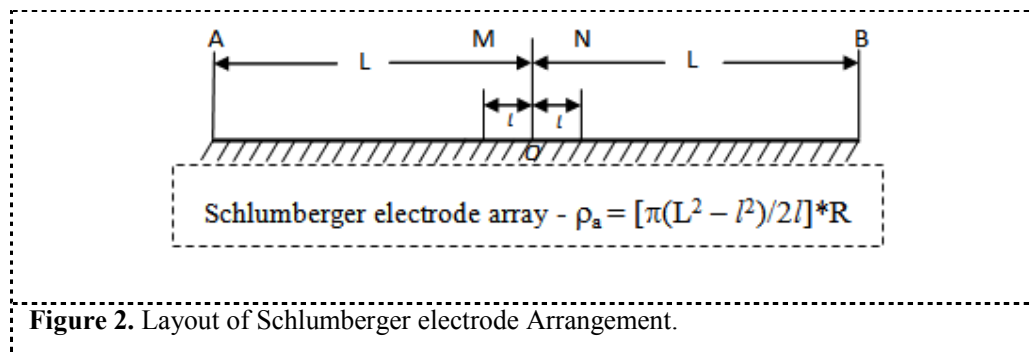


3. Methodology

Totally, 20 VES data was done in the areas of Lower Ponnaiyar watershed to delineate the subsurface lithology and explore the groundwater potential. The VES data were processed using the software packages. In this study, VES were conducted using the Schlumberger array

3.1 Schlumberger array

The Schlumberger method has a greater penetration than the Wenner. The one-dimensional VES were carried out in this research with Schlumberger electrode Array. The 4 electrodes (A, M, N, and B) were located lengthwise a straight-line proportionally over centre point 'O' (Vide Figure 2). The separation between potential electrodes (MN) was kept small when compared to the current electrode separation AB. Using $L = AB/2$ and $l = MN/2$ the configuration factor for Schlumberger array is $(\pi (L^2 - l^2) / 2l) * R$ and the apparent resistivity was calculated with the formula. In this method, a series of potential differences are acquired at successively larger electrode spacing while maintaining a fixed central reference point. The induced current passed through progressively deeper layers at greater electrode spacing. Apparent resistivity values calculated from measured potential differences which could be interpreted in terms of overburden thickness, water table depth and thicknesses of subsurface strata [7]. A total of twenty VES were done in the study area. The traverse separation is 5 m. The twenty traverses are represented as VES 1-20. An average spread of 100 m ($AB/2$) is covered.



3.2 Electrical resistivity survey in the field

The resistivity survey was done in this research to study groundwater potential in Lower Ponnaiyar sub-basin, such as depth, thickness, resistivity and sediment at which water can be obtained. The geoelectrical methods used in the survey are VES and with the aim of determining the sub-surface lithology and groundwater potential. Twenty VES were conducted using the Schlumberger configuration and horizontal spread covering the entire area. All these twenty locations were within the boundary of the study area (Figure 3). The VES technique measures the vertical variations in ground apparent resistivities with respect to a fixed Centre of array. VES data obtained are qualitatively and quantitatively iterated using Inverse Slope software for its partial curve matching. The values of the apparent resistivity obtained are plotted against current electrode spacing using a log-log graph paper. The field data are first curve matched and the result subjected to computer iteration software to obtain the layer true resistivity and thickness which are derived from VES 1 to VES 20 diagrams. Selected curve diagram (VES1) is showed in Figure 4. Based on the geoelectrical characteristics, the lithology and groundwater potential are interpreted.

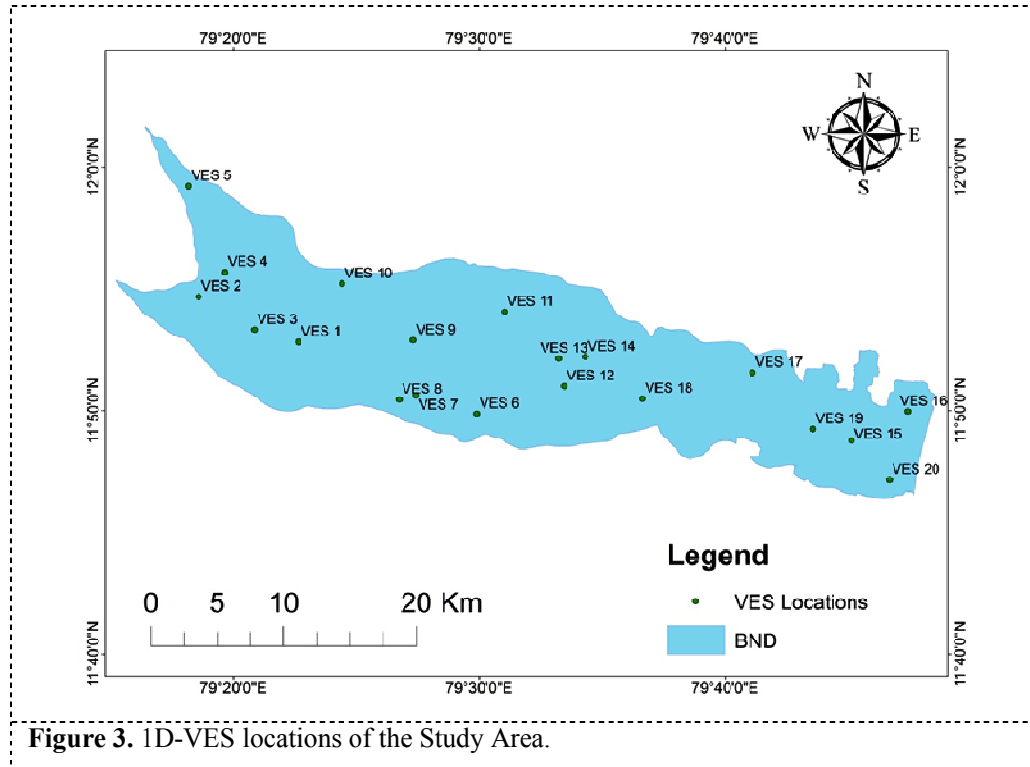


Figure 3. 1D-VES locations of the Study Area.

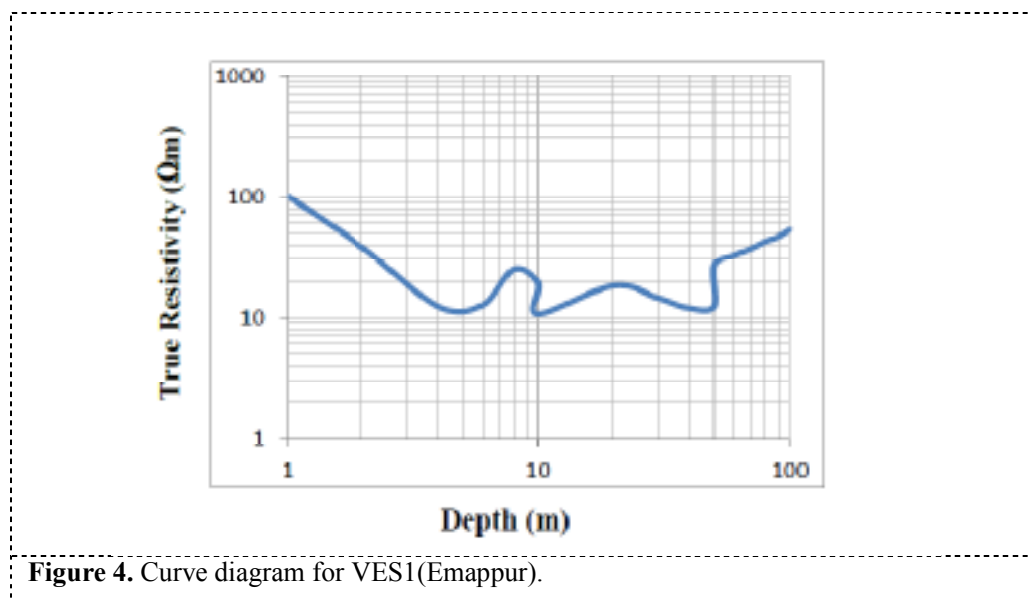


Figure 4. Curve diagram for VES1(Emappur).

4. Results and Discussion

The VES data were collected from 20 locations were interpreted to obtain layered resistivity parameters and to delineate potential zones in the deep aquifer of Lower Ponnaiyar sub-watershed.

4.1 Interpretation of VES curves

The Qualitative interpretation of VES data showed multi-layered resistivity curves for most of the locations based on the depth below the ground surface. Analysis of the layer curves (more than five curves) showed that potential fracture zones found in this resistivity profile. The apparent resistivity maps of each geoelectrical layers are prepared using Inverse slope software. The apparent resistivity and $AB/2$ values are plotted on the double-log sheet in Inverse slope software. Out of 20 curves, 8 are 5 layer type, 5 are 6 layer type and 7 are 7 layer type curves. The geoelectrical sections and its interpreted lithology of all VES locations 1 is depicted in Figure 5.

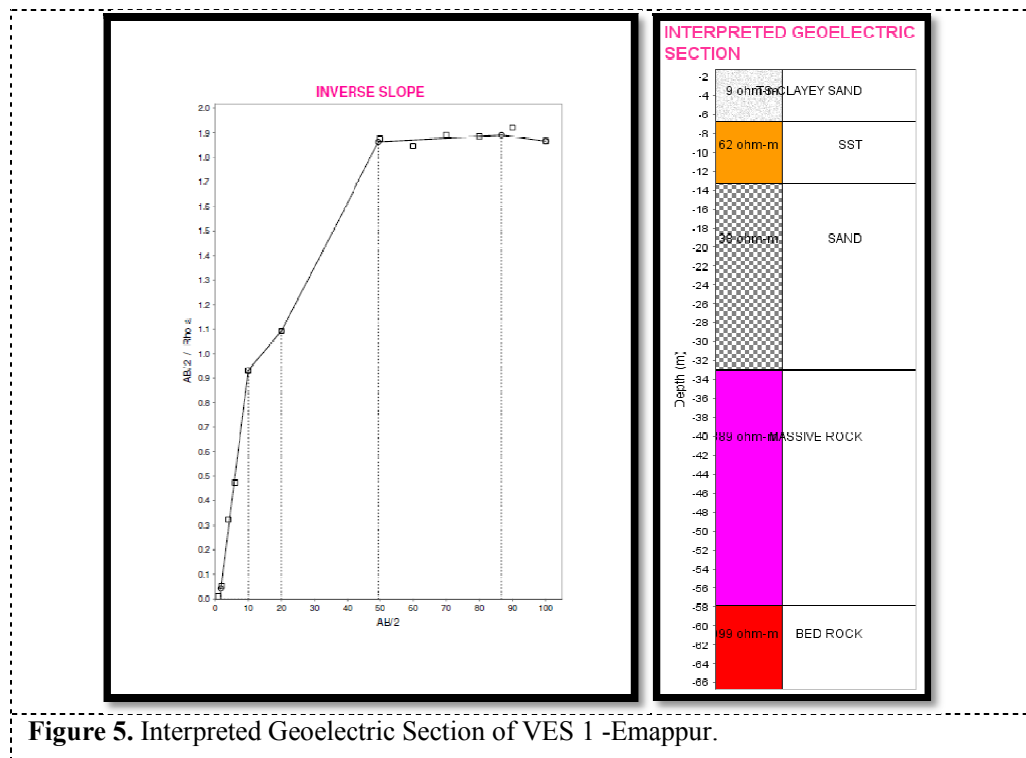


Figure 5. Interpreted Geoelectric Section of VES 1 -Emappur.

4.2 Delineation of sub surface lithology and groundwater potential

Totally, six geoelectrical layers are created to recognize and establish the anomaly zones.

- The thickness of the 1st layer is up to 6m from ground level and its apparent resistivity values ranged from 40 to 400 Ω m (vide Figure 6). This could be attributed, the presence of Clay, sand, silt and hard rock. Sands are exposed in VES-5 with high resistivity values in the study area, which yields good groundwater potential. The very low value less than 100 Ω m indicated the hard rock terrain of the study area. The sands are excellent aquifers which have moderate resistivity value of more than 200 Ω m and the clay has a low resistivity range, which has moderate and low groundwater potential. Some places, in the T.V.Nallur block, have covered good and moderate groundwater potential areas such as Karumbur, Semangalam, Anatur and some villages in Annagramam block.
- The resistivity of the 2nd geoelectrical layer still get decreased from -10 to 180 Ω m, which is with a thickness of up to 10 m when compared to the first layer (Figure 7), which could be interpreted as clay, sand and hard rock.
- The resistivity range of the 3rd layer (Figure 8) is further decreased from 0 to 170 Ω m, which is with a thickness of up to 20 m. It consists of soil types as clay and hard rock.

- The 4th layer has a low resistivity range between 0 and 300 Ωm consisting of clay, sand and hard rock with a thickness of up to 60 m (Figure 9). Most of the villages in Mugaiyur and T.V. Nallur blocks have moderate groundwater potential areas.
- The resistivity of the 5th layer reached up to 360 Ωm with the thickness 80 m, it could be attributed, the presence of sand, silt and rock.
- The resistivity increases in the Sixth geoelectrical layer between -40 and 400 Ωm with depth up to 100m compared to the fifth layer. Table 1 and 2 represented the consolidated interpreted subsurface lithology for various depth and the corresponding potential of the study area.
- GIS analysis also demarked for identifying areas of groundwater prospective to validate with this study which showed reliable results.

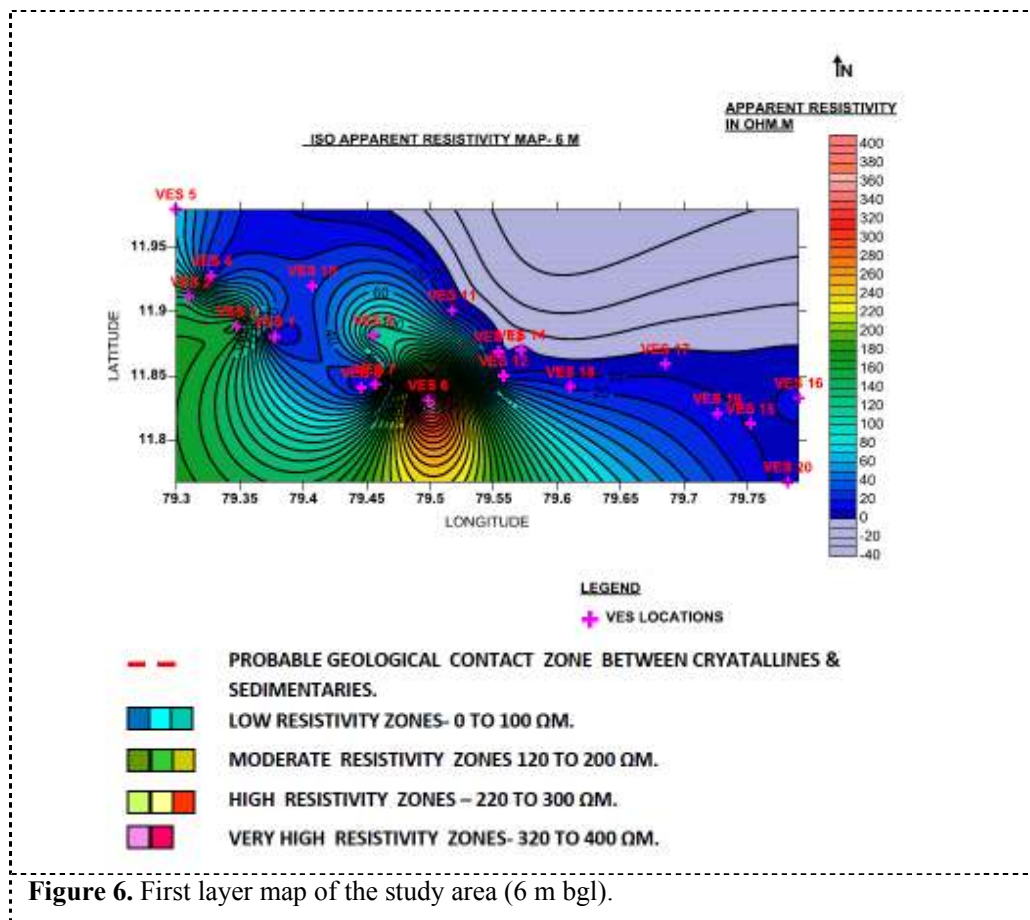


Figure 6. First layer map of the study area (6 m bgl).

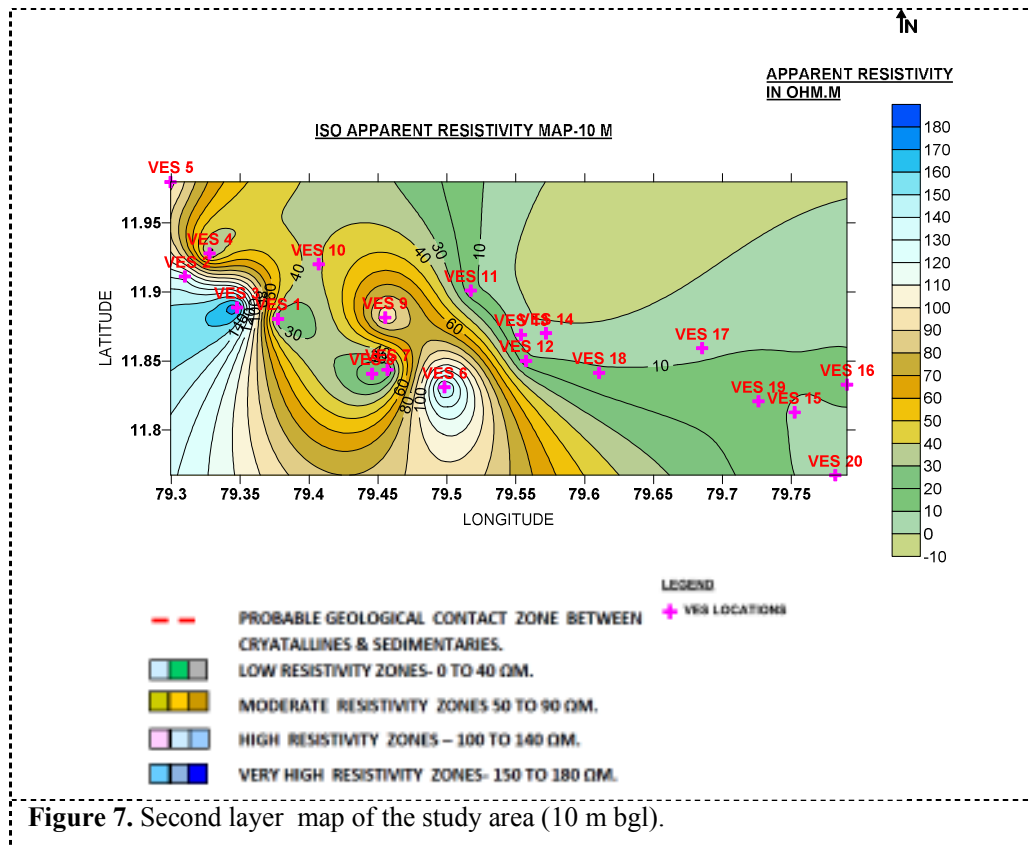


Figure 7. Second layer map of the study area (10 m bgl).

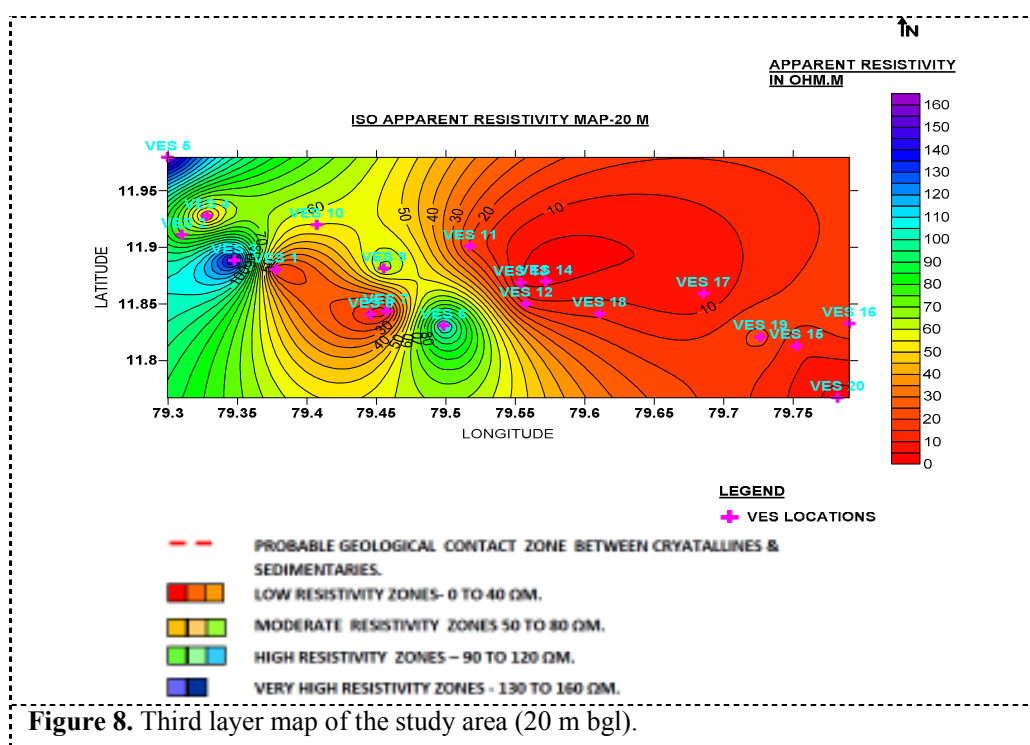


Figure 8. Third layer map of the study area (20 m bgl).

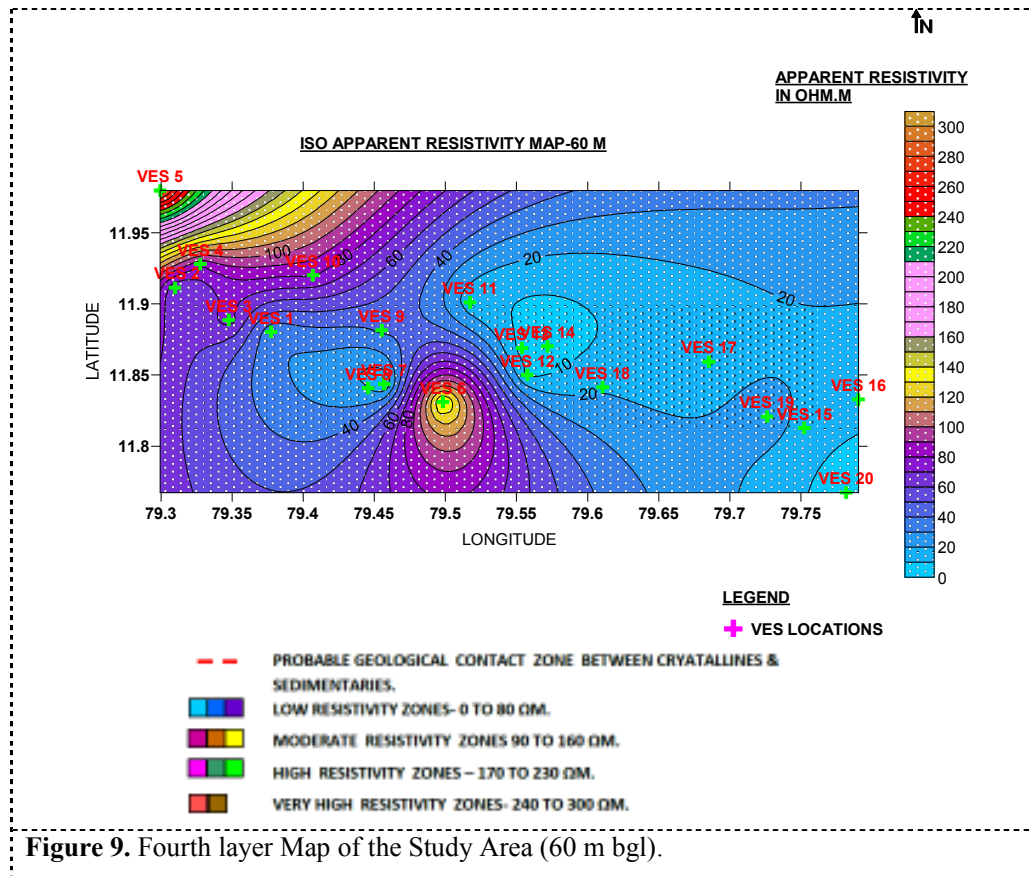


Figure 9. Fourth layer Map of the Study Area (60 m bgl).

Table 1. Interpreted Subsurface Lithology of the Lower Ponnaiyar Watershed for Various Depths and Resistivity Values

S. No.	Geoelectric Layers	True resistivity Range (Ωm)	Thickness of layers (m)	Interpreted subsurface lithology
1	I	-40 to 400	6	Clay, Sand, Silt & Hard rock
2	II	-10 to 180	10	Clay, Sand, Silt & Hard rock
3	III	0 to 160	20	Clay, Sand & Silt
4	IV	0 to 300	60	Clay, Sand and Gneiss
5	V	0 to 360	80	Clay, Sand and Gneiss
6	VI	-40 to 400	100	Clay, Sand, Silt & Hard rock

Table 2. Lithology and Groundwater prospective of the Lower Ponnaiyar Watershed

VES No.	No. of Layers	Lithology	Groundwater potential
1	5	Clay, Sand, Silt & Hard rock	High
2	5	Clay, Sand, Silt & Hard rock	High
3	7	Clay, Sand, Silt & Hard rock	High
4	5	Gneiss	Low
5	7	Gneiss	Low
6	6	Sand & Hard rock	Moderate
7	6	Clay, Sand, & Hard rock	Moderate
8	7	Clay, Sand, Silt & Hard rock	Moderate
9	7	Clay, Sand, Silt & Hard rock	Good
10	6	Gneiss	Low
11	5	Clay & Sand	Good
12	5	Clay & Sand	Good
13	6	Clay, Sand, Silt	Good
14	5	Clay, Sand & Silt	Good
15	5	Clay, Sand, Silt	Good
16	5	Clay, Sand, Silt	Good
17	7	Clay, Sand, Silt	High
18	7	Clay & Sand	High
19	6	Clay, Sand, Silt	High
20	7	Alluvium, Clay & Sand	Good

5. Conclusions

Based on the interpretation of geoelectrical data, VES indicated the presence of sand sediment (good water) with resistivity of more than 200 Ωm . It also revealed six geo-electric layers consisting of the sub-surface layer (Alluvium, sand, silt, clay, clayey sand and bed rock). Schlumberger's resistivity vertical electrical surveys proved to achieve better results for groundwater prospects in hard rock terrains. The potential for the occurrence of groundwater in the study area was classified as high (3%), good (50%), moderate (45%) and low (2 %) by interpreting the subsurface geophysical investigations. This study suggests favourable locations for artificial recharge structures to maintain the current status of groundwater.

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