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# WENNER ARRAY RESISTIVITY AND SP LOGGING FOR GROUND WATER EXPLORATION IN SAWERPURAM TERI DEPOSITS, THOOTHUKUDI DISTRICT, TAMIL NADU, INDIA

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## ABSTRACT

The objective of this study is to identify a good site for groundwater exploration in Teri deposits. In this rock types, groundwater occurs in secondary porosity developed due to weathering, faulting, fracturing in the subsurface formation. In such situations Wenner array with resistivity and SP logging is suitable method for groundwater exploration in the Teri deposits. Initially based topography, geomophological and hydrogeologial features, an area about 2km was segregate as a promising zone for groundwater exploration in the teri deposits of Sawerpuram, Thoothukudi District, Tamil Nadu, India. The Vertical Electrical Sounding was carried out using Wenner electrode configuration with help of equipment CRM 500. The interpretations were carried using Apparent Resistivity and SP logging techniques. The resistivity ranging from 100-120 Ohm.m indicates the freshwater zone in the study area.

**Keyword:** Teri deposit, resistivity, sp, groundwater, Thoothukudi.

## INTRODUCTION

Thoothukudi District is one of the important southern most districts of Tamil Nadu State. The district is located between $8^0$ 19′; Latitudes and $77^0$ 40 ′ to $78^0$ 10 ′ E Longitudes. The Sawyerpuram Teri ($78^0$ 02′ E: $8^0$ 44′) situated 25 km. Southwest Tuticorin and 30 km NW of Tiruchendur is selected for the study (Figure-1). Geology of the Thoothukudi district can be classified into Coastal sedimentary zones (Sedimentary rocks of marine origin occurring and tapering towards the North and South. Western part Teri Sediments occurring in between marine and hard rock formations and Quartzite exposed as small hillocks. Northern part - Black Cotton Soil with Kankar Deposits southern and Southwestern parts (Khondalite group including Garnatiferous Siliminite Gneiss.) (Antony ravindran *et al*., 2010 [1]. Red sediments, otherwise called as Teri deposits are exposed in juxtaposition of marine and hard rock formations. The top of the beds is generally loose and unconsolidated. Below that, the beds are very hard and compact due to consolidation. The red beds are showing colour variation. The thickness of these beds remains constant and the degree of reddening decreases downwards. Opaque minerals like Zircon, Monazite, Tourmaline, Apatite, Rutile make their appearance in order of dominance. Climate of the region is semi arid. Major rainfall is received during the North East Monsoon period. The maximum rainfall is received during November. The annual rainfall is ranging from 500mm to 750mm mean annual precipitation is 675. 71 mm. Air temperatures is hottest during the periods from April to July. December to February is the coolest months. Temperature of this area varies from $21^0$ C to $33^0$ C. The mean annual temperature is $28.3^0$ C. The Teri deposit of this region occurs elevations of about 37m to 42m above mean sea level.

### Hydrogeology

The Teri sediments are of medium size, moderately sorted, positively skewed and mesokurtic. High percolation is also present in region because of unconsolidated red soils. Surface drainage is absent. Tamrabarani River is a perennial river originating in the Western Ghats flowing west to East direction to a length of 130 km. Tamirabarani River is flowing about 15 km south of Sawerpuram Teri sediments. Tamirabarani River has a canal system in Murappanad and Srivaikundam. The Srivaikundam canal are connected irrigation tanks such as Korampallam tank, Peikkulam tank, Eral tanks which are situated on the surroundings of Sawerpuram Teri sediments. Since Teri deposits occurs between the hard and marine sediments and geographically distinguished as deserted land mark made up of loose, unconsolidated paleo coastal dunes. They are highly permeable and so the rain water percolated are stored up good ground water by Antony Ravindran *et al*., 2010 [2].

## MATERIALS AND METHODS

Geophysical surveys were carried out in three spots in Sawerpuram red Teri deposits. Electrical resistivity (or) Vertical Sounding (VES) method was adopted by using with equipment aqua meter CRM 500 (Antony Ravindran, 2012) [3]. To analyze Hydro geological and aquifer characteristic features of Sawerpuram Teri Sediments through electrical resistivity Technique. The electrical resitivity method is useful to investigate the nature of subsurface formations by studying the variation in their electrical properties. This method assumed considerable importance in the field of groundwater exploration and in the study of aquifers characteristic features because of its easy of operation, low cost and its capability to distinguish between the saline and fresh water zones. Resistivity profiling with an

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electrode separation of 1.5m was carried out by employing Wenner array method to find out the rock type, ground water zone and basement rock (Todd, 1984) [4].

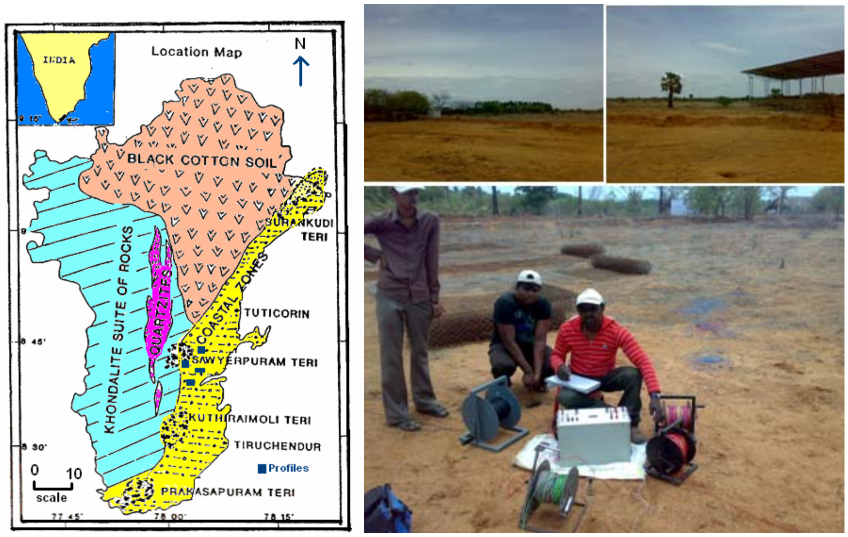


**Figure-1.** Location map of the study area and field work data collections.

The preliminary interpretation of the sounding data was done by using litholog plot. For the geophysical studies of the three selected spots of Sawerpuram Teri deposits, self potential method and resistivity methods were adopted (Figure-1). Self-potential studies measure the naturally occurring potential at the ground due to shallow subsurface conductors having differences in PH concentration at the top and the bottom. The resistivity values of the sub surface are mainly controlled by the water content and compactness of the subsurface formation. The Self Potential values and resistivity values had been obtained using CRM-500 resistivity meter by Wenner configuration.

**Interpretation Logging Technique**

The depth of penetration through the readings SP and resistivity values are increasing as a function of electrode spacing for each location. These were made as graphical representation. In each graph, both the SP and resistivity values were plotted on the ordinate and their respective electrode spacing “a” was taken on the obscissa. Through both the SP and resistivity values are plotted on the same ordinate scale, the SP value has no absolute zero and it can deflect on both sides, left (- ive) (or) right (+ ive) where as the resistivity starts from the zero line. The resistivity and self-potential values are plotted against depth Verma 1980, [5]. By comparing the inflection points observed on the SP Curve and the resistivity curve. The depth and thickness of sub surface layers were demarcated on the composite log of each plot in terms of electrode spacing. The interpretation of the depth wise variation of layers using composite logs of the Sp and the apparent resistivity correlated exactly with each other in identifying the subsurface lithology (Figures 2, 3 and 4). The curve elements in terms of peaks and troughs retrieved from the plot are considered as signature of the formations. The potential differences encountered in the study area are confined within the boundaries of clay in the right hand side and sand in the left hand side. Types of information such as mineralogy, clay, cement types, grain size, sorting and packing of the grains, fluid changes, bed thickness and homogeneity and heterogeneity of the bed can be extracted from the curve analysis of plots of the SP and apparent resistivity. The SP deflection towards the right side indicates impermeable formation such as clay, limestone, gneiss and other hard rocks like charnokite. The negative or left side deviation indicates permeable strata like sands, gravels and pegmatite and quartzite. The shape of the SP curve is important for quantitative interpretation. Factors Affecting and Influencing the Shape and Amplitude of SP Deflection Salinity of the fluid: The SP value becomes more negative with the increase of salt content in the formation water and also for the permeable formation. When the SP curve moves towards right the sand aquifer contains water with low salt content. When the SP curve is flat there is no clear difference between clays and porous and permeable beds. Boundaries between the clay and the permeable formation correspond to the point of inflection of the SP curve. Plateau peak of SP indicates the thick bed of clay. Plateau trough of the SP curve indicates thick sandy bed. Positive spike indicates thin layer of clay and negative spike indicates thin sand bed. When the curve element is flat, it shows the boundary between the clay and permeable sandy formation. Steps: Positive step of the curve corresponds to the sharp increase of the clay or shale. Negative step of the curve corresponds to a sharp decrease of clay or increase of the sandy horizon. The boundary associated with a step shows a sharp litho logical change. The low resistivity value indicates either a porous formation containing a conducting fluid such as saltwater

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sand, or a tight formation such as a shale or clay containing ionized fluid. The high resistivity values indicate either a non-porous or impermeable formation containing a non-conducting fluid such as freshwater, gas or oil. The combination of the SP and the resistivity values of the formations are used to infer the nature and type of subsurface layers (Table-1).

**Table-1.** The inferences made from the combination of the SP and the resistivity values (Ramakrishnan, 1998).

| S. No. | COMBINATION OF SP AND APPARENT RESISTIVITY | INFERENCE |
|---|---|---|
| 1 | Low SP and low apparent resistivity | Impermeable clay bed with ionized water |
| 2 | High SP and low apparent resistivity | Porous and permeable sand with saltwater. |
| 3 | High SP (+) and low apparent resistivity | Porous formation with low saltwater. |
| 4 | Low SP and high apparent resistivity | Impermeable formation like limestone, cemented sand stone, silt stone. |
| 5 | High SP (-) and high apparent resistivity | Permeable sand bed with freshwater. |
| 6 | High SP (+) and high apparent resistivity | Porous sand or other sandy formation with freshwater. |

The curve obtained from the plot of the above mentioned method has exhibited various types of curve features. A close study of the resistivity and the SP curves shows that many curve features are identifiable from curve to curve. Each curve feature may be considered as signature of the formation. The method of correlation is based on the pattern recognition of the curve elements such as peaks and troughs. A peak is a segment of a curve of which the resistivity increases with depth passes through a maximum and then decreases. This peak is bound by two consecutive inflection points, which define its boundaries (Antony ravindran *et al*., 2009 [6]. The trough is defined in terms of derivative variation in opposite sign.

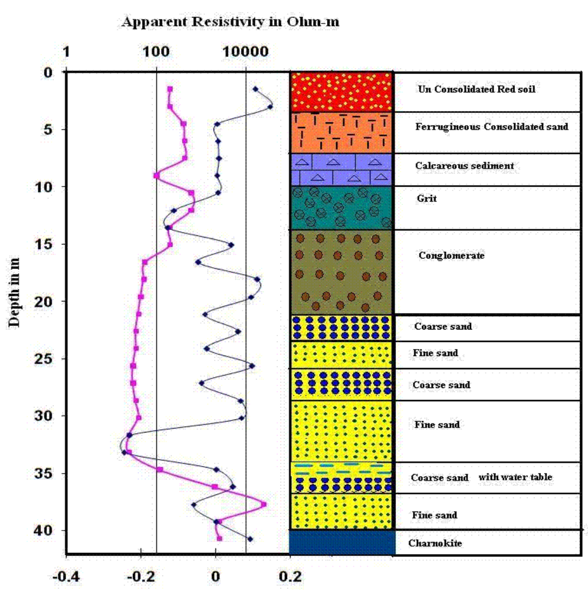


**Figure-2.** Shows the apparent resistivity and SP values litholog and stratigraphical variation at Sayarpuram Teri deposits profile1.

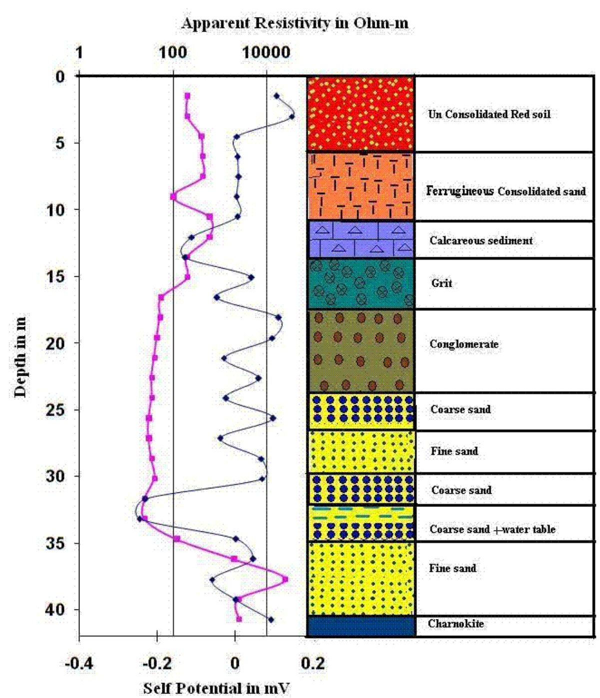


**Figure-3.** Shows the apparent resistivity and SP values litholog and stratigraphical variation at Sayarpuram Teri deposits profile 2.

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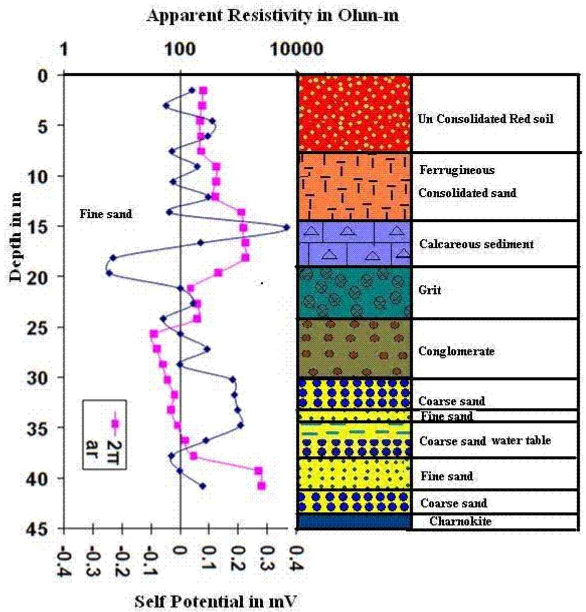


**Figure-4.** Shows the apparent resistivity and SP values litholog and stratigraphical variation at Sayarpuram Teri deposits profile 3.

The curve elements in terms of peaks and troughs rectified from the plot are considered as sign of formations. The SP deflection towards right side indicates impermeable formation such as ferruginous consolidated sand, grit, conglomerate and hard rock Charnockite by Barker 1989 [7]. The SP deflection towards left side (or) negative side indicates unconsolidated red soil and calcareous sediments. From the well site samples and geographical representation of Sp and resistivity values, we can find out the litho stratification of Teri sediments as follows:

From the ground level to 6.5 m unconsolidated red soils are seen. From 6.5m to 10m ferruginous consolidated red sands are seen. Calcareous sediments are present between 10m to13m. Grits are seen from 13m to 16m depths. From 16m to 20m are seen. Alternative beds of coarse to fine sediments are present from 20m to 45m. The basement rock charnockite starts below the depth 45m.

## RESULTS AND DISCUSSIONS

The field data obtained by electrical resistivity method (Wenner array method) for 3 spot of Teri deposits was analysed quantitatively by depth sounding curve and surface logging technique. The composite log from the Apparent Resistivity and SP verses a spacing reveals the lithological sequence in the study area. Generally we classified the sub surface lithology of the study area into three types based on the Eletrostratigraphic analysis. (1) Over burden-Dry Zone (ii) Aquifer-Fresh water Zone (iii) Hard rock-Basement.

### Over burden

The Top bed is composed of unconsolidated red soils having the thickness of 6.5 m and below that 4m thickness of ferruginous consolidated sand occurs. Calcareous sediments and Grits are present above the second formation of aquifers. The minimum resistivity value is 200-ohm m and the maximum resistivity value is 400-ohm m and the thickness of dry zone is 16m, which ranges from ground level to 16m depth of subsurface.

### Aquifer

The depth of the aquifer ranges from 17m to 45m. In the aquifer zone, the top bed is composed of conglomerate of 4m thicknesses. Below that the alternative bands of coarse to fine sediments occur. The resistivity ranges from 15-ohm m to 150 ohm m. The thickness of aquifer will be 28 m.

### Hard rock basement

The depth of hard rock basement starts from 45 m. The basement rock is Charnockite. Below that weathered Charnockite occurs. Hard rock basement is a zone of high resistivity and the maximum resistivity value is 2500-ohm m. The minimum resistivity value is 1700 ohm. The thickness of over burden in spot no: 1 is 15 m. The aquifer zone of Teri deposits occurs from 16.5m to 35m depth. The resistivity value ranges from 25-ohm m to 120-ohm m. The water Table occurs at the depth of 35 m at the junction between alternative bands of fine and coarse sand and Charnockite as the basement rock. The water Table is formed due to arrest of downward percolation of water by charnockite rock. The thichness of over burden in spot no: 2 are upto 19 m. The aquifer zone starts from 22.5m to 37.5 m depth. The thickness of aquifer zone will be 15 m. The resistivity value that ranges from 15 ohm m to 120 ohm m. The water Table occurs at the depth between alternative bands of coarse to fine sediments and basement rock. A sudden change in resistivity value indicates that water Table occurs above the basement rock. The depth of water Table zone is identified at a depth of 33-34m. The thickness of the overburden in spot 3 is upto 18.5 m depth. The SP deflection towards left side (or) negative side in top level in graphical representation indicates unconsolidated red soil and calcareous sediments. The SP deflection towards right side (or) + ive side indicates the impermeable formation such as ferrougeneous consolidated sand, Grit and Conglomerate. The water Table is found at the depth of 36 m with resistivity value of 120-ohm m. This water Table is found at the bottom level of alternative bands of fine to coarse sand and above the charnockite as basement rock. The quality of water is good for irrigational purpose and drinking purpose.

## CONCLUSIONS

The red teris are in the form of isolated patches just at the contacts of the marine and hard rock terrains of Thoothukudi district. The study of vertical stratigraphy and sedimentology of the borehole samples upto 45m reveals that the Teris are comprised of different sedimentation unit as discussed. Depth sounding curves in Wenner method is plotted using the apparent resistivity and SP value in the Excel graphical representation. The layer thickness of the each bed is demarcated with their maximum and minimum values. The number of layers with thickness is measured from the graph easily. In Sawerpuram Teri deposits spot 1, Overburden or Dry Zone occurs upto 15m thicknesses below that the aquifer zone occurs from 16m to 36m. The thickness of the aquifer will be 20m. The basement rock Charnockite starts from 36m. In Sawerpuram Teri deposits spot II, the overburden or Dry Zone is found upto 19.5m. The aquifer occurs from 21m to 38m. The thickness of the aquifer will be 17m. The basement rock starts from 36m. In Sawerpuram Teri deposits spot III, the overburden or Dry Zone occurs upto 18m. The aquifer zone starts from 19.5m to 37m and having the thickness of 17.5m. The water Table is found at the depth of 34.5m, in Sawerpuram Teri deposits spot I. In Sawerpuram Teri deposits spot II, the water Table is found at the depth of 33m. In spot III, the water Table is found at the depth of 35m. The resistivity values of the water Table formation in three spots of Sawerpuram Teri deposits are 120 ohm m. Due to high percolation of rainfall, the groundwater potentials are high. In the study area litho logical formation in between dry zone to hard rock zone of chranockite is completely occupied by leaky aquifer or semi confined aquifer. The quality of ground water is good. The Kankar intermixed with ferruginous materials were formed due to evaporation of water-soluble salts. The climatic significance of the Kankar or formed below the unconsolidated sediments signifies that the evaporation was more than the precipitation.

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