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Geoelectric signatures of the coastal aquifer system of Adappa watershed

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Abstract : The need for good quality water has increased extensively due to awareness and technology. The Groundwater is the viable alternative for the surface water sources; it becomes the most important component in our life support system. The Groundwater at all locations is not directly usable for domestic or irrigation and industrial purposes because of the poor quality of available water. Thus, many people rely on the exploration and exploitation of Groundwater. These problems can be solved using proper exploration techniques. Thus, numerous problems of Groundwater exploration and exploitation require the systematic use of scientific techniques. In coastal areas, due to over exploitation and natural disasters like the tsunami, the quality of fresh water aquifers gets deteriorated by seawater intrusion. In order to explore the Groundwater resources and to delineate the subsurface lithology of Adappa watershed in the Cauvery river basin of Tamilnadu, an integrated geological, geomorphological, hydrogeological and geophysical investigation has been taken as a research project. As a part of the research project, a multi oriented approach to study on the coastal geology, hydrogeomorphology and geoelectrical signatures of the coastal aquifer system of the Adappa watershed have been made in this study. To access the groundwater resources and to find the depth to fresh water and salt water interface, about nine VES have been carried out in the study area. The VES data were analyzed using IPI2 Win and surfer software programs and the geoelectric parameters were evaluated. The majority of the VES curves are QQ types with 3 to 6 geoelectric layers. From the geoelectric studies, it is inferred that the approximate depth of fresh water-salt water interface is in the range of 0.904 to 8.34 meters below ground level [MBGL]. From the true resistivity contour anomalies, it may be revealed that the quality of groundwater is poor in southern and southeastern parts of the study area. The Groundwater development in these areas must be carried out with necessary management strategies.

1. Introduction

Land reclamation is one of the most important strategic initiatives in India, to convert uncultivated land into productive agriculture lands. Aquifers and groundwater-dependant ecosystems are facing increasing pressure, which is a common global scenario [3]. Groundwater quality is influenced by the effects of human activities which cause pollution on the land surface because most groundwater originates by recharge of rainwater infiltrating from the surface [7]. In the recent years the unregulated mushroom growth of aquaculture farms in the coastal areas, has resulted in pollution of groundwater due to seepage of salt water and also as a consequence of excess pumping of fresh water leading to seawater intrusion [7]. The natural hydrodynamic balance has been disturbed due to natural and man-made causes. Seawater intrusion in coastal aquifers occurs when permeable formations outcrop into the body of seawater [6]. In coastal aquifer systems, the fresh water aquifers are connected to the sea and an interface exists between the fresh and saline water interface has moved landward causing saline intrusion,when groundwater abstraction has exceeded recharge [6].

2. Study Area

The study area, namely the Adappa watershed is a coastal rural watershed in the Cauvery river basin, lies between 10°16'N-10°44'N latitudes and 79°30'E-79°52'E longitudes and covers an area of 698 sq.km in both the parts of Nagappatinam and Thiruvarur districts of Tamilnadu. The Adappa watershed 4B1A2b falls in the Cauvery river basin and the river Adappar is a sub tributary of the river Cauvery, confluencing with a bay of Bengal. In this research work the coastal line of Adappa watershed is considered as a study area, covering a length of about 42.5 km from Prathabaramapuram in the north and Kodiakkarai in the south. Index map of the study area is presented in Figure 1

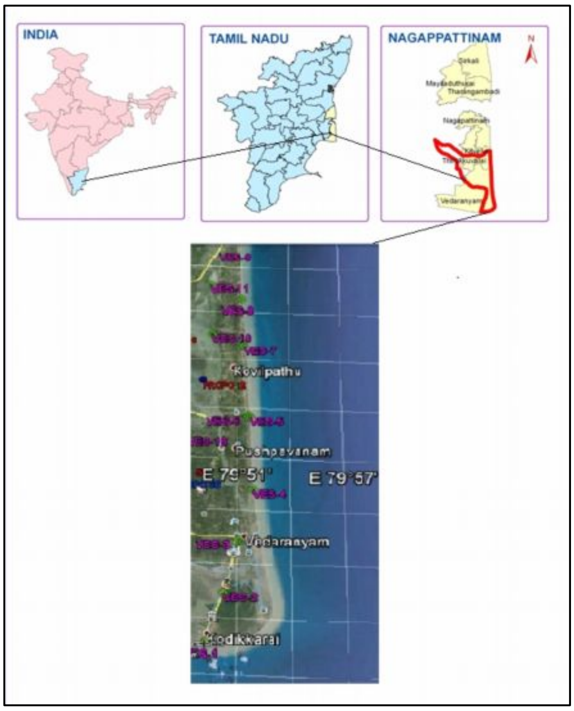


Fig 1 Index map of the study area

In the coastal areas, the occurrence and movement of groundwater are controlled by climate, topography, geomorphology, geology and structures, etc. The main recharging source of aquifer systems is the precipitation. This coastal region receives maximum rainfall during Northeast monsoon period ie October to December. The quality of groundwater of shallow aquifer is generally good along the coast. The quality deteriorates in the south and southeastern parts ie along Vedaranyam coast, which may be attributed to the marine and semi marine origin sediments.

2.1 Geology and Hydrogeology

The entire coastal belt of Adappa watershed is occupied by the Quaternary formations. The major geological formations are alluviums, fluvio marine shale, silt, marine sands and sandy clay. The geomorphic setup is the result of action of the major rivers, fluctuation in the sea level, the tidal effects of the Bay of Bengal and the forces of wind. Depositional regime comprises of a coastal plain under marine influence, a flood plain of fluvial regime with an intermixing section of both fluvial and marine influences. Sand dunes and beach ridges are very common along the sea coast.The major geomorphic units and land forms are beaches and beach ridges, coastal plains, delta plains, sedimentary plains, lagoon/ backwaters, marsh, natural levee, salt flat and water bodies.The area has mainly alluvial soil consisting of sand, silt and clay. The major part of the area is covered by black clayey soil. Some patches of Arenacious soils are also found along the coastal line.

2.2 The Coastal Aquifer System

The tail end of the Adappar river from Prathabaramapuram in the north to Kodiakkarai in the south constitutes the coastal aquifer system. The scenario of groundwater over exploitation is widely witnessed in coastal aquifers especially in high population zones. Coastal aquifers are typically characterized by variations in groundwater quality in space and time, and are vulnerable directly and indirectly to anthropogenic activities and climate change induced seawater intrusion.

3. Problems in the Study Area

The hydrogeological environment in the study area has been subjected to pollution considerably. The mushrooming and unregulated growth of aquaculture may lead to an alarming magnitude of pollution. Excess pumping of fresh water in coastal aquifer will lead to seawater intrusion. The coastal line is occupied by intensive agriculture, salt pan and aquaculture activities. The fresh water pocket in the sand dune areas are used for drinking purposes. The discharge of untreated wastewaters of aquaculture farms and chemicals used for the growing prawns will also affect the shallow fresh water pockets. The environmental hazards may arise in two kinds. (1) Due to the infiltration of irrigation water saturated with chemicals, insecticides, pesticides, fertilizers (2) the water of Cauvery is highly polluted with industrial effluents. The river water is reported to be polluted by the effluents discharged into the river by several textile processing industries in the upstream [4].

4. Methodology

Geological, Hydrogeological, Hydrogeomorphological and geoelectrical studies have been conducted in the coastal stretch to explore the groundwater potentials, impact of seawater intrusion, fresh water saline water interface and subsurface lithology.

4.1 Groundwater Exploration

Geophysical methods can be used to measure the spatial distribution of the physical properties of the subsurface specifically related to the position of water, quality and properties of geologic units. Geophysical methods, however, do not directly determine water quality or the geologic units. The application of Geophysical techniques to explore groundwater is referred as Groundwater geophysics or Hydrogeophysics. Various physical properties that are made use of in different geophysical techniques for groundwater exploration are electrical conductivity, magnetic susceptibility, density, gravity, elasticity, dielectric constant and radioactivity.

4.2 Electrical Prospecting Methods

Electrical methods of prospecting include a large group of geophysical techniques which are employed in investigating the electrical and electromagnetic fields of the earth. Such fields are generated in the Earth naturally or artificially by using generators [DC or AC] or batteries. The distribution and intensity of the electrical fields in the Earth depend on the source of excitation as well as upon electrical properties and geological structure in the region. Electrical methods are the most widely used geophysical methods for delineating the saline interface. This is because electrical resistivity is an intrinsic function of groundwater chemistry, and the degree of saline intrusion can be readily interpreted. Electrical methods also have the advantages of being non-intrusive, economical, and are relatively fast. Electrical resistivity is the property which controls the amount of current that passes through a rock when a potential difference is applied, given by ohms law, $V=IR$, *(V)* voltage, *(I)* current, *(R)* resistance. The resistivity is defined as the resistance offered by a unit length of a substance of a unit area to the flow of electric current when the voltage is applied at the opposite faces. The resistivity of pore fluid depends upon the concentration of ions in the fluid. Saline water has high concentrations of total dissolved solids, mostly sodium and chloride ions, which are highly conductive. Therefore, water with high salinity has a very low resistivity, approximately 0.3 Ωm for seawater.

4.3 Resistivity Sounding (VES)

The current (I) is generally injected into the ground through two outer electrodes called as the current electrodes and the potential difference (V) is measured between the inner electrodes referred to as the potential electrodes. The ratio between the potential difference and the current sent (V/I), gives the Resistance (R). Apparent resistivity is calculated by multiplying the value of 'R' with configuration factor. Resistivity sounding is a technique of studying the vertical variations in resistivity of subsurface by which thicknesses of various subsurface layers and their resistivities are estimated. In this approach, the center of the configuration is kept fixed and the measurements are made by progressively increasing the electrode spacings as shown in Fig 2.

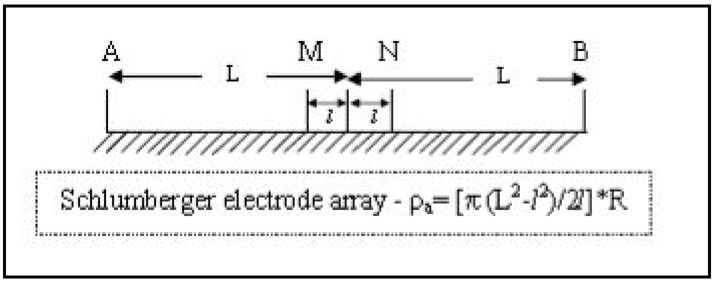


Fig 2 Schlumberger electrode array spacing

9 VES have been conducted along the coast approximately at an interval of 5 km from Prathabaramapuram to Kodiakkarai using advanced microprocessor based 1D resistivity system of both WTS, China make, model WDDS-2 and IGIS, Hyderabad makes, model SSR-MP-AT-S, employing a Schlumberger array with maximum AB/2 separation of 100 m. The acquired VES data have been downloaded to the computer for further analysis and interpretations. The VES data have been processed, both qualitatively and quantitatively by software packages Surfer- version 9, IPI2 Win version.

5. Results and Discussion

The geoelectrical method is an efficient tool for most of groundwater resources studies. resistivity pseudo maps, True resistivity, resistivity contour maps have been prepared and presented in Figures 3-5 to delineate the subsurface lithology. Fresh salt water interface and ultimately the groundwater potentials have been explored vide Figure 7. The resistivity of the coastal aquifer decreases towards south due to increasing salinity and presence of clay content.. Due to fluvial marine origin the brine water available in deeper depth so in Vedaranyam area more than 45km^2 areas covered by salt pan .

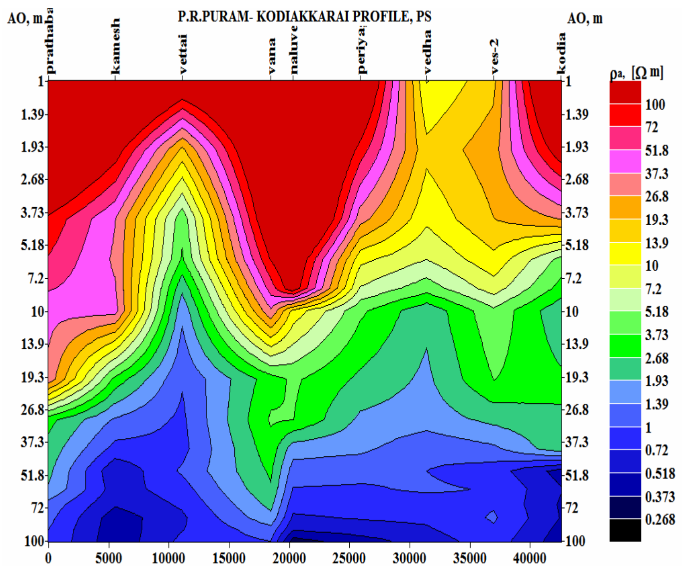


Fig 3 Prathabaramapuram to Kodiakkarai Resistivity Pseudo Section

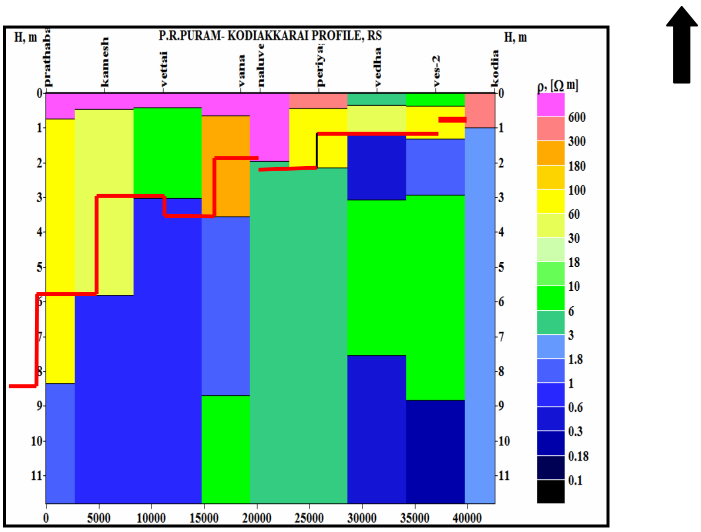
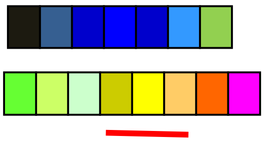


Fig 4 True Resistivity Distance (m)



Probable Salt /Brackish Water Aquifers

Probable Fresh Water Aquifers

Interpreted Freshwater, Salt Water Interface

- From the figure 4 which states that in Prathamaramapuram, resistivity ranges from 60-100 ohm-m due to the presence of sand dunes. In this area the fresh water is available upto the depth of 8m from below ground level (BGL).
- From Prathabarampuram to Nalluvedapathi approximately 25km towards south, the resistivity values reach more than 600 ohm-m, at 1m depth BGL. This is because of rainfall recharge. The presences of shallow aquifer of these areas are the only source for agriculture. Paddy and groundnut are the main cultivated crops in this area
- The low resistivity anomaly at Kodiakarai due to shallow saline aquifer because of not only seawater intrusion and also presences of fluvial marine origin.

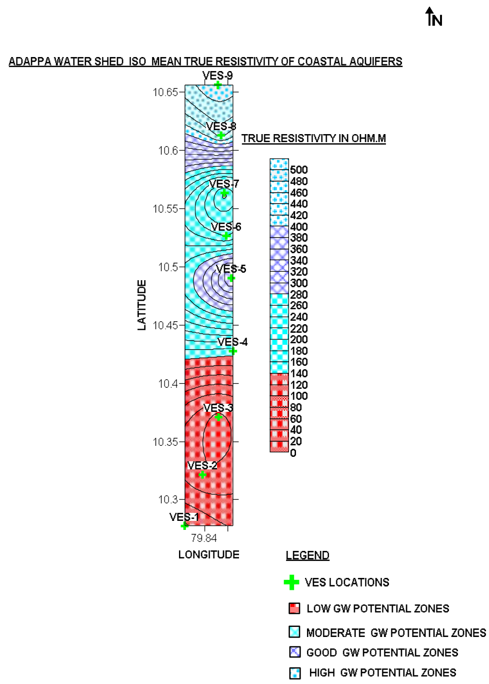


Fig 5 ISO Mean True Resistivity map

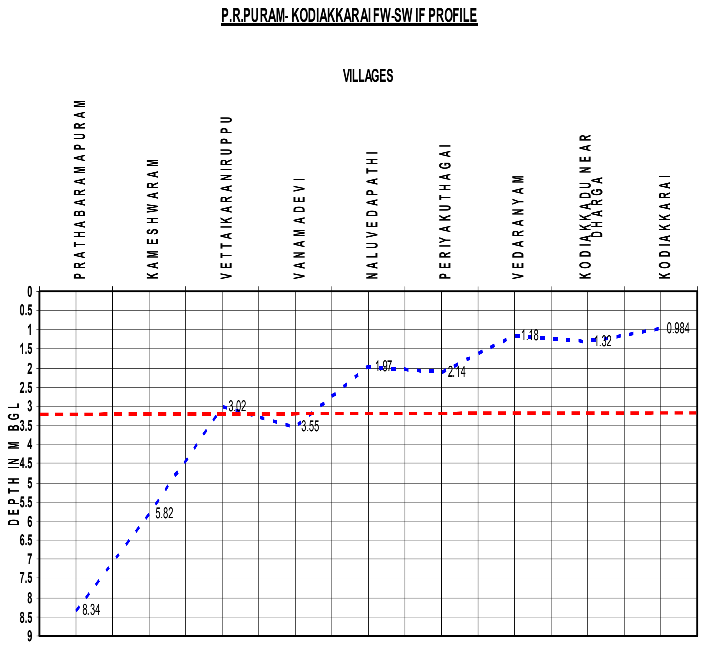


Fig 6 Fresh & Salt Water Interface Profile

- The average depth of interface is 3.2m so interface lies at the shallow level because of the shallow saline aquifer vide figure 6
- The geoelectric signature shows a very significant variation in resistivity values because use existence of different types of rocks such as clay and sand dunes from north to south of the study area

6. Conclusions

The minimum and maximum elevations of the 9 VES locations 1 and 4 are above msl with a gentle slope towards east and south east. The lithological units on the coast are fluvio marine sediments, soil, silt, beach sand, sandy clay. The geomorphic units are beach ridges, coastal plains, delta plains, sedimentary plains, marsh, natural levee, salt flat. The principal and potential aquifers are alluviums and sand. In the coastal aquifer system the groundwater occurs in the alluvial, flood and deltaic plains under pheratic conditions. The shallow sandy aquifers along the coast are fresh water in nature in general. The geoelectric layers of the coastal aquifer are of multi layered types with a minimum and maximum of 3 and 6 layers. Majority of the VES curves are QQ type. The coastal aquifers are observed to be intruded by sea water based on geoelectric studies. The tentative depth to fresh water, salt water interface ranges from 0.904 to 8.34 based on the geoelectric studies of nine VES along the coast. The depth to interface has a fluctuating trend and the depth decreases towards south. The depth of the interface is with reference to ground level. The depth will vary according to seasonal water level fluctuations, recharge and discharge. The minimum and maximum mean true resistivities are 1709 & 0.08 ΩM. The southern and southeastern zones of the watershed have a low groundwater potential in general with poor water quality due to marine origin sediments based on geoelectric parameters.

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