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Study of Identification of Effective Sand Bed in Aquifer Zones using Resistivity Survey in Tripura: Case Studies

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ABSTRACT: *Growing water scarcity in India is threatening for sustainable water supply source of the inhabitants. As the present water sources are not being able to provide water as per required demand so, groundwater can play an important role in ensuring complementary and sustainable water supply in parallel with the present water sources. Hence sustainable exploitation of this resource is needed and thus studies are needed to be done so that we can reach a sustainable yield of groundwater. Vertical Electrical Sounding (VES) is one such method by which resistivity of earth materials is checked and prospective ground water potential zones are identified along with sub soil stratifications. The resistivity meter (SAR-MP-ATS) was used to collect the VES data by employing Schlumberger electrode configuration and the field data were interpreted in terms of resistivity and the corresponding thickness of various subsurface layers using 'Interpex, IX1D' computer software. The present study focuses on identification of effective sand bed for Khowai District, West Tripura District, Sepahijala District and Gomati District in Tripura and as well as developing resistivity variation curve and interpreting lithologs / sub soil stratification from VES survey data. VES study may be used to find the litholog of the terrain without further making boreholes in the regions thus reducing cost incurred and labour required and thus finding groundwater potential zones economically.*

I. INTRODUCTION

A study was carried out to assess the prevailing groundwater condition in the South, Central, Northern part of Sagar Island region, West Bengal, India using surface resistivity method. Vertical electrical sounding (VES) survey at 38 sites using the Schlumberger array by the resistivity equipment DDR-4 manufactured by the Integrated Geo Instruments and Services Pvt. Ltd., Hyderabad, Andhra Pradesh, India with maximum current electrode spacing of 1200 m used in the study was conducted. The apparent resistivity datasets thus obtained were interpreted using 1D inversion technique by RESIST software with RMS error less than 5%. From the interpreted VES results he found the average upper and lower depths of fresh water bearing aquifer for all location are 187 m and 354 m respectively and the resistivity values were ranging from 32 Ω-m to 75.5 Ω-m with average value of 52 Ω-m. It was also proposed that the probable lithology of the study area which was the top soil, the saline water zone, the brackish groundwater zone and impermeable clay layer, clay with fine sand and silt lenses (Majumdar and Das, 2011). VES surveys were conducted at 44 locations in different hydro-geomorphic units to assess the types and thickness of different geo-electrical layers to understand the aquifer system in each unit at Bonai subdivision of Sundargarh district, Orissa, India. VES studies in the area revealed that the area had high potential for exploitation of groundwater through different kinds of groundwater structures. Depth to the bedrock ranged from 30 m to 70 m in most parts of the geomorphic units and 15 m to 30 m in some places. It was concluded that the dug-cum borewells along with dug wells might be constructed in areas where depth to bedrock lie between 15 m to 30 m and borewells along with dug wells and dug-cum-bore wells were suitable in areas where depth to bedrock was more than 30 m. (Sahu and Sahoo, 2006). 26 VES surveys were conducted by Rai et al., (2005) using Schlumberger electrode configuration in the Dhanbad district in Jharkhand, India. They concluded that the resistivity of water-bearing weathered / fractured rocks varied from 120 Ω-m to 150 Ω-m and the better zones, which were most promising for groundwater exploration could be dug up to depths of (30 ± 5) m. VES studies were carried out by Srinivasa, (2004) in order to delineate groundwater potential aquifers in Peddavanka watershed, a catchment of about 398 km2 in Anantapur District, Andhra Pradesh, India. A total of 99 VES surveys were conducted using the Schlumberger configuration with a maximum current electrode (AB/2) separation of 90 m, covering the entire watershed. It was revealed that the weathered and fractured portions in shale and limestone that occur in the southernmost and central portions of the watershed area constituted the productive water-bearing zones, which were categorized as good groundwater potential aquifers. It was concluded that the VES data gave reasonably accurate results that could be used to understand the subsurface layers and basement configuration in groundwater exploration. The VES surveys were performed by Sharifi et al., (2014) in 10 sounding points in the Tepal area, west of Shahrood, Iran using the Schlumberger array with electrode separations of a maximum 500 m. Then, one-dimensional (1-D) modeling and interpretation of the sounding results, using master curves and IX1D software, and two-dimensional (2-D) modeling and interpretation of the profiling results using Res2DINV were made. As a result of the interpretation and integration of the results, karstic water zones in the study area were recognized, and based on that, suitable locations for drilling to access and extract karstic groundwater were introduced. The research covered four small communities, namely, Zantele, Kanshegu, Nyengbalo and Zei. The Schlumberger electrode configuration was first used in the line profiling. Qualitative interpretation of the geoelectrical resistivity profiling data resulted in the identification of weathered regions. Vertical electrical sounding using the dipole-dipole array were then conducted with at specific points within the weathered zones. The spread length ranged from minimum of 12 m to maximum of 204 m to provide depth information. Interpex 1X1D v2 (Ezomo and Aigbogun, 2012) and v3 software was used to compute layered earth model of the subsurface beneath the sounding points. Interpretation of the one-dimensional inversion of the VES resistivity data provided the overburden and aquifer layering resistivities and thicknesses. The geoelectric sequence revealed predominantly a three subsurface layer which is largely congruous to the weathering profile above the fresh bedrock - thick top soil, the weathered and the variably weathered and fractured bedrock respectively. The geoelectric sections provide no evidence of a descent into the fresh bedrock. The geophysical target is a reasonably thick and extensive zone of saturated weathered rock beneath the overburden. On the basis of the perceived aquifer properties, sites were recommended for drilling water supply boreholes for the communities (Asare and Menyeh, 2013). Sikandar and Christen (2012) established an empirical relationship between the formation factor and hydraulic conductivity which was highly significant and as such can be helpful for the estimation of hydraulic conductivity for groundwater pumping investigations in this area and a study on dynamic groundwater assessment in Agartala city has been carried out by Debbarman et al (2013) to assess the groundwater potential. However, keeping in this view, the objective of this paper is to investigate the aquifer characteristics, thickness, layerwise soil type, and water table depth using Vertical Electrical Sounding (VES) resistivity survey technique and also to interpret resistivity variation curve from the data obtained from Vertical Electrical Sounding (VES) survey in different study areas by using computer software (IX1D).

II. MATERIALS AND METHODS

2. 1. Study Area

2.1.1. Khowai District

Khowai district lies in the northern part of Tripura state. The district is bounded on the north by the country Bangladesh, on the south by Gomati district, on the west by Dhalai district and on the east by West Tripura district. The district has total area of 1377.28 sq. km. and it lies between the Latitude 23°42' N to 24°14' N and Longitude 91°39' E to 91°46' E. The district is divided into 2 sub-divisions and 6 administrative blocks. The district comprises of 3 numbers of revenue circles, 2 numbers of nagar panchayats, 79 numbers of maujas and 107 numbers of villages. The total population of the Khowai district as per the 2011 census is 327564 persons. The district headquarter is located at Khowai (Ghosh, 2014).

2.1.2. West Tripura District

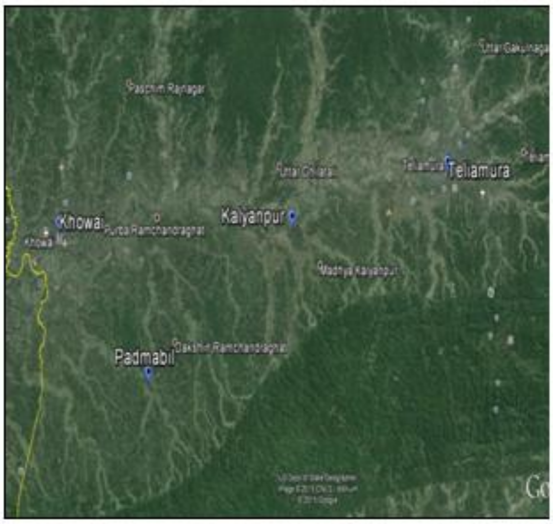
West Tripura district lies in the western part of Tripura state. The district is bounded on the north by the country Bangladesh, on the south by Sepahijala district, on the west by the country Bangladesh and on the east by Khowai district. The district has total area of 983.63 sq. km. and it lies between the Latitude 23°16' N to 24°14' N and Longitude 91°47' E to 92°20' E. The district is divided into 3 sub-divisions and 9 administrative blocks. The district comprises of 1 number of Municipal Corporation, 1 number of Nagar Panchayat. The total population of the West Tripura district as per the 2011 census is 918200 persons. The density of population is 576 persons per sq. km. The district headquarter is located at Agartala, which is also the capital of the state Tripura.

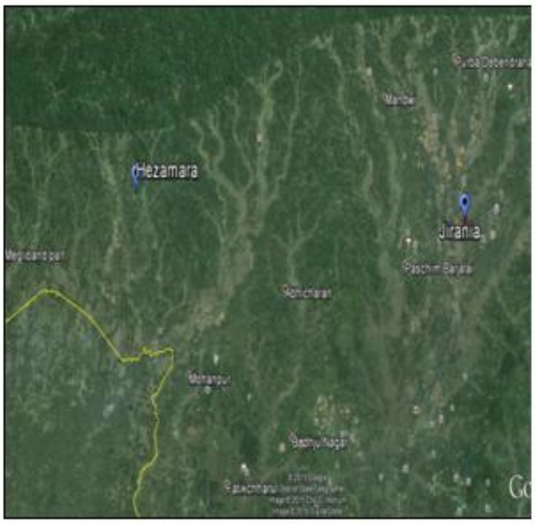
2.1.3. Sepahijala District

Sepahijala district lies in the western part of Tripura state. The district is bounded on the north by West Tripura district, on the south by the country Bangladesh, on the west by the country Bangladesh and on the east by Gomati district. The district has total area of 1043.58 sq. km. and it lies between the Latitude 23°16' N to 24°14' N and Longitude 91°47' E to 92°20' E. The district is divided into 3 sub-divisions and 5 administrative blocks. The district comprises of 2 numbers of Nagar Panchayat. The total population of the Sepahijala district as per the 2011 census is 483687 persons. The density of population is 576 persons per sq. km. The district headquarter is located at Bishramganj.

2.1.4. Gomati District

Gomati district lies in the southern part of Tripura state. The district is bounded on the north by the West Tripura district and Khowai district, on the south by South Tripura district and Bangladesh, on the west by Sepahijala district and on the east by Dhalai district. The district has total area of 2624.35 sq. km., which is about 25% of the total state area. It lies between the Latitude 22°56' N to 24°32' N and Longitude 91°59' E to





92°22' E. The district is divided into 3 sub-divisions and 8 administrative blocks. The district comprises of 7 numbers of revenue circles, 1 number of Municipal Corporation, 1 number of Nagar Panchayat and 157 numbers of villages. The total population of the Gomati district as per the 2011 census is 442336 persons. The district headquarter is located at Udaipur.

III. METHODOLOGY

To examine the geoelectrical properties of the area, electrical resistivity survey has been carried out using the SSR-MP-ATS resistivity meter with the Schlumberger configuration at 4 locations (Teliamura, Kalyanpur, Padmabil, Khowai) in Khowai district, Tripura. A GPS receiver is used in the field to get the position data of each VES site at the study area. All the survey points are shown in Fig.1(a) using Google Earth image.

To examine the geo-electrical properties of the area, electrical resistivity survey has been carried out using the SSR-MP-ATS resistivity meter with the Schlumberger configuration at 2 locations (Jirania, Hezamara) in West Tripura district, Tripura. A GPS receiver is used in the field to get the position data of each VES site at the study area. All the survey points are shown in Fig.1(b) using Google Earth image.

To examine the geoelectrical properties of the area, electrical resistivity survey has been carried out using the SSR-MP-ATS resistivity meter with the Schlumberger configuration at 5 locations (Maheshpur, Kathalia, Paharpur, Sonamura, Boxanagar) in Sepahijala district, Tripura. A GPS receiver is used in the field to get the position data of each VES site at the study area. All the survey points are shown in Fig.1(c) using Google Earth image.

To examine the geoelectrical properties of the area, electrical resistivity survey has been carried out using the SSR-MP-ATS resistivity meter with the Schlumberger configuration at 5 locations (Tepania, Matabari, Amarpur, South Karbook, East Karbook) in Gomati district, Tripura. A GPS receiver is used in the field to get the position data of each VES site at the study area. All the survey points are shown in Fig.1 (d) using Google Earth image.

3.1. IX1D software: Interpretation of VES survey data

The subsurface layering was derived based on the distinct resistivity values of the upper layer (ρ1), second layer (ρ2), third layer (ρ3) and so on. The distinctive characteristics features in the apparent resistivity curves were characterized by the considerable spatial variability of the groundwater quality and inhomogenity of the subsurface aquifer conditions. Therefore, depending upon the shape of the curve, different layer earth data were classified into different types. The shape of the VES curve at any location is controlled by the underlined formation distribution i.e. the resistivity (ρi) and thickness (hi) of the geoelectric layers and the total depth investigated.

Two layer section in resistivity method means the first layer thickness is finite while that of the second layer is infinite. The only two situations that can occur for a two layer section are either the resistivity of the first layer is greater than the second (ρ1 > ρ2) or less than the second (ρ1 < ρ2); the former case is 'Ascending Type' curve and the later is 'Descending Type' curve.

Orellana and Mooney (1966) presented 4 types of interpreted curves based on the 3 layered earth model as given in TABLE 1. Accordingly, the 3 layered earth can be classified into 'Q', 'H', 'K' and 'A' Type curves based on their shapes. The distribution of resistivities associated with different subsurface layers with different settings is described below (Srinavasa, 2004):

Table 1. Details of curve types for three layer case

Sl. No.	Curve Type	Resistivity Details
1	Q type	ρ1 > ρ2 > ρ3
2	H type	ρ1 > ρ2 < ρ3
3	K type	ρ1 < ρ2 > ρ3
4	A type	ρ1 < ρ2 < ρ3

A total 8 types of 4 layer curves are possible depending upon the resistivity distribution of the various layers as highlighted in TABLE 2.

Table 2. Details of curve types for four layer case

Sl. No.	Curve Type	Resistivity Details
1	QQ type	ρ1 > ρ2 > ρ3 > ρ4
2	QH type	ρ1 > ρ2 > ρ3 < ρ4
3	AA type	ρ1 < ρ2 < ρ3 < ρ4
4	AK type	ρ1 <ρ2 < ρ3 > ρ4
5	HA type	ρ1 > ρ2 <ρ3 < ρ4
6	HK type	ρ1 >ρ2 < ρ3 >ρ4
7	KH type	ρ1 < ρ2 > ρ3 < ρ4
8	KQ type	ρ1 < ρ2 > ρ3 > ρ4

Similarly a five layer section can yield 16 possible types of curves and so on. A geological formation may be comprised of more than one geoelectric layers and vice versa.

The apparent resistivity values collected from the study areas are to be plotted against half of the current electrode spacing on a transparent log-log paper at the same scale as of two and three layers standard curves. The interpretation by curve matching technique of VES data is to use the curve of apparent resistivity versus electrode spacing, plotted from field measurements, to obtain the parameters of the geoelectrical section, the layer resistivities and thicknesses. The use of standard curves matching technique requires an identification of the curve type followed by a comparison with standard curves of that type to obtain the best match. Two-layer and three-layer curves can be used for complete interpretation of VES curves of more layers by the Auxiliary Point Method, which requires the use of a small set of auxiliary curves and some constructions. This is the early method of interpreting sounding curves which used curve-matching techniques. A set of standard curves developed by Orellana and Mooney (1966) and Zohdy (1969) is shown in Fig. 2. This technique has also been used by many researchers such as Shankar (1994), Lashkaripour (2003), Lashkaripour et al. (2005) and Oseji et al. (2006). Based on this preliminary interpretation, initial estimates of the resistivities and thickness (layer parameters) of the various geoelectric layers were obtained.

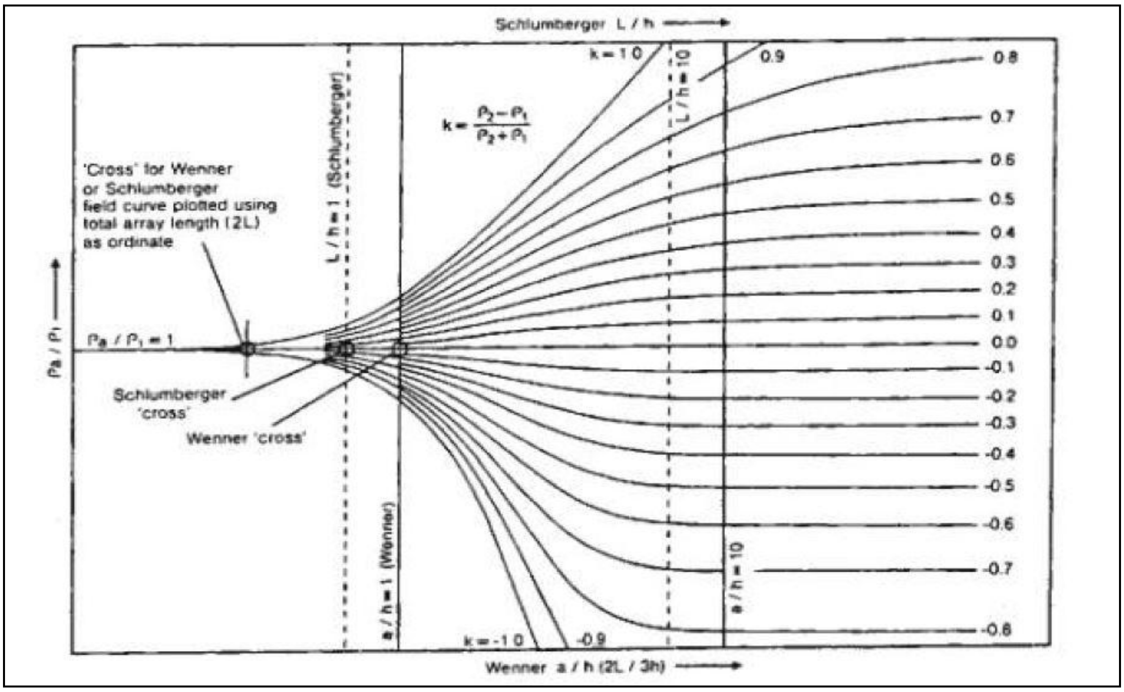


Fig. 2. Master curve for two layered system (Source: Bernard, 2003)

In the second analysis, the layered parameters derived from the graphical curve matching were then matched with the interpreted sounding data in terms of the final layer parameters through 1-D inversion technique software (IX1D v3.0, Interpex, USA). This software produces the resistivity model, fitting the acquired field data with the least root mean square (RMS) error between the synthetic data generated from the model and the actual data themselves. The method of iteration was performed until the fitting errors between field data and synthetic model curve became least and constant. The output of true resistivities (or simply resistivities) values of the subsurface layer, their thickness and depth from the ground surface after interpreting field data (apparent resistivities) by fitting curve to input data using IX1D computer software. The electrical resistivity of sediments depends on lithology, water content, clay content and salinity (Bernard, 2003; Choudhury and Saha, 2004). Some interpretation problems for VES can occur when mapping subsurface salinity, since resistivities for salt water, saturated clay and sand overlaps. It is therefore important to correlate the VES results with the lithological and hydrological information of the same sites.

IV. RESULTS AND DISCUSSION

Since the study area falls on sedimentary tract, the water prospect here is by the saturated water present in the sand aquifers below. The tract is alluvial and water availability here is good, the aquifers zones are unconfined and are very prospectful zones for groundwater development by deep tubewells.

4.1. Khowai District

VES curve at Teliamura and Padmabil is classified as Type Q Curve reflecting the presence of three subsurface layers which gives the resistivity relationship of $\rho1 > \rho2 > \rho3$. VES curve at Kalyanpur is classified as Descending Type Curve reflecting the presence of two subsurface layers which gives the resistivity relationship of $\rho1 < \rho2$. VES curve at Khowai is classified as Type K Curve reflecting the presence of three subsurface layers which gives the resistivity relationship of $\rho1 < \rho2 > \rho3$. All the VES curves are presented in Fig. 3 (Fig. 3a to Fig. 3d).

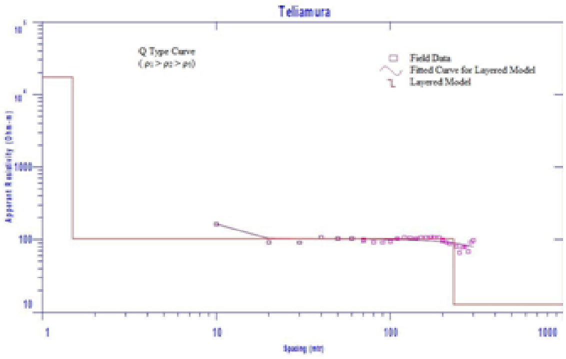


Fig. 3a. VES curve for location Teliamura

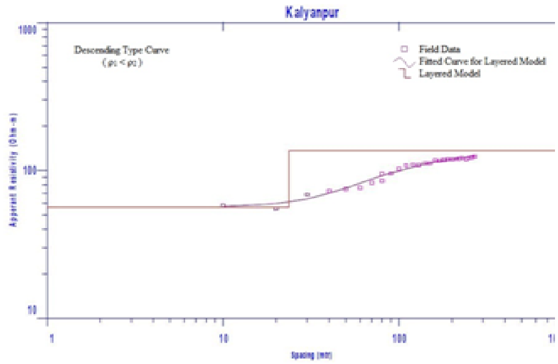


Fig. 3b. VES curve for location Kalyanpur

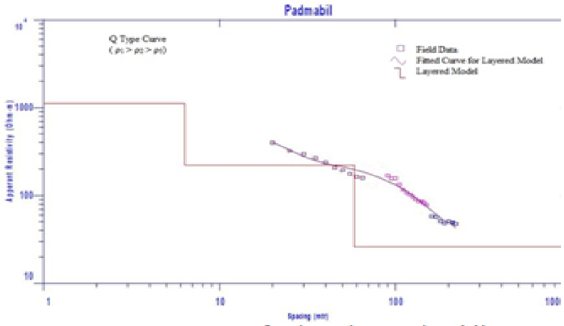


Fig. 3c. VES curve for location Padmabil

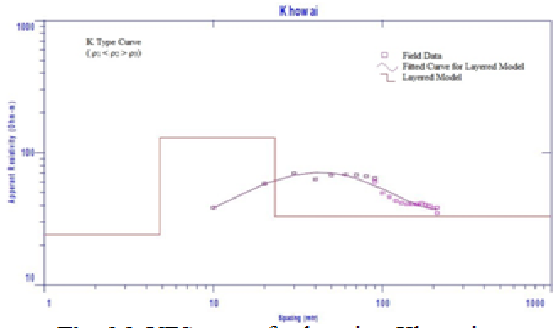


Fig. 3d. VES curve for location Khowai

From the interpreted true resistivities at Khowai district, Tripura, we can see that subsurface formations are highly variable. At Teliamura we can see three subsurface layers out of which the top layer is generally formed with very coarse sand particles with gravel, the second layer is generally formed with clay mixed with fine sand particles and the bottom layer is generally formed with clay. At Kalyanpur we can see two subsurface layers out of which the top layer is generally formed with clay with conserved moisture contents and the bottom layer is generally formed with clay mixed with fine sand particles. At Padmabil we can see three subsurface layers out of which the top layer is generally formed with very coarse sand particles, the second layer is generally formed with dry silty clay and the bottom layer is generally formed with clay. At Khowai we can see three subsurface layers out of which the top layer is generally formed with clay, the second layer is generally formed with clay mixed with fine sand particles and the bottom layer is generally formed with clay with conserved moisture contents.

4.2 West Tripura district

VES curve at Jirania is classified as Type KH Curve reflecting the presence of three subsurface layers which gave the resistivity relationship of $\rho 1 < \rho 2 > \rho 3 < \rho 4$. VES curve at Hezamara is classified as Ascending Type Curve reflecting the presence of two subsurface layers which gave the resistivity relationship of $\rho 1 > \rho 2$. All the VES curves are presented in Fig. 4 (Fig. 4a and Fig. 4b).

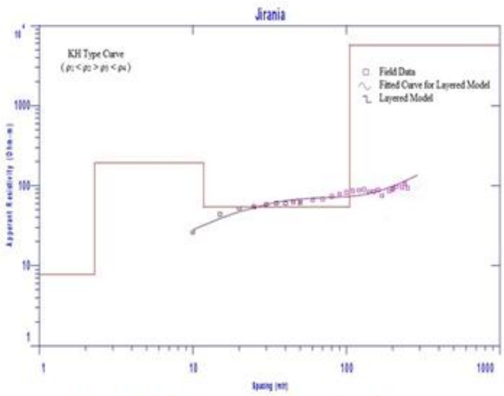


Fig. 4a. VES curve for location Jirania

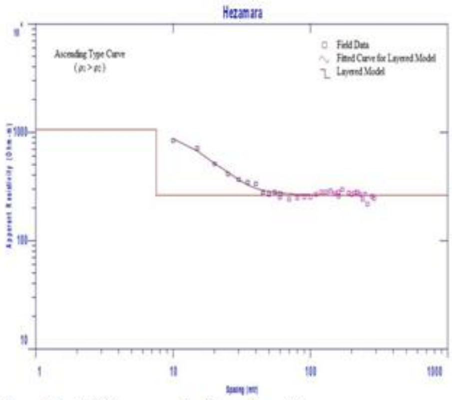


Fig. 4b. VES curve for location Hezamara

From the interpreted true resistivities at West Tripura district, Tripura, we can see that subsurface formations are highly variable. At Jirania we can see four subsurface layers out of which the top layer is generally formed with impervious type clay, the second layer is generally formed with clay mixed with fine sand particles, the third layer is generally formed with clay with conserved moisture contents and the bottom layer is generally formed with very coarse sand particles with gravel. At Hezamara we can see two subsurface layers out of which the top layer is generally formed with very coarse sand particles and the bottom layer is generally formed with silty clay.

4.3 Sepahijala district

VES curve at Maheshpur and Kathalia is classified as Descending Type Curve reflecting the presence of two subsurface layers which gives the resistivity relationship of $\rho1 < \rho2$. VES curve at Paharpur is classified as Type Q Curve reflecting the presence of three subsurface layers which gives the resistivity relationship of $\rho1 > \rho2 > \rho3$. VES curve at Sonamura is classified as K Type Curve reflecting the presence of three subsurface layers which gives the resistivity relationship of $\rho1 < \rho2 > \rho3$. VES curve at Boxanagar is classified as KHK Type Curve reflecting the presence of five subsurface layers which gives the resistivity relationship of $\rho1 < \rho2 > \rho3 < \rho4 > \rho5$. All the VES curves are presented in Fig. 5 (Fig. 5a to Fig. 5e).

From the interpreted true resistivities at Sepahijala district, Tripura, we can see that subsurface formations are highly variable. At Maheshpur we can see two subsurface layers out of which the top layer is generally formed with hard impervious type clay and the bottom layer is generally formed with clay with conserved moisture contents. At Kathalia we can see two subsurface layers out of which the top layer is generally formed with hard impervious type clay and the bottom layer is generally formed with clay mixed with fine sand particles.

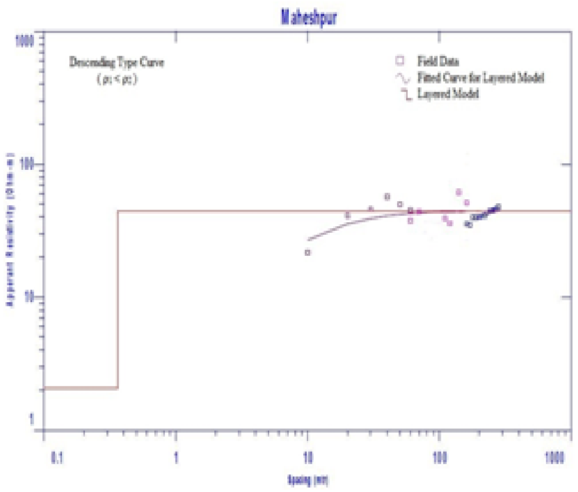


Fig. 5a. VES curve for location Maheshpur

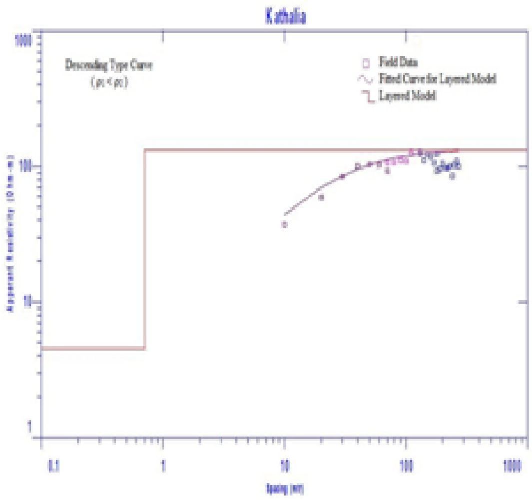


Fig. 5b. VES curve for location Kathalia

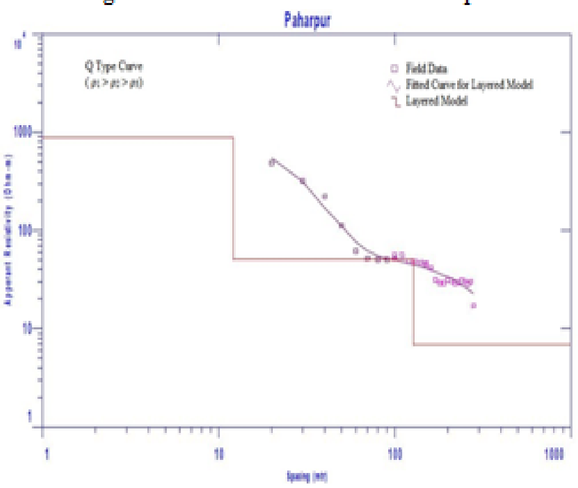


Fig 5c. VES curve for location Paharpur

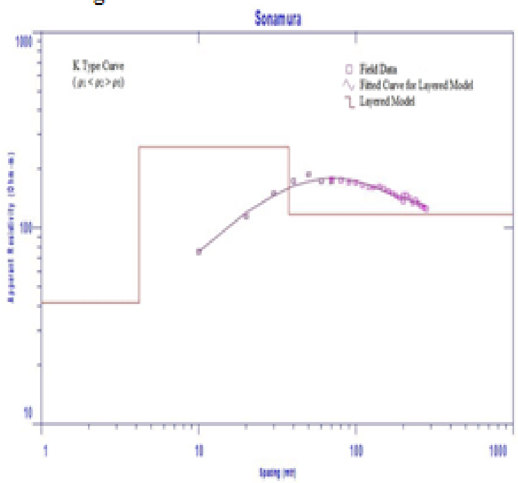


Fig. 5d. VES curve for location Sonamura

At Paharpur we can see three subsurface layers out of which the top layer is generally formed with very coarse sand particles, the second layer is generally formed with clay with conserved moisture contents and the bottom layer is generally formed hard impervious type clay. At Sonamura we can see three subsurface layers out of which the top layer is generally formed with clay with conserved moisture contents, the second layer is generally formed with dry silty clay and the bottom layer is generally formed with clay mixed with fine sand particles. At Boxanagar we can see five subsurface layers out of which the top layer is generally formed with clay, the second layer is generally formed with clay mixed with fine sand particles, the third layer is generally formed with impervious type clay, the fourth layer is generally formed with clay mixed with very fine sand particles and the bottom layer is generally formed with clay with conserved moisture contents.

4.4 Gomati district

VES curve at Tepania is classified as Type QH Curve reflecting the presence of four subsurface layers which gives the resistivity relationship of $\rho1 > \rho2 > \rho3 < \rho4$. VES curve at Matabari and Amarpur is classified as Type Q Curve reflecting the presence of three subsurface layers which gives the resistivity relationship of $\rho1 > \rho2 > \rho3$. VES curve at South Karbook is classified as Type K Curve reflecting the presence of three subsurface layers which gives the resistivity relationship of $\rho1 < \rho2 > \rho3$. VES curve at East Karbook is classified as Ascending Type Curve reflecting the presence of two subsurface layers which gives the resistivity relationship of $\rho1 > \rho2$. All the VES curves are presented in Fig. 6 (Fig. 6a to Fig. 6e).

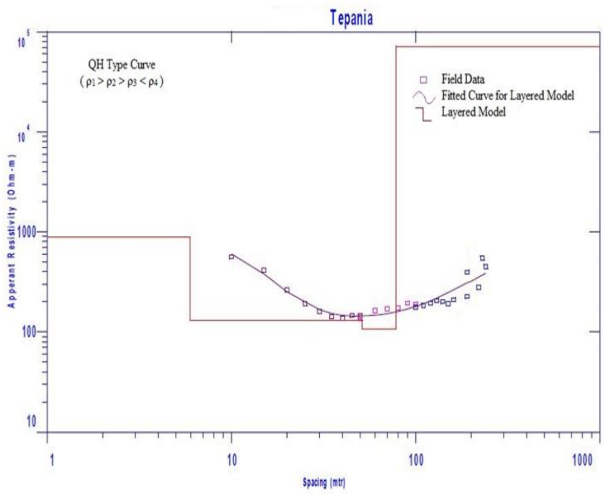


Fig. 6a. VES curve for location Tepania

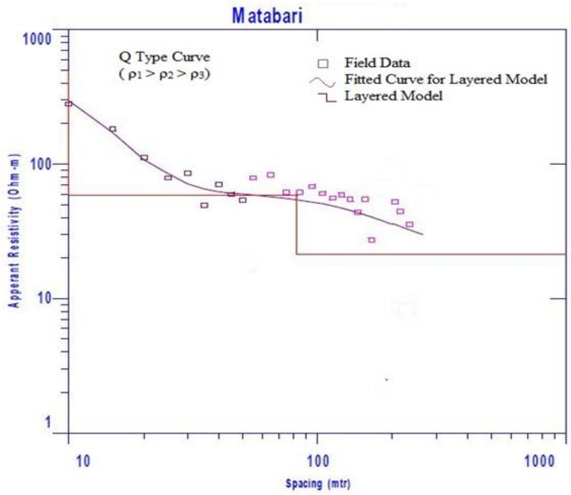


Fig. 6b. VES curve for location Matabari

From the interpreted true resistivities at Gomati district, Tripura, we can see that subsurface formations are highly variable. At Tepania we can see four subsurface layers out of which the top layer is generally formed with coarse sand particles, the second layer is generally formed with clay mixed with fine sand particles, the third layer is generally formed with clay mixed with very fine sand particles and the bottom layer is generally formed with very coarse sand particles with gravel. At Matabari we can see three subsurface layers out of which the top layer is generally formed with coarse sand particles, the second layer is generally formed with clay with conserved moisture contents and the bottom layer is generally formed with clay. At Amarpur we can see three subsurface layers out of which the top layer is generally formed with silty clay, the second layer is generally formed with clay mixed with fine sand particles and the bottom layer is generally formed with clay with conserved moisture contents. At South Karbook we can see three subsurface layers out of which the top layer is generally formed with clay with conserved moisture contents, the second layer is generally formed with clay mixed with fine sand particles and the bottom layer is generally formed with clay. At East Karbook we can see two subsurface layers out of which the top layer is generally formed with coarse sand particles and the bottom layer is generally formed with clay.

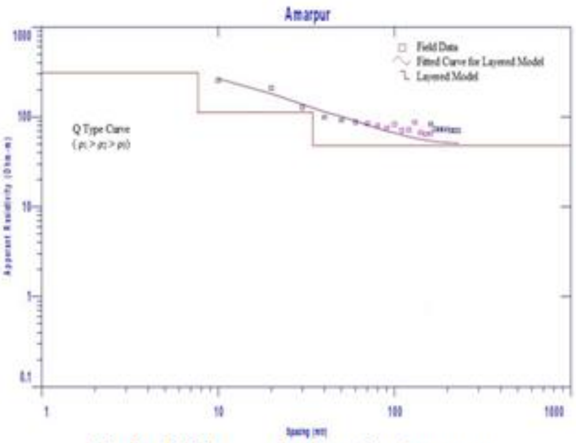


Fig. 6c. VES curve for location Amarpur

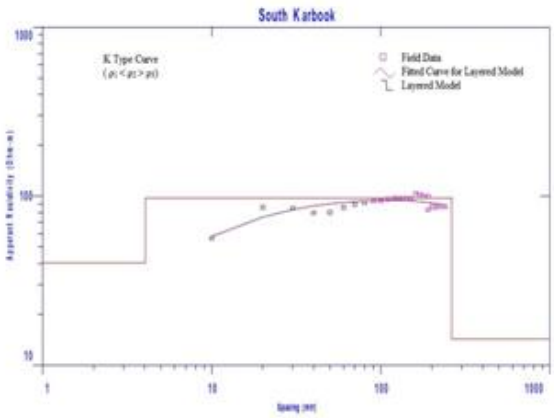


Fig. 6d. VES curve for location South Karbook

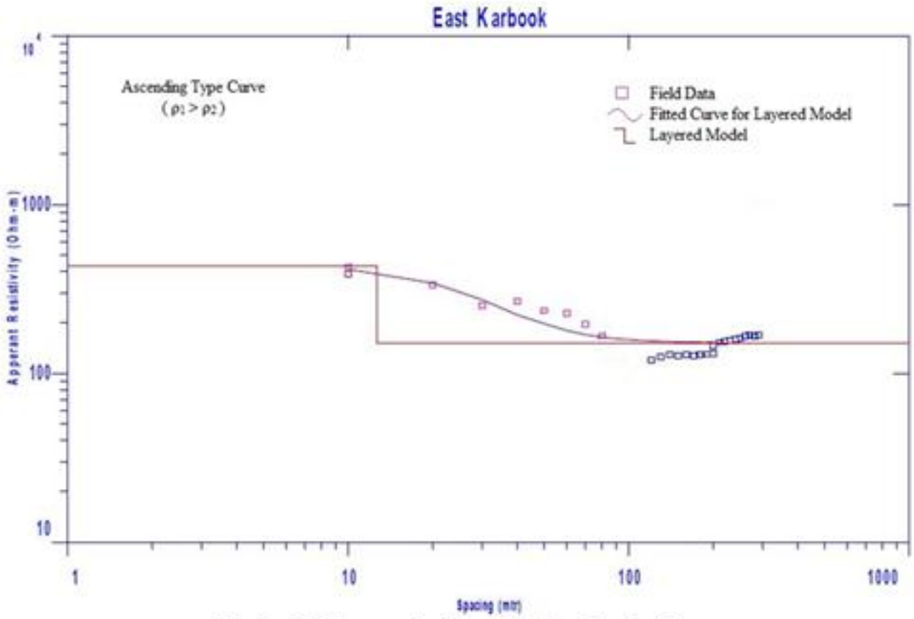


Fig. 6e. VES curve for location East Karbook

The two important Dar Zarouk parameters viz. Total Transverse Resistance and Total Longitudinal Conductance calculated for each VES point for this study area varies within 0.747 ohm-m^2 to 46293.1 ohm-m^2 and 0.00713 Siemens to 2.7599 Siemens respectively. From the values it can be seen that Teliamura, Paharpur and South Karbook are the locations which have both the above said parameters value near the maximum i.e., these are the locations having good groundwater potential and Maheshpur and Kathalia are the locations which have both the above said parameters value near the minimum i.e., these are the locations having poor groundwater potential.

V. CONCLUSION

After studying the geological & geophysical properties of the area and interpreting the field data it is suggested / recommended that, since the area falls on sedimentary tract, the water prospect here is by the saturated water present in the sand aquifers below. The tract is alluvial and water availability here is good, the aquifers zones are unconfined and are very useful zones for groundwater development by deep tubewells.

From the interpreted true resistivities at Khowai district, Tripura, we can see that subsurface formations are highly variable. Very coarse sand particles with gravel, clay mixed with fine sand particles, clayey soil, clay with conserved moisture contents, very coarse sand particles, silty clay are the main subsurface formations of this area. The survey yields that for getting a water quantity of (8000 - 10000) gallon per hour at Teliamura location drilling up to 190 m, at Kalyanpur location drilling up to 180 m, at Padmabil location drilling up to 180 m and at Khowai location drilling up to 170 m is recommended.

From the interpreted true resistivities at West Tripura district, Tripura, we can see that subsurface formations are highly variable. Impervious type clay, clay mixed with fine sand particles, clay with conserved moisture contents, very coarse sand with gravel, very coarse sand particles, silty clay are the main subsurface formations of this area. The survey yields that for getting a water quantity of (10000 - 12000) gallon per hour at Jirania location drilling up to 180 m is recommended and for getting a water quantity of (8000 - 10000) gallon per hour at Hezamara location drilling up to 200 m is recommended.

From the interpreted true resistivities at Sepahijala district, Tripura, we can see that subsurface formations are highly variable. Hard impervious type clay, clay with conserved moisture contents, clay mixed with fine sand particles, very coarse sand particles, silty clay, clayey soil are the main subsurface formations of this area. The survey yields that for getting a water quantity of (8000 - 10000) gallon per hour at Maheshpur location drilling up to 185 m is recommended, for getting a water quantity of (10000 - 11000) gallon per hour at Kathalia location drilling up to 180 m, at Sonamura location drilling up to 180 m, at Boxanagar location drilling up to 175 m is recommended and for getting a water quantity of (10000 - 12000) gallon per hour at Maheshpur location drilling up to 185 m is recommended.

From the interpreted true resistivities at Gomati district, Tripura, we can see that subsurface formations are highly variable. Dry layer of coarse sand, clay mixed with very fine sand particles, very coarse sand particles with gravel, coarse sand particles, clay with conserved moisture contents, clayey soil, silty clay are the main subsurface formations of this area. The survey yields that for getting a water quantity of (8000 - 10000) gallon per hour at Tepania location drilling up to 190 m, at Matabari location drilling up to 180 m, at South Karbook location drilling up to 170 m, at East Karbook location drilling up to 170 m is recommended and for getting a water quantity of (10000 - 11000) gallon per hour at Amarpur location drilling up to 170 m is recommended.

VI. RECOMMENDATIONS

Based on the results of VES resistivity survey, this study leads to the following recommendations:

- ✓ The VES survey has the potential to provide reasonable accurate results that can be used to understand the subsurface layers in groundwater exploration. The results of the VES must be verified with secondary hydro-geological data available in the study area.
- ✓ Other geophysical methods like the Seismic Refraction, Electromagnetic Method and Dipole-dipole electrical resistivity survey can be used to complement the methods used for this study.
- ✓ The VES survey should be avoided in monsoon season as the mobilization of the field personals during the survey becomes difficult due to precipitation as well as the water saturation of the top soil might yield inaccurate results.
- ✓ For getting accuracy horizontal profiling should also be done. Profiling also detects the geological faults and fissures.
- ✓ For development of correlation coefficient and regression analysis equation between results of VES survey and borehole litholog data large number of survey points should be taken so that accuracy could be achieved.
- ✓ For correlation of results obtained from interpreting data of VES data with litholog obtained from borehole drilling, the drilling should be done as nearer possible to the centre of the survey.

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