ISSN No:-2456-2165

Groundwater Investigation and Shallow Subsurface Evaluation of Granite Gneiss Formation using Electrical Resistivity Tomography Survey of Mauranipur Block, Jhansi District, Uttar Pradesh, India

Vinit J Ganvir[1], Anil Kumar Chaurasiya[2], Amaresh Singh[3]
Scientist 'SE' & Head of Groundwater Resource Division[1], Project Scientist[2&3]
Remote Sensing Application Centre, Department of Science and Technology, Uttar Pradesh, India

Abstract:- Geophysical methods employ indirect, non-intrusive observations to characterize and map variations in the physical properties of what lies concealed beneath the ground surface. The apparent resistivity (ρa) of the ground can be calculated using Electrical resistivity method. Using electrical properties of ground subsurface to characterize and map the granite gneiss hard rock formation of study area. The apparent resistivity (ρa) of the ground can be calculated, and since low porosity bedrock usually exhibits an electrical resistivity higher than overlying sediment, the buried topography can be interpreted. Electrical resistivity can map lateral and vertical variations in apparent resistivity of geologic material. Resolution is a function of electrode spacing and resistivity contrast between lithologically different earth materials. The resolution of electrical resistivity tomography (ERT) profile defines the accuracy of interpretation of subsurface conditions. Because of variability in resistivities of earth materials, interpretation of electrical resistivity tomography (ERT) data must be handled with caution. During ERT survey, when current is induced to flow through deeper layers, the distance between current and potential electrodes is gradually increased. This affects the sensitivity of the ERT method. Gradually increasing the distance between electrodes lowers the intensity of current flow, and accordingly the sensitivity of ERT survey. Thus, interpretation of smaller scale objects at greater depths becomes increasingly difficult. Factors such as temperature, porosity, conductivity, salinity, clay content, saturation and lithology generally affect the resistivity of earth materials and can affect the ability of different materials to conduct electrical current. For instance, dry soil usually has much higher resistivity than saturated soil. The same situation appears with weathered and un-weathered rock. Weathered rock is usually more porous and fractured, and it becomes more saturated with groundwater; as a result, weathered rock has lower resistivity than intact rock. Total 15 ERT profile carried out in different geomorphological formation of study area. It is observed that the apparent resistivity value of weathered zone occurs less than 100 Ω-m in the north-west region of study area and the apparent resistivity value of water saturated weathered zone is varies from 100 Ω-m to 200 Ω-m. The resistivity value of fractured zone is greater than 200 Ω-m with varying depth from 80 m to 100 m. In north-west region of study area occurs in good water potential zone with high yield and south-east region of study area having low groundwater potential zone with low yield. The most part of study area occurs in poor to moderate groundwater potential zone. The methods provided a more precise hydro-geomorphologic model for the study area. Results from this study area useful for technical groundwater managements and they clearly identified suitable borehole for long term groundwater prospecting. 2D electrical resistivity imaging method provides promising input to Groundwater evaluation in complex geology weathered environment.

Keywords:- *Electrical Resistivity Tomography, Induced Polarization, (Schlumberger, Gradient and Dipole-Dipole array Imaging Profile), Inverse resistivity model, Remote Sensing & GIS, Borewell data, Dug well water level, Jhansi district resource map of GSI.*

I. INTRODUCTION

The groundwater potential zone of hard rock area is determined by a complex inter-relationship between the geology, tectonic history (fractures), weathering processes and depth, nature of the weathered layer, groundwater flow pattern, recharge and discharge processes (Olorunfemi et al.1999). In hard rock terrain possesses a limited quantity and is mostly concentrated in the weathered zone and fractured zone. In such a situation, the proper identification of the potential zones is necessary to prevent financial loss and wasting of time and effort. This type of proper identification is possible with knowledge of the geological, hydrogeological, and geophysical aquifer characteristics. These studies mainly emphasize the successful application of geology, geomorphology, rainfall, drainage, slope, groundwater level depth, lineament etc., Finding and locating the water bearing fractures zones, with the provision of electrical resistivity method is considered as the best and most accepted and generalized technique. ERT surveys measure variations in the electrical resistivity of the ground, gathered by applying a small electric current to the ground across an array of electrodes. The resistivity values

ISSN No:-2456-2165

vary with rock lithology and properties. Rock composition, crystal structure, water content, permeability, porosity, faulting, chemical weathering, mechanical disruption and fracturing can change the specific values of resistivity by several orders of magnitude (Petr et al.2017). The specific objective of the study area to (a) determine the depth, thickness and extent of potential water bearing formation (b) generate a 2D resistivity model of the shallow subsurface showing the thickness of weathered and fracture zone, and (c) develop a model of the structural and stratigraphic condition controlling the groundwater in the shallow subsurface of the study area.

II. STUDY AREA

Mauranipur is a city and a municipal board in Jhansi district state of Uttar Pradesh, India. Total geographical area of the Mauranipur block is about 54200 hectares. In Jhansi district Mauranipur is located at {25°14′23″N 79°11′47″E}. The study area of block lies between Latitude (25^0 06′30″- 25º26′30″) N and Longitude (79°04′30″- 79°19′30″) E. It has an average elevation of 192 metres (630 ft). Mauranipur is 69.43 km from the city of Jhansi and 352 km from Uttar Pradesh's capital city Lucknow, Calculated by land area. The Sukhnai, a tributary of the Dhasan River which itself is a tributary of the Vetravati, flows from west to east around the town. it is the largest tehsil in India. The terrain of Jhansi lies in the Peninsular Shield, and is differentiated in to a rocky surface of Bundelkhand highland and alluvial surface of Ganga Plain. The rocky surface contains Pediment and Denudation hills, which is highly dissected and rugged. The drainage density is higher in hilly area and lower in marginal alluvial area. Dendritic drainage pattern is common and trellis drainage pattern is observed in hard rock area. The general slope of the tract is from South to North. The topography is influenced or modified by the existing rivers and streams. Canals are the main source of irrigation in northern region of the study area. Ranipur canal is the main canal in the study area which is flowing from West to north direction and lies in northern part of the region. Many minor and distributaries are connected to it which are flowing from west to north direction. Markari, Rupadhamna, and Barori minor are three minors of Ranipur canal which are running from west to north in northern part of the study area. Panchwara and Buraiminoe are two minors of Siaori main canal which are also flowing from west to north direction of the study area. This canals system fulfils the irrigation requirement of the area.

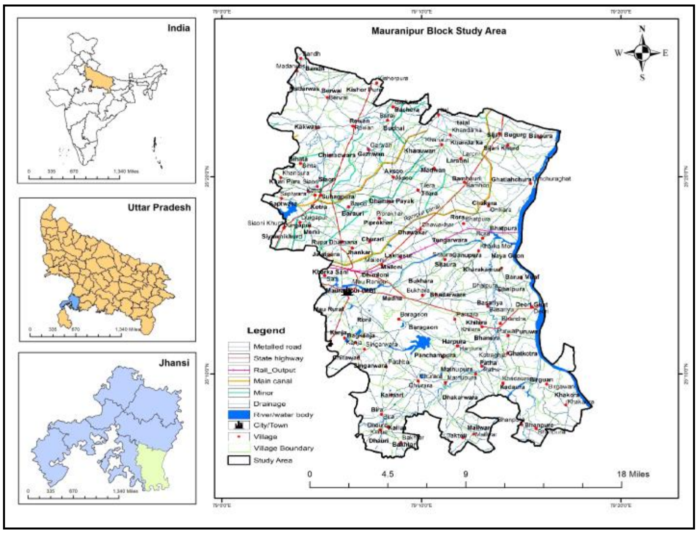


Fig. 1: Location map of study area

ERT No.	Village	Direction	Imaging GPS point	
			Longitude (E)	Latitude (N)
ERT01	Kadaura	NW-SE	79.244454	25.168082
ERT02	Tilera	SW-NE	79.187695	25.332699
ERT03	Baragaon	SW-NE	79.158102	25.223707
ERT04	Basariya	E-W	79.239915	25.240515
ERT05	Dhawakar	NE-SW	79.188525	25.303952
ERT06	Patha	E-W	79.224734	25.195897
ERT07	Chuarara	SW-NE	79.1905858	25.175477
ERT08	Roni	SE-NW	79.125392	25.229605
ERT09	Berwai	W-E	79.117956	25.422761
ERT10	Rewan	SE-NW	79.130853	25.357476
ERT11	Bhatpura	E-W	79.225935	25.294608
ERT12	Bamhauri	NE-SW	79.233062	25.343135
ERT13	RupaDhamna	N-S	79.125707	25.291343
ERT14	Akseo	N-S	79.175573	25.334822
ERT15	Patha	SW-NE	79.228429	25.194405

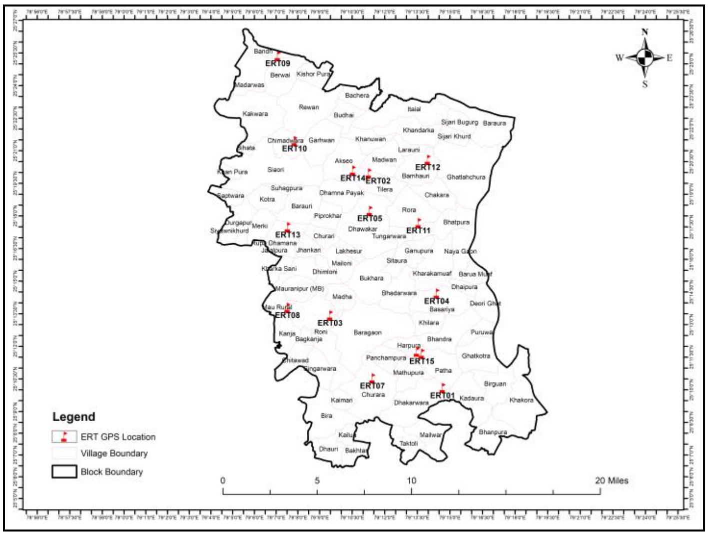


Fig. 2: ERT GPS location map of study area

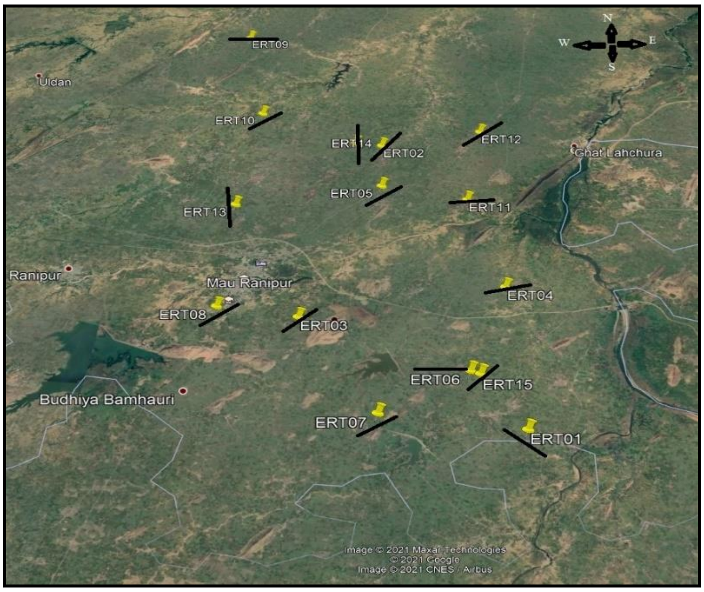


Fig. 3: ERT GPS location & profile direction map of study area

III. DATA SOURCE

The study area is covered in Survey of India (SOI) toposheets No. 54O/3, 54O/4, 54O/7 and 54O/8 on 1:50,000 scale. The basic information such as road network, settlement, canal, drainages pattern, water body etc. has been inferred from these toposheets. Satellite based observation are generally most applicable to regional mapping of different landform features (Salomonson, 1919). LISS IV and Cartosat-1 merge data (Spatial Resolution 2.5) of 7 January to 15 March 2012 has been used for the present study. Total 15 (ERT) electrical resistivity tomography were conducted in different location at different hydrogeomorphic units of the selected micro-watersheds of Mauranipur block for demarcation of groundwater potential zones. Location of sites surveyed in different villages of selected micro watersheds is shown in Figure-2. Different thematic layer such as base map, structural map geomorphological, lithological and location, soil and land use/land cover maps has been prepared using these data. Hydro-geomorphology information of study area is taken from CGWB District resource map of Jhansi, is very helpful for study area. The existing data from different sources viz. CGWB, U.P. Jal Nigam, Irrigation Department and Dug-well data local site monitoring etc. has also been utilized for the study. The drilling data available from U.P. Jal Nigam has been used to correlate the geophysical data.

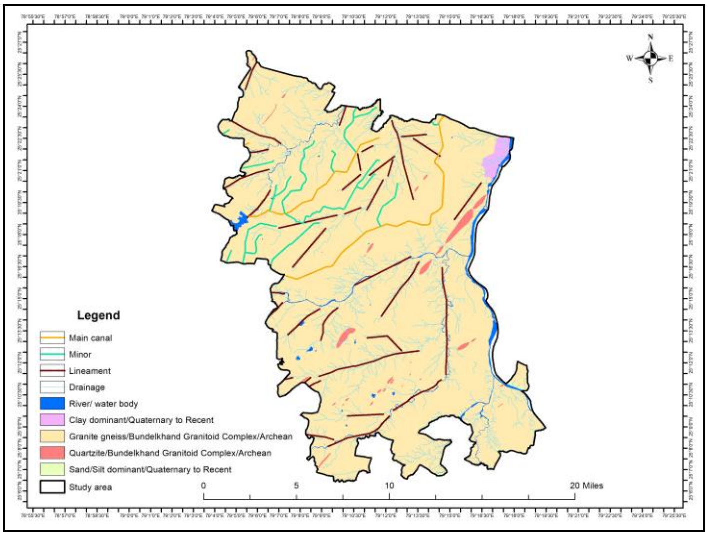


Fig. 4: Geological map of study area

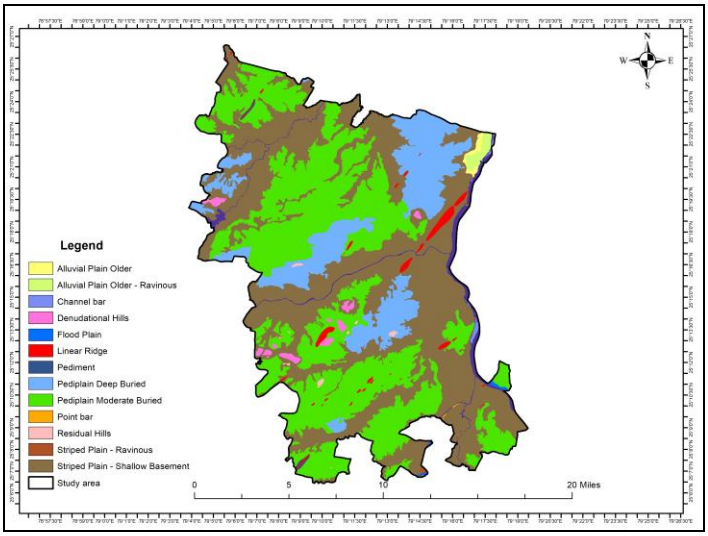


Fig. 5: Lithological map of study area

The different thematic layer was prepared using Liss-IV (Multispectral, resolution 5.8 m) cartosat-1 (panchromatic resolution 2.5 m) merged satellite data, which give the basic idea about undersanding the geological formation and site selection for conducting ERT survey area. According to Hydro-geomorphological map most area cover under the shallow burried and deep burried pedipiain. On the basis of lineament direction and length, ERT profile should be decieded at that place where high lineament density occurs. Fracture zone will be occurs at lineament intersection point of the study area. The during field observation dug well water level of study area having 10 m to 20 m.

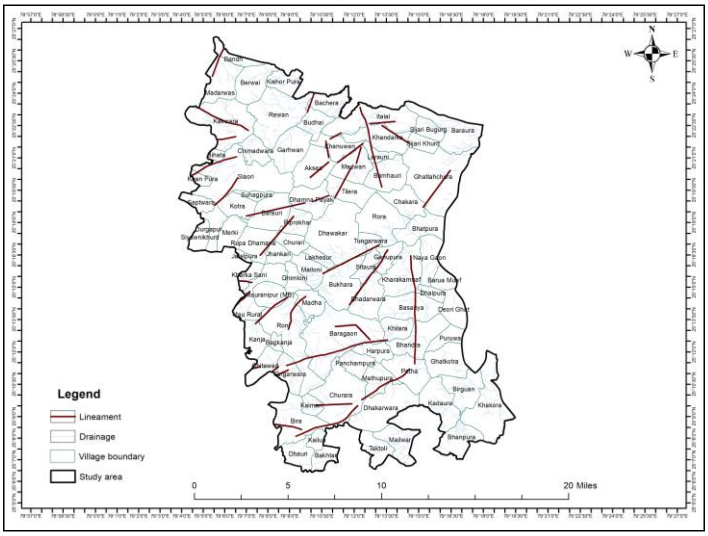


Fig. 6: Lineament density map of study area

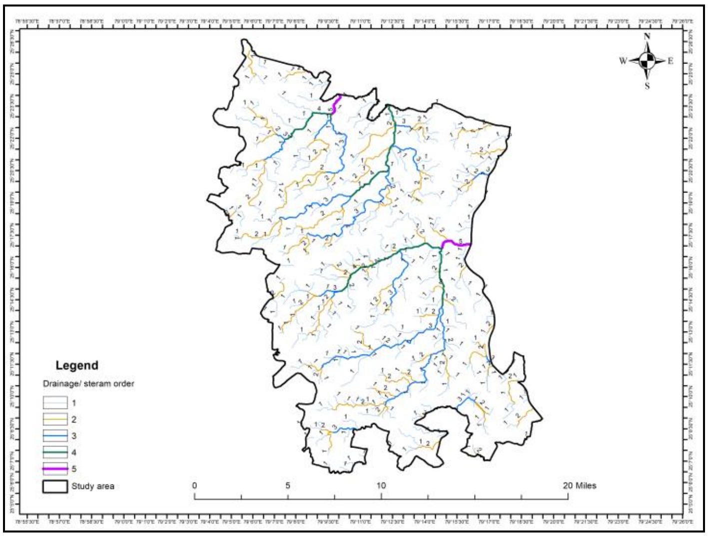


Fig. 7: Drainage density map of study area

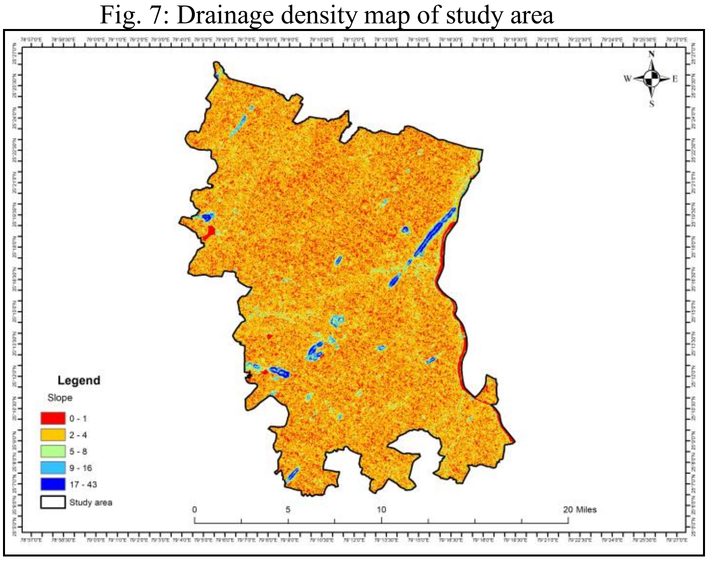


Fig. 8: Slope map of study area

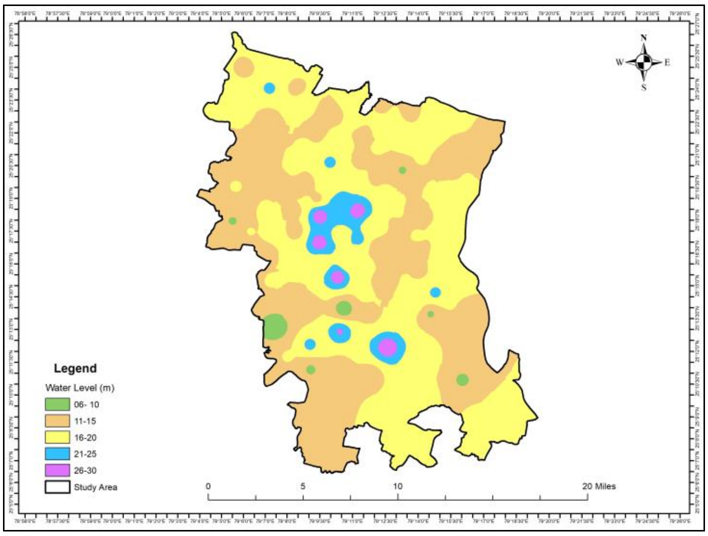


Fig. 9: Dugwell water level map of study area

IV. GEOPHYSICAL FIELD SURVEY/ INVESTIGATION

Geophysical surveys are being carried out to delineate the ground water bearing strata (aquifer). The most commonly used geophysical technique in ground water exploration technique is electrical resistivity method, with the help of this technique one can delineate the different layer of the earth on the basis of their electrical resistivity, from which one can indirectly infer the ground water bearing formation and the quality of the water. The most common electrical method is Profiling, which is being used to delineate the variation in the resistivity in lateral direction. The geoelectrical layers inferred are correlated with available drilling data and thus lithology is inferred.

V. ELECTRICAL RESISTIVITY TOMOGRAPHY METHOD

Electrical resistivity Tomography (ERT) is a geophysical technique for imaging sub-surfaces structures from electrical measurements made at the surface with multi-electrode system. 2-D resistivity imaging technique is the latest State of the art available to map the complex geological features. A more accurate model of the subsurface is at two-dimensional (2-D) model where the resistivity changes in the vertical direction, as well as in the horizontal directional along the survey line. Therefore, 2-D Resistivity survey is one of the most practical and economic compromise between obtaining very accurate results and keeping the survey costs down.

Basically, four electrode configurations have been used in Electrical resistivity imaging survey such as Schlumberger, Wenner, Gradient and Dipole-Dipole array. Gradient and Dipole-Dipole array have better resolution, greater probing depth, and less time-consuming as compare to Schlumberger & Wenner array. The basic arrangement and formula for calculating the apparent resistivity is given as:

ISSN No:-2456-2165

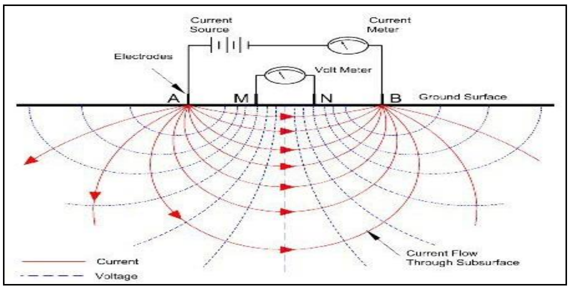


Fig. 10: ERT GPS location map of study area

$$\rho_a = \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \pi \left(\frac{V}{I}\right)$$

VI. INSTRUMENTATION AND MEASUREMENT PROCEDURE

For carrying out 2-D electrical imaging/tomography surveys large number of electrodes, connected to a multi-core cable. A microcomputer together with electronics witching unit is used to automatically select the relevant four electrodes for each measurement. Multi- electrode Resistivity system was used for automatic data collection with 1 to 81 electrodes spacing of 10 m intervals. Gradient and Dipole-Dipole array were used for data acquisition with 800 m to 1200 m long profile.

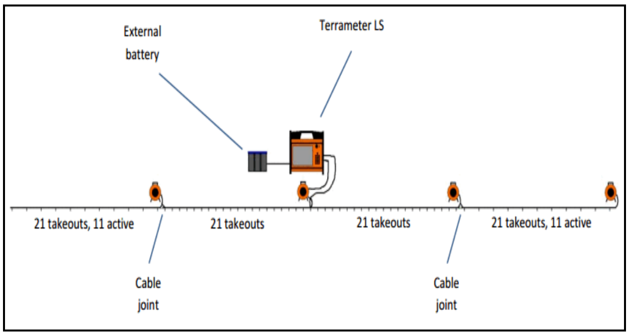


Fig. 11: Basic Electrode Spacing and Arrangement for Terrameter LS-2 Instruments

This equipment is capable of running self-checks for connectivity of electrodes and generates warnings on bad contacts. Bad contacts were resolved by pouring water around the electrode. Normally a constant spacing between adjacent electrodes is used. The multi-core cable is attached to an electronic switching unit, which is connected to the resistivity imaging system. These quinces of measurements to take, the type of array to use and other survey parameters (such the current to use) is normally entered into a text file which can be read and fix in the instrument. After reading the control file, the instrument program then automatically selects the appropriate electrodes for each measurement. In a typical survey, most of the time- consuming process in the data acquisition is the laying of the multi core imaging cables and electrodes. After that, the entire profile line connection is checked automatically by the instrument for noise and bad connection. Once all the electrode connection is proper, then the equipment is ready to take measurements. Data acquisition for each set of measurement is made automatically with constant current supply and stored in the system. The acquired field data is then down loaded to the computer and then processed by using RES2DINV software.

VII. PSEUDO SECTION DATA PLOTTING PROCEDURE

To plot the data from a 2-D imaging survey, the pseudo section contouring method is normally used. In this method, the horizontal location of the point is placed at the mid-point of the set of electrodes used to make that measurement. The vertical location of the plotting point is placed at a distance, which is proportional to the separation between the electrodes. Another method is to place the vertical position of the plotting point at the median depth of investigation (Edwards 1977), or pseudo depth, of the electrode array used. The pseudo section plot obtained by contouring the apparent resistivity values is a convenient means to display the data. The pseudo section gives a very approximate picture of the true subsurface resistivity distribution. However, the pseudo section gives a distorted picture of the subsurface because the shape of the contours depends on the type of array used as well as the true subsurface resistivity. The pseudo section is useful as a means to present the measured apparent resistivity values in a pictorial form, and as an initial guide for further quantitative interpretation. One common mistake made is to try to use the pseudo section as a final picture of the true subsurface resistivity.

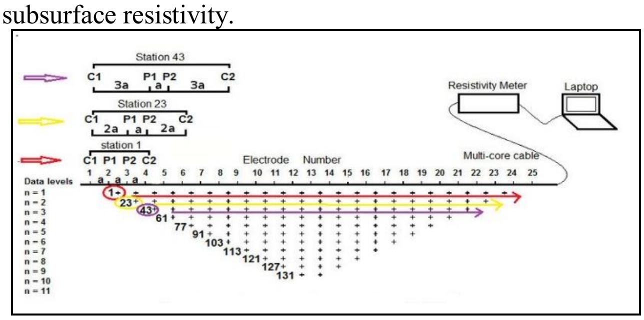


Fig. 12: Sequence of measurements to build up a pseudo section

VIII. INVERSION PROCEDURE

All inversion methods essentially try to find model for the subsurface whose response agrees with the measured data. In the cell-based method used by the Earth-Imager-2D/RESINV-2D programs, the model parameters are the resistivity values of the model blocks, while the data is the measured apparent resistivity values. It is well known that for the same data set, there is a wide range of models whose calculated apparent resistivity values agree with the measured values to the same degree. Besides trying to minimize the difference between the measured and calculated apparent resistivity values, the inversion method also attempts to reduce other quantities that will produce certain desired characteristics in the resulting model. The additional constrains also help to stabilize the inversion process. The program uses an iterative method whereby starting from an initial model, the program tries to find an improved model whose calculated apparent resistivity values are closer to the measured values.

ISSN No:-2456-2165

IX. DESCRIPTION OF DIFFERENT LAYERS WITH RESISTIVITY

The resistivity of top soil is highly variable and its thickness is varying from 1 to 5 meters. The layer which is underlying this layer is clay and kanker whose resistivity varies from 10 to 80 Ω-m & thickness from 2 to 15 meter. Water bearing formation is also present at a depth of 20 to 50 meter with the thickness of 30 to 80 meter having resistivity less than 300 ohm-m.

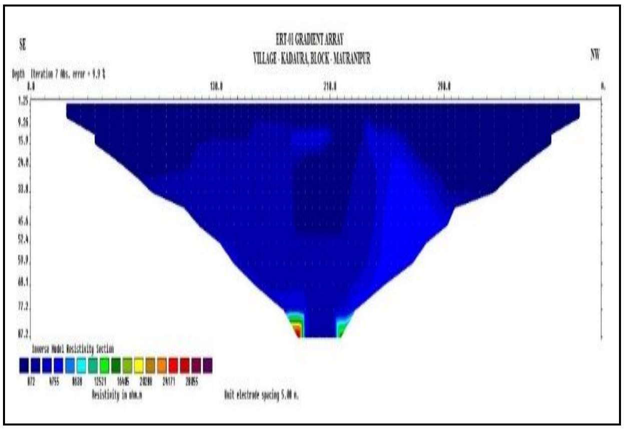
s. n.	Thickness (m)	Inferred Lithology	Groundwater prospect
1	1-5	Top soil	Unsaturated
2	5-15	Loose strata clay and Kankar	Unsaturated
3	15-30	Weathered zone (Unconfined)	Saturated with potable water
4	30-50	Semi-Weathered zone	Saturated with potable water
5	50-80	Fracture granite & semi-fracture granite	Saturated with potable water
6	>80	Compact basement	unsaturated

Table 1: Inferred lithology along corresponding Groundwater prospect with depth

S. N.	2D model resistivity data (ohm-m)	Resistivity inferred Characteristic Geological formation
1	<15	Clay
2	3-35	Clayey sand and wet sand
3	<100	Weathered/semi-weathered granite saturated with water
4	100-150	Water saturated fractured granite
5	150-200	Fractured granite
6	200-1000	Messy Fractured granite
7	>1000-5000	Massive granite, basement Granite gneiss rock

Table 2: ERT Resistivity stratification with Inferred lithology

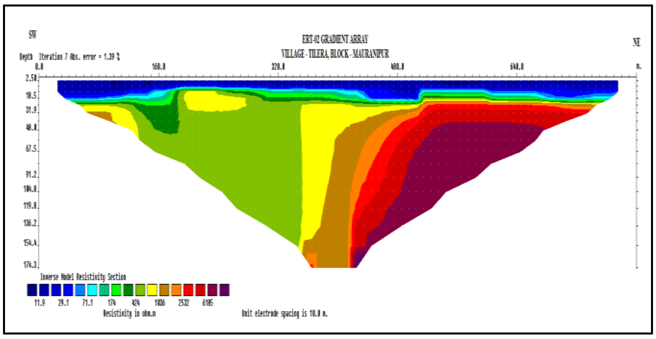
A. Resistivity Imaging Section/ ERT-01



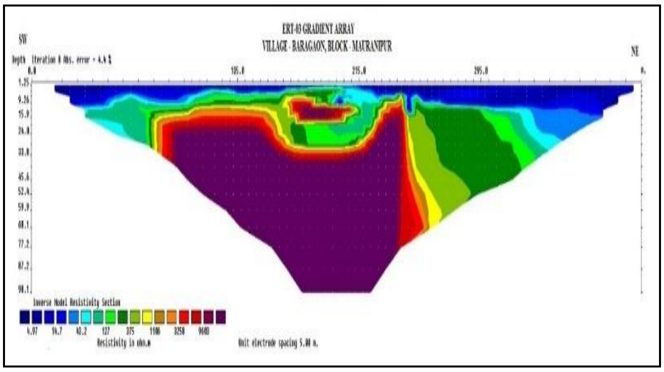
2D Resistivity Imaging survey has been carried out at Kadaura village which lies in south-east part of the study area. The profile having slight slope of 3 m in SE to NW direction. The interpreted resistivity range on the basis of subsurface geology and hydro-geological condition along the proposed line is minimum 1.5 Ω-m & maximum >28000 Ω-m. In ERT-01 profile, one sections have been generated to interpret the subsurface by using Gradient array configuration. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 20-25m in SE to NW in the profile. The basement is not deeper in begging of profile up to 400 m end of profile below the ground level. After weathered & fractured granite, there is presence of strong bedrocks up to probed depth no any fracture zone is interpreted at deeper depth in bed rock. Depth and thickness of weathered zone is same in SE portion in comparison to NW portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 25 m scattered pattern & saturated zones may present only in this fractured/weathered zone up to 25 m depth. After overburden, no any fracture zone is interpreted at deeper depth in bedrock. Only shallow drilling may not be recommended due to high resistivity zone between profile lengths starting to ending of the profile with depth.

B. Resistivity Imaging Section/ ERT-02

2D Resistivity Imaging survey has been carried out at Tilera village which lies in western part of the study area. The profile having slight slope of 2 m in NE to SW direction. In ERT-02 profile, one sections have been generated to interpret the subsurface by using Gradient array configuration. Based on the resistivity values, three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 20 m in SW to NE and at deeper depth 25-150 m in SW between starting to 350 m middle portion of profile. The basement deeper in begging of profile up to 350 m with depth 150 m and then it is the running horizontally up to 800 m in profile the depth of 25 m below the ground level. ERT sections Gradient are well correlate and giving almost same pattern for subsurface interpretation. After weathered & fractured sand granite, there is presence of strong bedrocks up to probed depth no any fracture zone is interpreted at deeper depth in bed rock. Only shallow drilling may be recommended along the profile with low discharge. Depth and thickness of weathered zone is same in SW portion in comparison to NE portion of profile. it has been interpreted that overburden/fractured/ weathered rock has been interpreted depth up to varying depth from 25 m 150 m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 25 m to 150 m depth. After overburden, there is presence of strong bed rock up to probed depth. In between profile up to 350 m fracture zone may be interpreted at deeper depth in bedrock. Only shallow drilling may be recommended only in lower resistivity zone between profile lengths up to 800m end of the profile up to 30m depth but in the starting to 350 m length of profile depth of drilling is 150 m for deep drilling. At deeper depth in profile, there is indication of fracture zone for ground water due to high compact hard rock formation in between 320 m to 480 m of profile length.

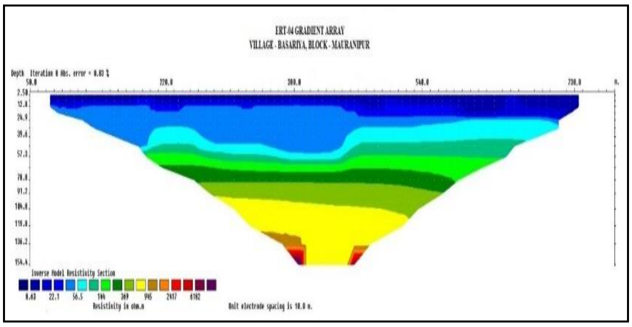


C. Resistivity Imaging Section/ ERT-03



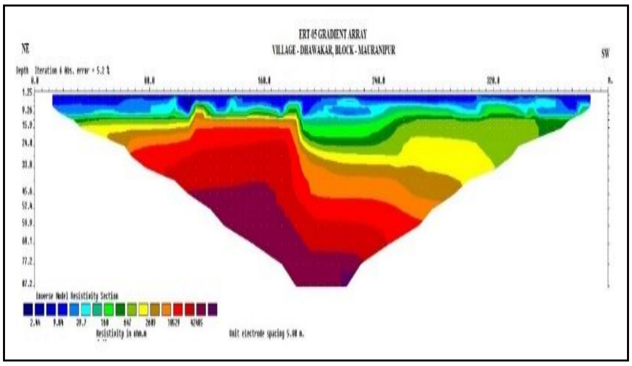
2D Resistivity Imaging survey has been carried out at Baragaon village which lies in Eastern part of the study area. The profile having slight slope of 4 m in NE to SW direction. Based on the resistivity values, three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 15 m in SW from staring to 150 m profile and at deeper depth 30 m in central portion between 150 to 230 m of profile. The basement is not deeper in begging of profile up to 60 m and then it is the running horizontally up to 400 m in the depth range of 15 m to 30 m in profile length 260m, and to end of profile again basement depth is going down up to 60 m below the ground level. After weathered & fractured granite, there is presence of strong bedrocks up to probed depth 25 m to 35 m depth up to 60 m to 250 m in the profile length. There may be fracture zone is interpreted at deeper depth in bed rock. Depth and thickness of weathered zone is more in NE portion in comparison to SW portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 15 m to 60 m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 25 m depth. Both deep and shallow drilling may be recommended only in lower resistivity zone between profile lengths starting to 250 m and deep drilling recommended for end of the profile up to 60 m depth.

D. Resistivity Imaging Section/ ERT-04



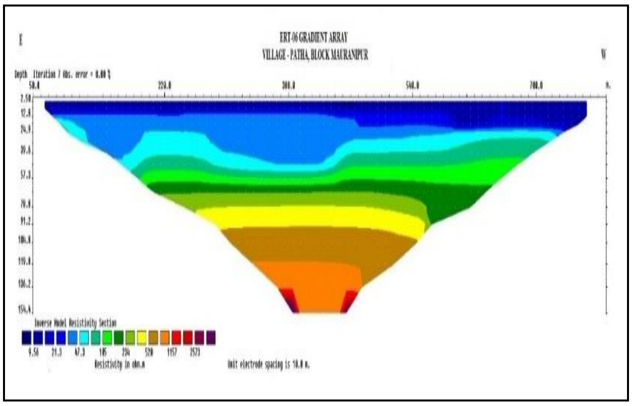
2D Resistivity Imaging survey has been carried out at Basariya village which lies in eastern part of the study area. The profile having slight slope of 1 m in west east direction. Based on the resistivity values, three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 45 m in west and at deeper depth 60 m in the central portion and 40 to 45 m in east portion of the profile. The basement is deeper in begging of profile length up to 80 m and then it is the running horizontally up to 800 m in the depth range of 80 m to 90 m at the end of profile below the ground level. Depth and thickness of weathered zone is more in western and central portion in comparison to eastern portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 45 m to 90 m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 45 m to 90 m depth. Both shallow and deep drilling may be recommended only in lower resistivity zone between profile lengths starting to 800 m end of the profile up to 90 m depth.

E. Resistivity Imaging Section/ ERT-05



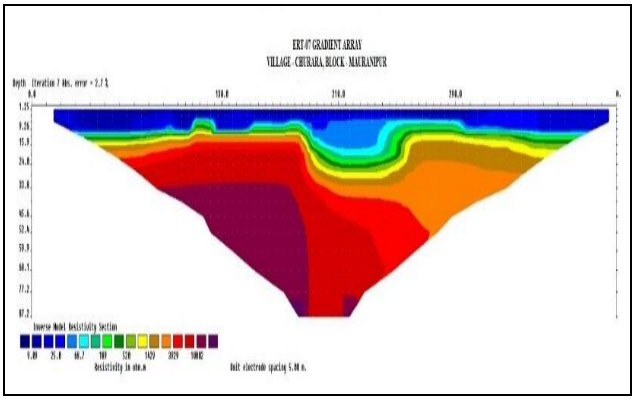
2D Resistivity Imaging survey has been carried out at Dhawakar village which lies in central part of the study area. The profile having slight slope of 1 m in NE to SW direction. The depth of investigation is 90 m. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 15m in NE and at deeper depth 15 m to 30in SW. The basement is not deeper in begging of profile up to 160 m and then it is the running horizontally up to 210 m in the depth range of 15 m and 210 m to end of profile again basement depth is going down up to 35 m below the ground level. Depth and thickness of weathered zone is more in SW portion in comparison to NE portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 15 m to 35 m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 35m depth. Only shallow drilling may be recommended only in lower resistivity zone between profile lengths beginning to 220m at the central portion and from 220 m to end of the profile up to 35 m depth.

F. Resistivity Imaging Section/ ERT-06



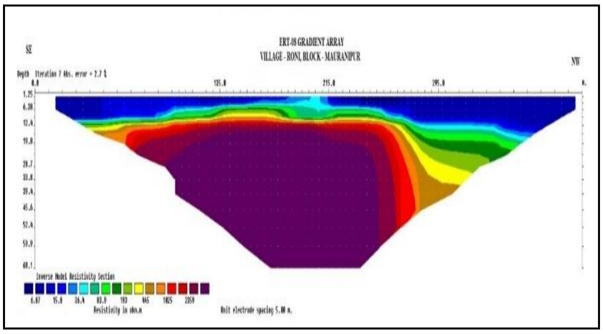
2D Resistivity Imaging survey has been carried out at Patha village which lies in south-east part of the study area. The profile having slight slope of 3 m in west to direction. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 55 m in east and at deeper depth 90 m in west. The basement is deeper in begging of profile up to 300 m and then it is the running horizontally up to 350 m in the depth range of 90 m to 100 m to end of below the ground level. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 55 m to 90m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 60 m depth. Deep and shallow drilling may be recommended only in lower resistivity zone between profile lengths beginning to 800 m end of the profile up to 55 m to 90 m depth. At deeper depth in profile, there is no indication of any fracture zone for ground water due to high compact hard rock formation.

G. Resistivity Imaging Section/ ERT-07



2D Resistivity Imaging survey has been carried out at Churara village which lies in south-west part of the study area. The profile having slight slope of 2 m in NE to SW direction. The depth of investigation was 90 m. three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 10-15 m in NE and at deeper depth 25-30m in central portion of the profile. The basement is deeper in begging of profile up to depth 25 at profile length 150 m and then it is the running horizontally up to 250 m in the depth range of 25 m to 35 m and 250m to end of profile again basement depth is going down up to 15 m below the ground level. Depth and thickness of weathered zone is less in NE portion in comparison to SW portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 15 m to 35 m in scattered pattern & saturated zones may present only in this fractured/weathered zone up to 15 m depth. Only shallow drilling may be recommended only in lower resistivity zone between profile lengths 150 m to 250 m of the profile with depth up to 15 and at the end of the profile up to 10m depth. there is no indication of any fracture zone for ground water due to high compact hard rock formation.

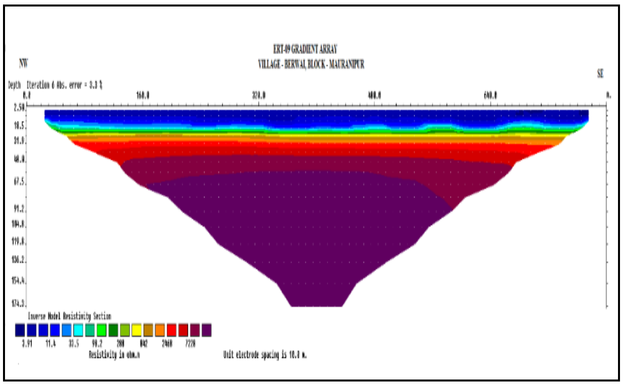
H. Resistivity Imaging Section/ ERT-08



2D Resistivity Imaging survey has been carried out at Roni village which lies in western part of the study area. The profile slope direction is 4 m from north-west to south-east direction. The depth of investigation is 70 m. Three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 15 m in SE and at deeper depth 25 m in NW. The basement is deeper in begging of profile up to 100 m and then it is the running horizontally up to 250 m in the depth range of 15 m and 250m to end of profile again basement depth is going down up to 25 m below the ground level. Depth and thickness of weathered zone is SE in western portion in comparison to NW portion of profile. it has been interpreted that overburden/fractured/weathered rock has been interpreted depth up to varying depth from 15 m to 25 m in scattered pattern & saturated zones may present only in this fractured/weathered zone up to 25 m depth. Only shallow drilling may be recommended only in lower resistivity zone between beginning profile length to 400 m end of the profile up to 25 m depth. At deeper depth in profile, there may be indication of fracture zone for ground water due to high compact hard rock formation.

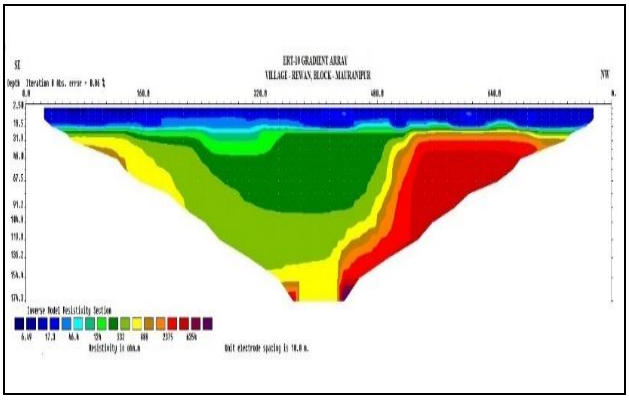
ISSN No:-2456-2165

I. Resistivity Imaging Section/ ERT-09



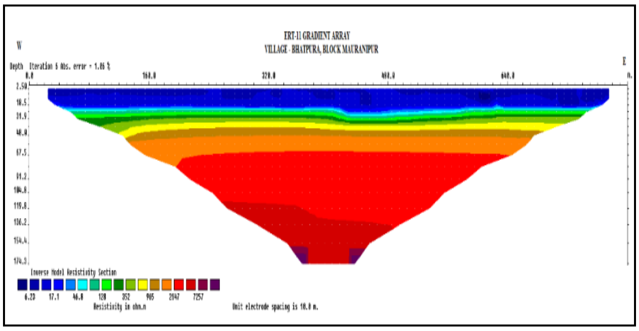
2D Resistivity Imaging survey has been carried out at Berwai village which lies in north-west part of the study area. The profile having slight slope of 3 m in SE to NW direction. Two sections have been generated to interpret the subsurface by using Dipole-Dipole & Gradient array configuration. Based on the resistivity values, three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 20-25m in NW to SE in profile. The basement is not deeper in begging of profile and then it is the running horizontally up to 800 m end of profile below the ground level. Both ERT sections (Gradient & Dipole-Dipole) are well correlate and giving almost same pattern for subsurface interpretation. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 25 m to 40 m in scattered pattern & saturated zones may present only in this fractured/weathered zone up to 25 m depth. Only shallow drilling may be recommended only in lower resistivity zone between profile lengths up to 800m end of the profile up to 25 m depth. After overburden, there is presence of strong bed rock up to probed depth. No any fracture zone is interpreted at deeper depth in bedrock.

J. Resistivity Imaging Section/ ERT-10



2D Resistivity Imaging survey has been carried out at Rewan village which lies in north-west part of the study area. The profile slope direction is 1 m from SE to NW direction. The depth of investigation was 175 m. Two sections have been generated to interpret the subsurface by using Dipole-Dipole & Gradient array configuration. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 20-25m in SE to NE and at deeper depth 25-100m in between 120 m to 480. The basement is deeper in begging of profile up to 100 m and then it is the running horizontally up to 800 m profile up to the depth range of 25 m to 30 m and 480 m to end of profile again basement depth is going up to 30 m below the ground level. Depth thickness of weathered zone is more in SE portion in comparison to NE portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 25 m to 100 m in scattered pattern& saturated zones may present only in this fractured /weathered zone up to 25 m depth. Shallow and deep drilling may be recommended only in lower resistivity zone between profile lengths 160 m to 480 m of the profile up to 30m to 100 m depth. At deeper depth in profile, there is indication of fracture zone in between profile length 320 m to 480 m for ground water due to high compact hard rock formation.

K. Resistivity Imaging Section/ ERT-11

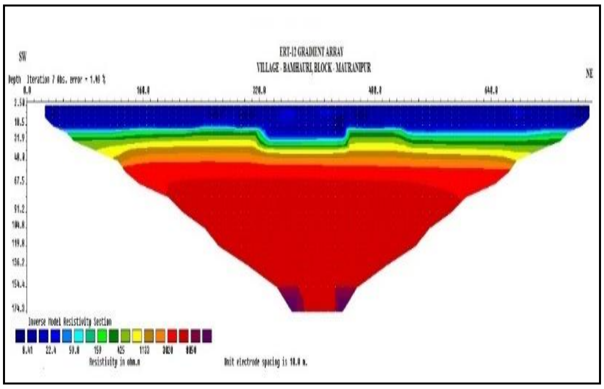


2D Resistivity Imaging survey has been carried out at Bhatpura village which lies in eastern part of the study area. The profile having slight slope of 1 m in west to east direction. The depth of investigation is 180 m. In ERT-11 profile, two sections have been generated to interpret the subsurface by using Dipole-Dipole & Gradient array configuration. Based on the resistivity values, three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered granite and fractured granite is present throughout the profile which is at shallow depth 30 m in west and at deeper depth 35 m in east. The basement is deeper in profile up to 65 m and then it is the running horizontally up to 420 m to 620 m in the depth of 35m and 620 m to end of profile again basement depth is going up to 30 m below the ground level. Depth and thickness of weathered zone is more in central portion in comparison to western and eastern portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 25 m to 30 m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 30 m depth. After overburden, there is presence of strong bed rock up to probed depth 65 m. No any fracture zone is interpreted at deeper depth in bedrock. Only shallow drilling may be recommended only in lower resistivity zone between profile lengths up to 800m end of the profile up to 30m depth. At deeper depth in profile, there is no indication of any fracture zone for ground water due to high compact hard rock formation.

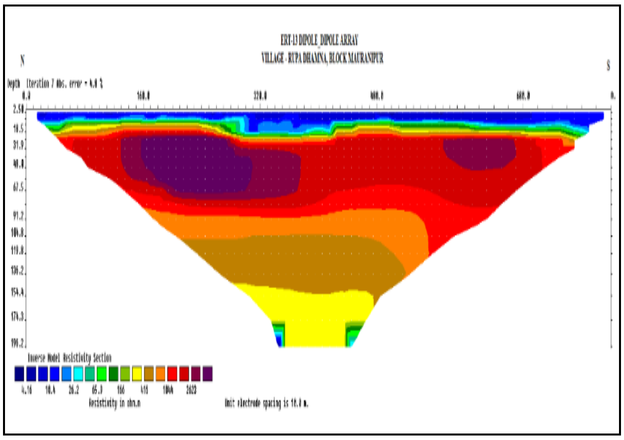
ISSN No:-2456-2165

L. Resistivity Imaging Section/ ERT-12

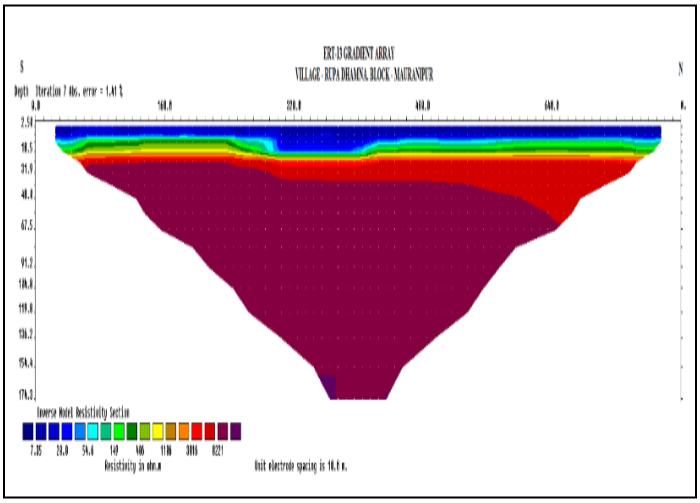
2D Resistivity Imaging survey has been carried out at Bamhauri village which lies in north-east part of the study area. The profile having slight slope of 2 m in SW to NE direction. A thin layer of weathered sandstone and fractured sandstone is present throughout the profile which is at shallow depth 20-25 m in west and at deeper depth 25-30 m in east. The basement is deeper in begging of profile up to 250 m and then it is the running horizontally up to 620 m in the depth range of 35m to 40 m and 620m to end of profile again basement depth is going down up to 60m below the ground level. Depth and thickness of weathered zone is more in western portion in comparison to eastern portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 25 m to 40 m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 25 m depth. Only shallow drilling may be recommended only in lower resistivity zone between profile lengths 680 m to 800 m end of the profile up to 30 m depth. At deeper depth in profile, there is no indication of any fracture zone for ground water due to high compact hard rock formation.

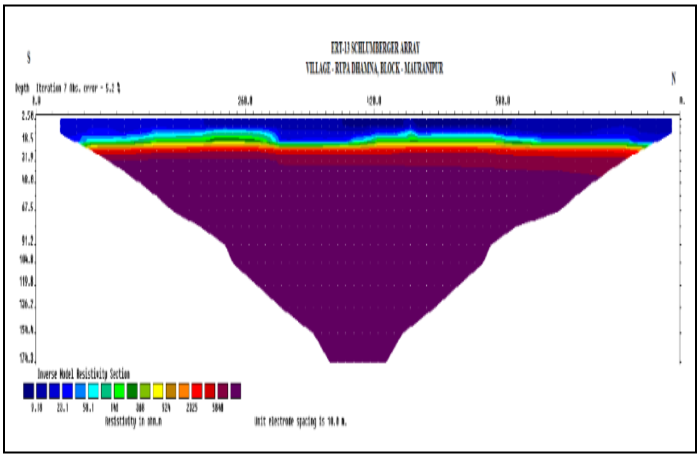


M. Resistivity Imaging Section/ ERT-13



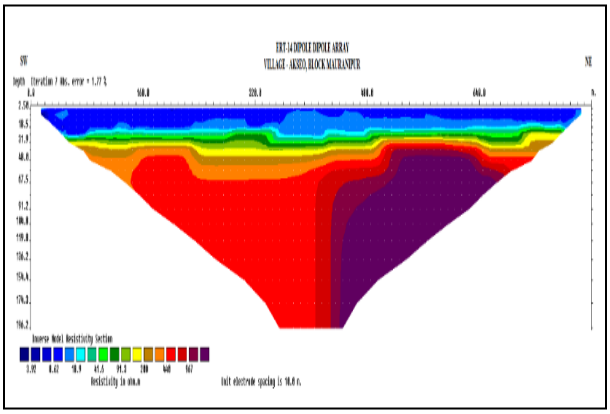
2D Resistivity Imaging survey has been carried out at RupaDhamna village which lies in western part of the study area. The profile having slight slope of 3 m in N to S direction. In ERT-13 profile, three sections have been generated to interpret the subsurface by using Dipole-Dipole, Gradient array Schlumberger array configuration. Based on the resistivity values, two resistivity zones have been classified for interpretation of subsurface. In this profile line between 160 m to 320 up to depth 20 m to 65 m and 600 m to 680 m up to depth 20 to 40 m having some hard rock patches. A thin layer of weathered granite and fractured granite is present throughout the profile which is at shallow depth 18 m to 22 m in south to north and at deeper depth 25-30m in central portion between 320 to 480 m of profile line. The basement is not deeper in begging of profile up to 320 m and then it is the running horizontally up to 480 m in the depth range of 25 m to 30 m and 480 m to end of profile again basement depth is not going down up to 25 m below the ground level. ERT sections (Schlumberger, Gradient & Dipole-Dipole) are well correlate and giving almost same pattern for subsurface interpretation. After weathered & fractured granite, there is presence of strong bedrocks up to probed depth no any fracture zone is interpreted at deeper depth in bed rock. Only shallow drilling may be recommended along the profile with low discharge. Depth and thickness of weathered zone is same in southern portion to northern portion of profile. As per outcome of all ERT sections, it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 25 m to 35 m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 25 m depth. Only shallow drilling may be recommended only in lower resistivity zone between profile lengths to 800m end of the profile up to 30m depth, at deeper depth in profile.



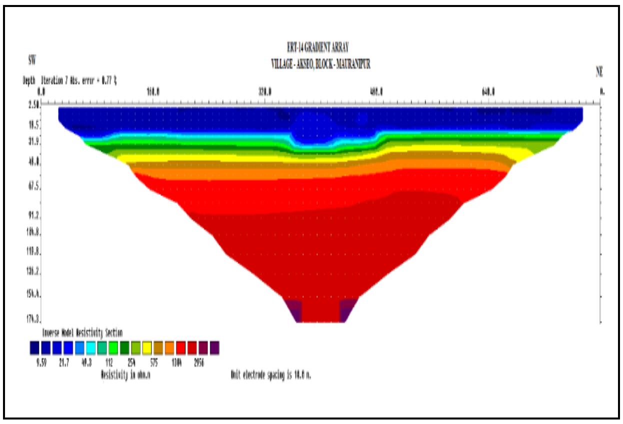


ISSN No:-2456-2165

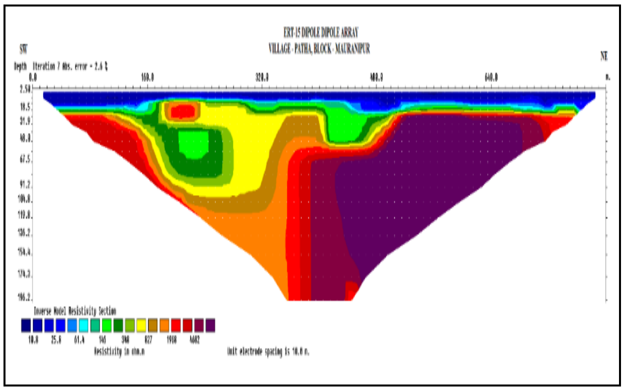
N. Resistivity Imaging Section/ ERT-14



2D Resistivity Imaging survey has been carried out at Akseo village which lies in northern part of the study area. The profile having slight slope of 3 m in SW to NE direction. In ERT14 profile, two sections have been generated to interpret the subsurface by using Dipole-Dipole & Gradient array configuration. Based on the resistivity values, three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered granite and fractured granite is present throughout the profile which is at shallow depth 30-35 m in SW from starting and at deeper depth 35-40 m in NE ending. The basement is deeper up to depth 50 m in begging of profile up to ending of profile and then it is the running horizontally up to 800 m in the depth range of 30 m to 40 m and 10 m to end of profile again basement depth is going down up to 50m below the ground level. Both ERT sections (Gradient & Dipole-Dipole) are well correlate and giving almost same pattern for subsurface interpretation. After weathered & fractured sand stone. Depth and thickness of weathered zone is more in central portion at 320 m to 480 m in comparison to SW and NE portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 25 m to 40 m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 35 m depth. Only shallow drilling may be recommended only in lower resistivity zone between profile lengths starting to 800 m end of the profile up to 35 m depth and between profiles 320 m to 480 m up to 40 m depth drilling recommended.



O. Resistivity Imaging Section/ ERT-15



2D Resistivity Imaging survey has been carried out at Patha village which lies in western part of the study area. The profile having slight slope of 2 m in SW to NE direction. Based on the resistivity values, three resistivity zones have been classified for interpretation of subsurface. A thin layer of weathered and fractured granite is present throughout the profile which is at shallow depth 20-25m in SW and at deeper depth 25-30m in NE. The basement is not deeper in begging of profile up to 160 m and then it is the running horizontally up to 320 m in the depth range of 25m to 30 m and at the middle of 160 m to 320 m of profile again basement depth is going down up to 80 m below the ground level. Both ERT sections (Gradient & Dipole-Dipole) are well correlate and giving almost same pattern for subsurface interpretation. After weathered & fractured granite formation, there is presence of strong bedrocks up to probed depth. In profile 320 m to 480 m may be a fracture zone is interpreted at deeper depth in bed rock. Depth and thickness of weathered zone is more in central portion as comparison to SW and NE portion of profile. it has been interpreted that overburden/ fractured/ weathered rock has been interpreted depth up to varying depth from 25m to 40m in scattered pattern& saturated zones may present only in this fractured/weathered zone up to 25m depth. After overburden, there is presence of strong bed rock up to probed depth. Fracture may be identified between the profile's length 320 m to 370 m zone is interpreted at deeper depth in bedrock. Both deep and shallow drilling may be recommended only in lower resistivity zone between profile lengths 160 m to 800m end of the profile up to 25 m depth. At deeper depth in between profile 320 to 370 m with lower resistivity zone in profile, so the drilling at this portion may be 90 m recommended for deep drilling. There may be indication of a fracture zone for ground water due to high compact hard rock formation.

X. RESULTS AND DISCUSSION

On the basis of ERT field data, the study epitomizes and discloses the subsurface geological setting and structure of the hard rock's as well as availability of groundwater resources in the area of study. ERT has been helpful in delineating the potential groundwater zones at deeper depths. Electrical Resistivity Tomography interpretation results give the vertical as well as lateral variation of the resistivity up to 70-150 m depth. The extent of fracturing purpose by these surveys can be used to indicate a high groundwater potential at the study area.

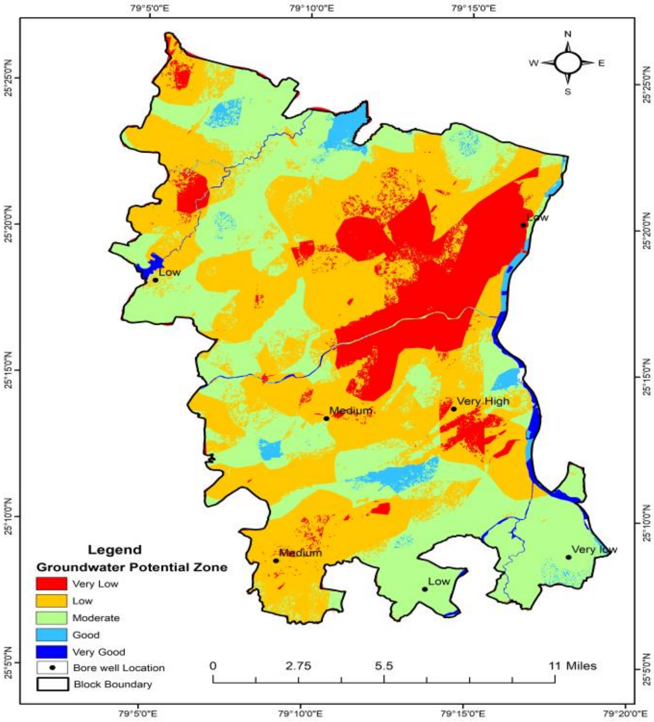


Fig. 13: Ground water potential zone map of study area

It is recommended to correlate 20-150 Ω-m zones with weathered and fractured zone. The pseudo & resistivity cross sections reveal that the depth of weathered and fractured zone is variable as 20 m to 60 m on all locations. Approximately, the weathered and fractured zones observed on pseudo resistivity cross sections suggest water-saturated zones. These zones occur at Tilera (ERT02), Baragaon (ERT03), Basariya (ERT04), Dhawakar (ERT05), Patha (ERT06), Churara (ERT07), Roni (ERT08), Berwai (ERT09), Rewan (ERT10), Bhatpura (ERT11), Bamhauri (ERT12), Rupa Dhamna (ERT13), Akseo (ERT14) and Patha (ERT15) are almost agrees with field observations. During field visits it was noticed that the low resistivity zones were occurring near river banks and low drainage density area. The Pseudo and resistivity sections of watershed show a large weathered and fractured zone of medium resistivity (200-250 ohm-m) at Tilera (ERT02), Baragaon (ERT03), Churara (ERT07), Roni (ERT08), Rewan (ERT10), Rupa Dhamna (ERT13) and Patha (ERT15). It is also suggested that at these ERT sites may be fracture will be identified in the further investigation of sites by improving the length of ERT profile. In the study area such a high resistivity zones occur at village Kadaura (ERT01), as high resistivity rocks such as compact granite rock occur in the field. These high resistivity (>500 ohm-m) zones are also very well appeared in pseudo & resistivity cross sections in all ERT profile with varying depth 40 m to 180 m at all ERT sites. Electrical resistivity tomography survey carried out in different geomorphic units, existing site's location and their strata charts and keeping in view the requirement, recommended sites for drilling of bore well are suggested at village Tilera (ERT02), Baragaon (ERT03), Churara (ERT07), Roni (ERT08), Rewan (ERT10), RupaDhamna (ERT13) and Patha (ERT15). It is recommended that geophysical well logging is essential before lowering the assembly to carefully tape water bearing zone for good discharge.

XI. CONCLUSIONS

In highly deformed area geophysical studies namely ERT were carried out at Mauranipur for mapping the shallow subsurface layers because the daily need of water is not sufficient for the resident people for the domestic and agriculture purposes due to water depletion within the study area. Geophysical technique ERT is essential to select the appropriate places to do this survey because the study area was surrounded by small mounds, which made us very difficult to spread the cable in all directions. This site is not very intricate and heterogeneous in nature as discovered from resistivity model up to a depth of 40 to 60 m. The inverted resistivity model at Mauranipur site shows a conspicuous lateral homogeneity in ERT with a gradual increase in resistivity with depth. The inverse model resistivity section imparts us an idea about the initial deposition of rock in a horizontal way followed by metamorphism in a basin, which was confirmed by a borehole drilling up to a depth of 80 m. Taking into consideration the results of 2D geophysical models, bore well drilling confirmed, for tube well and hand pump at different sites recommended on the basis of ERT geophysical data in this study area. This finding from geophysical and drilling data was also corroborated with the interpreted data of study. As the ground water potentiality of the study area is on average, moderate rainfall is erratic and ground water trend showing a declined trend every year, so availability of ground water is decreasing every year. Therefore, a long-term plan is required for conservation and management of ground water resources. Sustainable development can be achieved by utilising existing surface water resources by constructing recharge structures and by installing tube well at suitable location.

REFERENCES

[1.] A.A.R. Zohdy (1989): A new method for the automatic interpretation of Schlumberger and Wenner curves. Journal Geophysics; Col54, pp:245-253

[2.] A.A.R. Zohdy, G.P. Eaton and R.D. Mabey (1974): Application of surface Geophysics to ground water investigations

[3.] ArcGis 9.3 (2007) welcome to ArcGis Desktop, http://webhelp.esri.com/arcgisdesktop/9.3 (Accessed March 8, 2014).

[4.] Arulbalaji, P., Padmalal, D. & Sreelash, K. GIS and AHP Techniques Based Delineation of Groundwater Potential Zones: a case study from Southern Western Ghats, India. Sci Rep 9, 2082 (2019). https://doi.org/10.1038/s41598-019-38567-x

[5.] Banker, R.D. (1981). The offset system of electrical resistivity sounding and its use with a multicore cable. Geophysics prospecting 29:128-143.

[6.] Basavarajappa H.T, Dinakar S and Manjunatha M.C (2014c). Analysis on land use/ land cover classification around Mysuru and Chamarajanagara

ISSN No:-2456-2165

district, Karnataka, India, using IRS-1D, PAN+LISS III Satellite data, International Journal of Civil Engineering and Technology (IJCIET), Vol.5, Issue.11, Pp: 79-96.

[7.] Basavarajappa H.T, Dinakar S, Satish M.V, Nagesh D and Manjunatha M.C (2014a). Applications of Remote Sensing and GIS in Morphometric Analysis on Precambrian Rocks, Kollegal Shear Zone, Chamarajanagar District, South India International Journal of Earth Sciences and Engineering (IJEE), Vol.7, No.1, Pp: 230-241.

[8.] Basavarajappa H.T, Dinakar S, Satish M.V, Nagesh V, Balasubramanian A and Manjunatha M.C (2013). Delineation of Groundwater Potential Zones in Hard rock terrain of Kollegal Shear Zone (KSZ), South India using Remote Sensing and GIS, International Journal of Earth Sciences and Engineering (IJEE), Vol.6, No.5 (1), Pp: 1185-1194.

[9.] Basavarajappa H.T, Manjunatha M.C and Jeevan L (2014b). Application of Geoinformatics on Delineation of Groundwater Potential Zones of Chitradurga district, Karnataka, India, International Journal of Computer Engineering and Technology (IJCET), Vol.5, Issue.5, Pp: 94-108.

[10.] D. C. Jhariya, Rubia Khan, K. C. Mondal, Tarun Kumar, Indhulekha K. and Vikal K. Singh; (Volume 7, 1 May, 2021). Assessment of groundwater potential zone using GIS-based multi-influencing factor (MIF), multi-criteria decision analysis (MCDA) and electrical resistivity survey techniques in Raipur city, Chhattisgarh, India

[11.] Dehlin, T. 2D resistivity surveying for environmental and engineering applications. First break 1996, 14, 275-283. [Cross Ref]

[12.] Dehlin, T. the development of electrical imaging techniques. Comput. Geocsi. 2001, 27, 1019-1029.

[13.] G.S. Yadav& H. Abolfazi (1998): Geophysical sounding and their relationship to hydraulic parameters in semi-arid region of Jalore, NW India, Journal of Applied Geophysics; Vol.39 pp; 35-51

[14.] Geotomo software, (2006). Res2dinv software, ver 3.55.64, http: www.geoelectrical.com

[15.] Griffiths, D.H. & Barker, R.D., (1993), Two-dimensional resistivity imaging and Modelling in areas of complex geology: Applied Geophysics 29:211-226.

[16.] Ifediegwu, S.I. Assessment of groundwater potential zones using GIS and AHP techniques: a case study of the Lafia district, Nasarawa State, Nigeria. Appl Water Sci 12, 10 (2022). https://doi.org/10.1007/s13201-021-01556-5

[17.] J. Earth Syst. Sci. 123, no. 3, April 2014, pp. 531-534

[18.] Jagannathan Krishnamurthy, Arul Mani, Venkatakrishnan Jayaraman and M Manivel December (2000): Groundwater resources development in hard rock terrain - An approach using remote sensing and GIS techniques, International Journal of Applied Earth Observation and Geoinformation

[19.] K.S.R. Murthy (2000): Groundwater potential in a semi-arid region of Andhra Pradesh Geographical information approach. Int. jr. of Remote Sensing; Vol.21 pp; 1867-1884.

[20.] Loke, M.H.,Barker, R.D.,(1996). Rapid least squares inversion of apparent resistivity pseudo-sections by a quasi-Newton method. Geophysics, prospect. 44, 131-152

[21.] Loke, M.H.; Barker, R.D. (1996) Rapid least-squares investigation of apparent resistivity pseudosestions by a quasi-Mewton method. Geophys. Prospect. 1996, 44, 135-156. [Cross ref]

[22.] Loke,M.H. (2000) Electrical Imaging Surveys for Environmental and Engineering Studies. A Practical Guide to 2D and 3D surveys. http://www.heritagegeophysics.com

[23.] Palacky, G.J.; Kadekaru, K. effect of tropical weathering on electrical and electromagnetic measurments. Geophysics 1979,44,69-88..[Cross Ref]

[24.] Pandey H.K. (2013): Groundwater Broucher of Sonbhadra district, U.P.

[25.] RES2DINV (2013) Rapid 2-D resistivity & IP inversion using the least- squares method

[26.] S.K. Nath, H.P. Patra & Shamsuddin Shahid (2000): Geophysical prospecting for groundwater.

[27.] S.K. Valdiya, S.B. Bhatia & V.K. Gaur (1982): Geology of Vindhyachal.

[28.] S.M. Ranasamy (1994): Remote Sensing for Groundwater Exploration Edited by SankaraPitchaiah.

[29.] SankhikiyaPatrika (2018): Department of Planning, Govt. of U.P.

[30.] Telford,W.M,; Geldart, L.P.;Sheriff, R.E. Applied Geophysics, 2nd ed.; Cambridge University press:Cambridge,UK,199