REPORT

ON

ANALYSIS OF SUBSURFACE PROFILE USING 2D ELECTRICAL RESISTIVITY SURVEY AND LABORATORY METHODS

COURSE – EH611

NEAR SURFACE GEOPHYSICS

SUBMITTED BY

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1. INTRODUCTION

Traditional methods of soil analysis often involve invasive and time-consuming procedures, which may not provide a comprehensive understanding of the soil profile. In recent years, non-invasive geophysical techniques have gained prominence for subsurface investigations due to their ability to provide detailed information about the subsurface without the need for excavation. Among the various geophysical methods, Electrical Resistivity Tomography (ERT) has emerged as a powerful tool for subsurface imaging. ERT is based on the principle that the electrical resistivity of the subsurface materials varies with their composition, moisture content, and other physical properties. A 2D ERT survey involves the measurement of electrical resistivity data along a two-dimensional profile, which can be used to generate cross-sectional images of the subsurface. These images offer valuable insights into the soil layering, moisture content, and the presence of any anomalies or heterogeneities within the soil profile. In this report, we present an analysis of soil subsurface using 2D ERT survey and validate the ERT results through laboratory soil sampling and testing. The study aims to demonstrate the efficacy of integrating geophysical and laboratory techniques for subsurface characterization, highlighting the benefits and limitations of each method and their complementary roles in soil analysis.

1.1 OBJECTIVE

Analyzing the variation in the soil strata and validating the ERT data (Noninvasive technique) with the laboratory sampling data (collected by invasive technique).

1.2 NEED FOR THE STUDY

Electrical Resistivity Tomography has gained prominence in soil strata analysis due to its non-invasive nature and high resolution. Unlike other geophysical methods, ERT can provide detailed, 2D cross-sectional images of the subsurface, offering insights into soil layering, moisture content, and anomalies. Its ability to map large areas quickly and cost-effectively makes it particularly advantageous for site characterization and environmental monitoring. Additionally, ERT is sensitive to variations in soil properties, allowing for the differentiation of different soil strata based on their electrical resistivity. This makes ERT a valuable tool for identifying and delineating geological features, such as clay layers, gravel beds, and groundwater tables. Its versatility and accuracy have made ERT the preferred choice for many soil strata analysis applications over traditional methods like seismic refraction, ground-penetrating radar, and magnetometry.

2. METHODOLOGY OF THE STUDY

Selection of site and planning of layout specifications

2D Data Acquistion by using 1D Electrical Resistivity instrument from the feild

ERT Data processing using RES2DINV software gives 2D tomograph of subsurface

Validating the ERT results with laboratory soil sampling datas such as density, water content and fine contents

Discussion and Interpretation of the results

3. FIELD TESTING OF ER SURVEY AND RESULTS

The equipment used for testing is the AIMIL stacked Deep Resistivity meter 125W-400V-2A. The figure 1 shows the Data Acquisition equipment setup.

Fig 1. ER Instrument - (2 voltage meters, 2 Current meters, External Battery, tape, four electrodes, display system)

3.1 WORKING PRINCIPLE OF ER SURVEY

The ER Survey works based on Ohm's law, $V = IR$. The typical arrangement of the four electrodes is represented in the figure. ERmethodology involves applying a direct current between two surface current electrodes(AB), while additional two electrodes (MN) gauge the voltage drop. It is shown in the figure 2. Deeper depths can be explored by adjusting or increasing the spacing and layout of the electrodes.

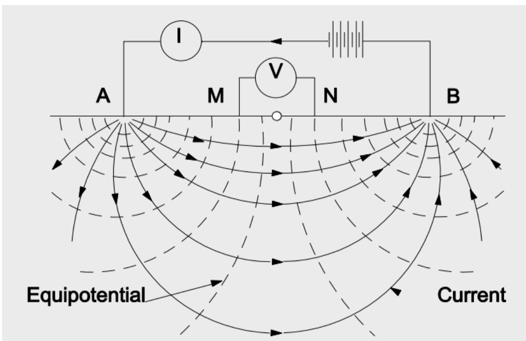


Fig 2. Schematic representation of the Working principle of ER survey

When conducting a ER survey, electrodes are arranged in a specific configuration on the ground, tailored to the desired depth and anticipated subsurface structure. Common setups include Schlumberger, Wenner, and Dipole-Dipole arrays. Following electrode placement, the resistivity meter applies current between two current electrodes, with the potential difference measured between two other potential electrodes. This procedure is repeated for differing electrode spacings to gather data at different depths. Subsequently, the collected data is analyzed to ascertain resistivity values at varying depths. This analysis examines the relationship between electrode spacing, current flow, and measured voltage. Mathematical models like Ohm's law may be utilized to estimate subsurface resistivity and deduce lithological properties. The apparent electrical resistivity from the field can be obtained using the following equation,

$$\boxed{V_{MN} = \frac{\rho I}{2\pi}\left(\frac{1}{r_{AM}} - \frac{1}{r_{MB}} - \frac{1}{r_{AN}} + \frac{1}{r_{BN}}\right)}$$

Where V_{MN} is the voltage between the two potential electrodes

ρ is the apparent electricity obtained, and I is the Electric current applied.

$r_{AM} = r_{MB} = r_{AN} = r_{BN}$ is the distance between the respective current and potential electrode.

3.2 SITE LOCATION

The site was chosen behind the research park of IIT Gandhinagar for both invasive as well as non-invasive testing.

3.3 LAYOUT OF THE TESTING

The layout has been modeled for the 2D testing analysis with the use of 1D instrument in multi electrode system

Table 1 Array and survey Layout details

Array Configuration	Schlumberger
Array number	7
Length of survey , meters	32
Spacing ‘a’ , meters	a=1 for n = 1 to 5, a=2 for n = 3 to 7
No of datum levels	10
Total No of datum points	185
No of electrodes used	17

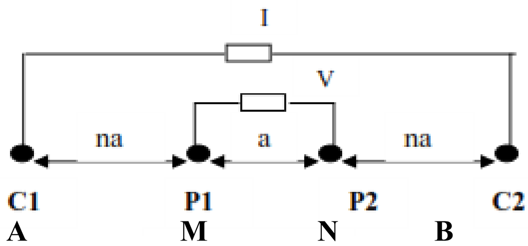


Fig 3. Schlumberger Array Configuration

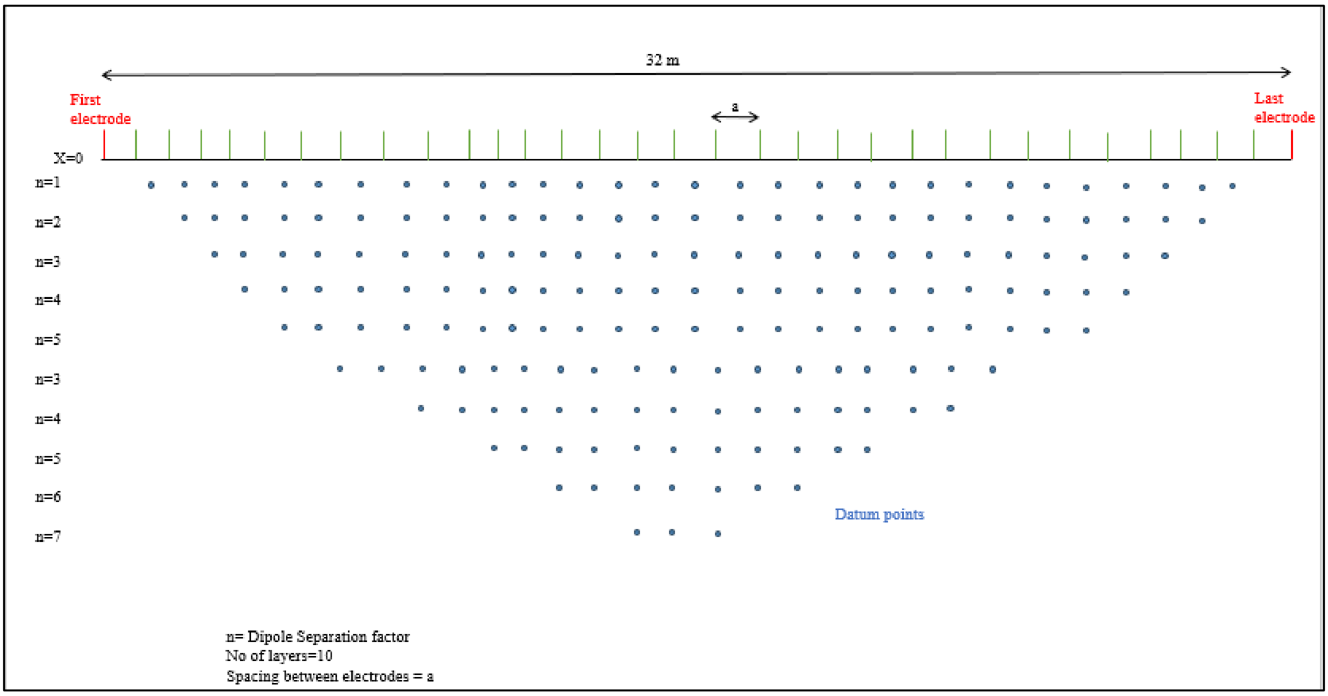


Fig 4. Layout specification of 2D testing for Schlumberger array

3.4 DATA COLLECTION

The following tables of readings of electrical resistivity were collected in the field till n= 7 with varied 'a' spacing.

Table 2 2D Schlumberger Electrical Resistivity Data

n=1					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	1	1	1	158.07
2	1	1	1	1	149.32

3	2	1	1	1	154.81
4	3	1	1	1	151.61
5	4	1	1	1	145.07
6	5	1	1	1	140.91
7	6	1	1	1	136.09
8	7	1	1	1	140.37
9	8	1	1	1	132.35
10	9	1	1	1	150.35
11	10	1	1	1	133.44
12	11	1	1	1	136.83
13	12	1	1	1	137.62
14	13	1	1	1	122.74
15	14	1	1	1	133.53
16	15	1	1	1	137.14
17	16	1	1	1	125.36
18	17	1	1	1	152.68
19	18	1	1	1	125.29
20	19	1	1	1	146.36
21	20	1	1	1	135.02
22	21	1	1	1	135.19
23	22	1	1	1	133.36
24	23	1	1	1	151.76
25	24	1	1	1	139.42
26	25	1	1	1	156.45
27	26	1	1	1	149.75
28	27	1	1	1	162.88
29	28	1	1	1	151.72
30	29	1	1	1	149.42

n=2					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	2	1	2	139.1
2	1	2	1	2	136.93
3	2	2	1	2	159.06
4	3	2	1	2	138.09
5	4	2	1	2	134.12
6	5	2	1	2	128.13
7	6	2	1	2	138.64
8	7	2	1	2	133.3

9	8	2	1	2	129.27
10	9	2	1	2	134.35
11	10	2	1	2	134.68
12	11	2	1	2	139.56
13	12	2	1	2	124.7
14	13	2	1	2	125.42
15	14	2	1	2	151.05
16	15	2	1	2	129.43
17	16	2	1	2	136.91
18	17	2	1	2	138.26
19	18	2	1	2	148.87
20	19	2	1	2	140.26
21	20	2	1	2	147.44
22	21	2	1	2	150.87
23	22	2	1	2	151.47
24	23	2	1	2	152.99
25	24	2	1	2	158.06
26	25	2	1	2	168.59
27	26	2	1	2	160.82
28	27	2	1	2	148.9

n=3					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	3	1	3	129.01
2	1	3	1	3	143.56
3	2	3	1	3	131.48
4	3	3	1	3	126.19
5	4	3	1	3	126.86
6	5	3	1	3	127.99
7	6	3	1	3	121.52
8	7	3	1	3	128.01
9	8	3	1	3	126.45
10	9	3	1	3	126.33
11	10	3	1	3	128.19
12	11	3	1	3	128.65
13	12	3	1	3	124.79
14	13	3	1	3	138.6
15	14	3	1	3	127.91
16	15	3	1	3	140.57
17	16	3	1	3	131.08
18	17	3	1	3	146.83

19	18	3	1	3	141.41
20	19	3	1	3	145.01
21	20	3	1	3	145.58
22	21	3	1	3	148.31
23	22	3	1	3	151.85
24	23	3	1	3	159.34
25	24	3	1	3	152.44
26	25	3	1	1	165.24

n=4					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	4	1	4	141.18
2	1	4	1	4	123.39
3	2	4	1	4	121.71
4	3	4	1	4	125.81
5	4	4	1	4	121.17
6	5	4	1	4	129.06
7	6	4	1	4	125.36
8	7	4	1	4	128.08
9	8	4	1	4	122.11
10	9	4	1	4	128.98
11	10	4	1	4	119.11
12	11	4	1	4	124.47
13	12	4	1	4	150.39
14	13	4	1	4	132.96
15	14	4	1	4	134.5
16	15	4	1	4	158.54
17	16	4	1	4	140.76
18	17	4	1	4	144.3
19	18	4	1	4	154.85
20	19	4	1	4	151.25
21	20	4	1	4	152.04
22	21	4	1	4	163.2
23	22	4	1	4	159.02
24	23	4	1	4	160.86
23	22	4	1	4	159.02
24	23	4	1	4	160.86

n=5					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	5	1	5	114.26
2	1	5	1	5	144.51
3	2	5	1	5	152.67
4	3	5	1	5	152.07
5	4	5	1	5	151.01
6	5	5	1	5	161.67
7	6	5	1	5	167.04
8	7	5	1	5	148.65
9	8	5	1	5	160.82
10	9	5	1	5	143
11	10	5	1	5	160.87
12	11	5	1	5	176.61
13	12	5	1	5	160.59
14	13	5	1	5	185.89
15	14	5	1	5	183.68
16	15	5	1	5	180.03
17	16	5	1	5	190.35
18	17	5	1	5	189.76
19	18	5	1	5	187.99
20	19	5	1	5	195.1
21	20	5	1	5	194.64
22	21	5	1	5	157.13

n=3					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	6	2	6	104.74
2	1	6	2	6	106.27
3	2	6	2	6	107.2
4	3	6	2	6	106.76
5	4	6	2	6	111.35
6	5	6	2	6	109.15
7	6	6	2	6	106.47
8	7	6	2	6	102.63
9	8	6	2	6	105.7
10	9	6	2	6	115.33
11	10	6	2	6	114.06
12	11	6	2	6	116.71

13	12	6	2	6	123.67
14	13	6	2	6	127.83
15	14	6	2	6	127.29
16	15	6	2	6	122.68
17	16	6	2	6	127.81
18	17	6	2	6	129.5
19	18	6	2	6	130.89

n=4					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	8	2	8	91.63
2	1	8	2	8	92.07
3	2	8	2	8	95.64
4	3	8	2	8	90.83
5	4	8	2	8	91.43
6	5	8	2	8	53.9
7	6	8	2	8	92.19
8	7	8	2	8	99.29
9	8	8	2	8	101.88
10	9	8	2	8	101.91
11	10	8	2	8	105.62
12	11	8	2	8	110.51
13	12	8	2	8	110.84
14	13	8	2	8	107.75
15	14	8	2	8	104.88

n=5					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	10	2	10	79.49
2	1	10	2	10	79.65
3	2	10	2	10	76.45
4	3	10	2	10	77.35
5	4	10	2	10	77.06
6	5	10	2	10	81.46
7	6	10	2	10	83.19
8	7	10	2	10	80.33
9	8	10	2	10	86.17
10	9	10	2	10	93.32

n=6					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	12	2	12	65.66
2	1	12	2	12	66.61
3	2	12	2	12	67.65
4	3	12	2	12	69.39
5	4	12	2	12	73
6	5	12	2	12	71.59
7	6	12	2	12	72.09

n=7					
Sno	**from origin**	**AM (na)**	**MN (a)**	**NB (na)**	**ρ (Rho-m)**
1	0	14	2	14	52.37
2	1	14	2	14	59.18
3	2	14	2	14	62.32

3.5 DATA PROCESSING AND RESULTS

3.5.1 ABOUT RES2DINV: The Collected data were processed in the RES2DINV software.Res2DInv is a software designed for 2D inversion of electrical resistivity data obtained from Electrical Resistivity Tomography (ERT) surveys. Developed by Geotomo Software, it features an intuitive interface for easy data input, processing, and interpretation. The software supports various data formats and uses robust inversion algorithms to generate high-quality subsurface resistivity models. Res2DInv provides comprehensive visualization tools to display inverted models, observed data, and misfit values. It also allows users to optimize inversion parameters and export results in multiple formats for further analysis and reporting. At first, we need to create a text file format which can be inputted in the software. The text file format is given below in figure 4.

3.5.2 BASIC RESISTIVITY ALGORITHM OF RES2DINV

The fundamental physical law used in resistivity surveys is Ohm's Law, which governs the flow of current in the ground. The equation for Ohm's Law in vector form for current flow in a continuous medium is given by

$$J = \sigma E$$

Where σ is the conductivity of the medium, J is the current density, and E is the electric field intensity. The relationship between the electric potential and the electric field intensity is given by

$$dV = - E.dr.$$

Applying the principle of conservation of charge over a volume and use the equation of continuity, we get

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \mathbf{j} = 0.$$

In this case, over an elemental volume ΔV surrounding the current source I, located at (x_s, y_s, z_s), the relationship between the current density and the current is given by,

$$\nabla.\mathbf{J} = \left(\frac{I}{\Delta V}\right)\delta(x - x_s)\delta(y - y_s)\delta(z - z_s)$$

The basic equation that gives the potential distribution in the ground due to the point current source is

$$-\nabla \bullet [\sigma(x,y,z)\nabla\phi(x,y,z)] = \left(\frac{I}{\Delta V}\right)\delta(x - x_s)\delta(y - y_s)\delta(z - z_s)$$

By doing forward modelling for the above equation we will get the calculated apparent resistivities.

3.5.3 INPUT FILE AND DATA

```
Research park - 2d testing
 1
 7
 185
1
0
1.5     1       1       158.07
2.5     1       1       149.32
3.5     1       1       154.81
4.5     1       1       151.61
5.5     1       1       145.07
6.5     1       1       140.91
7.5     1       1       136.09
8.5     1       1       140.37
9.5     1       1       132.35
10.5    1       1       150.35
11.5    1       1       133.44
12.5    1       1       136.83
13.5    1       1       137.62
14.5    1       1       122.74
15.5    1       1       133.53
16.5    1       1       137.14
17.5    1       1       125.36
18.5    1       1       152.68
19.5    1       1       125.29
20.5    1       1       146.36
21.5    1       1       135.02
22.5    1       1       135.19
23.5    1       1       133.36
24.5    1       1       151.76
25.5    1       1       139.42
26.5    1       1       156.45
27.5    1       1       149.75
28.5    1       1       162.88
29.5    1       1       151.72
30.5    1       1       149.42
2.5     1       2       139.1
3.5     1       2       136.93
4.5     1       2       159.06
5.5     1       2       138.09
6.5     1       2       134.12
7.5     1       2       128.13
8.5     1       2       138.64
9.5     1       2       133.3
10.5    1       2       129.27
11.5    1       2       134.35
12.5    1       2       134.68
13.5    1       2       139.56
14.5    1       2       124.7
15.5    1       2       125.42
16.5    1       2       151.05
17.5    1       2       129.43
18.5    1       2       136.91
19.5    1       2       138.26
20.5    1       2       148.87
21.5    1       2       140.26
22.5    1       2       147.44
23.5    1       2       150.87
24.5    1       2       151.47
25.5    1       2       152.99
26.5    1       2       158.06
27.5    1       2       168.59
28.5    1       2       160.82
29.5    1       2       148.9
3.5     1       3       129.01
4.5     1       3       143.56
5.5     1       3       131.48
6.5     1       3       126.19
7.5     1       3       126.86
8.5     1       3       127.99
9.5     1       3       121.52
10.5    1       3       128.01
11.5    1       3       126.45
12.5    1       3       126.33
13.5    1       3       128.19
14.5    1       3       128.65
15.5    1       3       124.79
16.5    1       3       138.6
17.5    1       3       127.91
18.5    1       3       140.57
19.5    1       3       131.08
20.5    1       3       146.83
21.5    1       3       141.41
22.5    1       3       145.01
23.5    1       3       145.58
24.5    1       3       148.31
25.5    1       3       151.85
26.5    1       3       159.34
27.5    1       3       152.44
28.5    1       3       165.24
4.5     1       4       141.18
5.5     1       4       123.39
6.5     1       4       121.71
7.5     1       4       125.81
8.5     1       4       121.17
9.5     1       4       129.06
10.5    1       4       125.36
11.5    1       4       128.08
12.5    1       4       122.11
13.5    1       4       128.98
14.5    1       4       119.11
15.5    1       4       124.47
16.5    1       4       150.39
17.5    1       4       132.96
18.5    1       4       134.5
19.5    1       4       158.54
20.5    1       4       140.76
21.5    1       4       144.3
22.5    1       4       154.85
23.5    1       4       151.25
24.5    1       4       152.04
25.5    1       4       163.2
26.5    1       4       159.02
27.5    1       4       160.86
5.5     1       5       114.26
6.5     1       5       144.51
7.5     1       5       152.67
8.5     1       5       152.07
```

9.5	1	5	151.01
10.5	1	5	161.67
11.5	1	5	167.04
12.5	1	5	148.65
13.5	1	5	160.82
14.5	1	5	143
15.5	1	5	160.87
16.5	1	5	176.61
17.5	1	5	160.59
18.5	1	5	185.89
19.5	1	5	183.68
20.5	1	5	180.03
21.5	1	5	190.35
22.5	1	5	189.76
23.5	1	5	187.99
24.5	1	5	195.1
25.5	1	5	194.64
26.5	1	5	157.13
7	2	3	104.74
8	2	3	106.27
9	2	3	107.2
10	2	3	106.76
11	2	3	111.35
12	2	3	109.15
13	2	3	106.47
14	2	3	102.63
15	2	3	105.7
16	2	3	115.33
17	2	3	114.06
18	2	3	116.71
19	2	3	123.67
20	2	3	127.83
21	2	3	127.29
22	2	3	122.68
23	2	3	127.81
24	2	3	129.5
25	2	3	130.89
9	2	4	91.63
10	2	4	92.07
11	2	4	95.64
12	2	4	90.83
13	2	4	91.43
14	2	4	53.9
15	2	4	92.19
16	2	4	99.29
17	2	4	101.88
18	2	4	101.91
19	2	4	105.62
20	2	4	110.51
21	2	4	110.84
22	2	4	107.75
23	2	4	104.88
11	2	5	79.49
12	2	5	79.65
13	2	5	76.45
14	2	5	77.35
15	2	5	77.06
16	2	5	81.46
17	2	5	83.19
18	2	5	80.33

19	2	5	86.17
20	2	5	93.32
21	2	5	92.97
13	2	6	65.66
14	2	6	66.61
15	2	6	67.65
16	2	6	69.39
17	2	6	73
18	2	6	71.59
19	2	6	72.09
15	2	7	52.37
16	2	7	59.18
17	2	7	62.32
0			
0			
0			
0			

Fig 5. Txt file format for data input in software

The data processing involves two steps: Forward modelling and inverse modelling. The forward modelling helps to create a theoretical subsurface by solving the partial derivative Poisson equation in the finite difference method and inverse modelling reduced and smoothens the misfit between measured apparent resistivity and calculated apparent resistivity. The details of the parameters were mentioned.

Table 3 Setting Parameters

Initial Damping Factor	0.15
Minimum Damping Factor	0.02
First layer Damping Factor	5
Damping Factor for Side edges	5
Convergence limit	5 %

The model blocks are created throughout the survey length and for all data points for the flexible analysis of the problem and is represented by

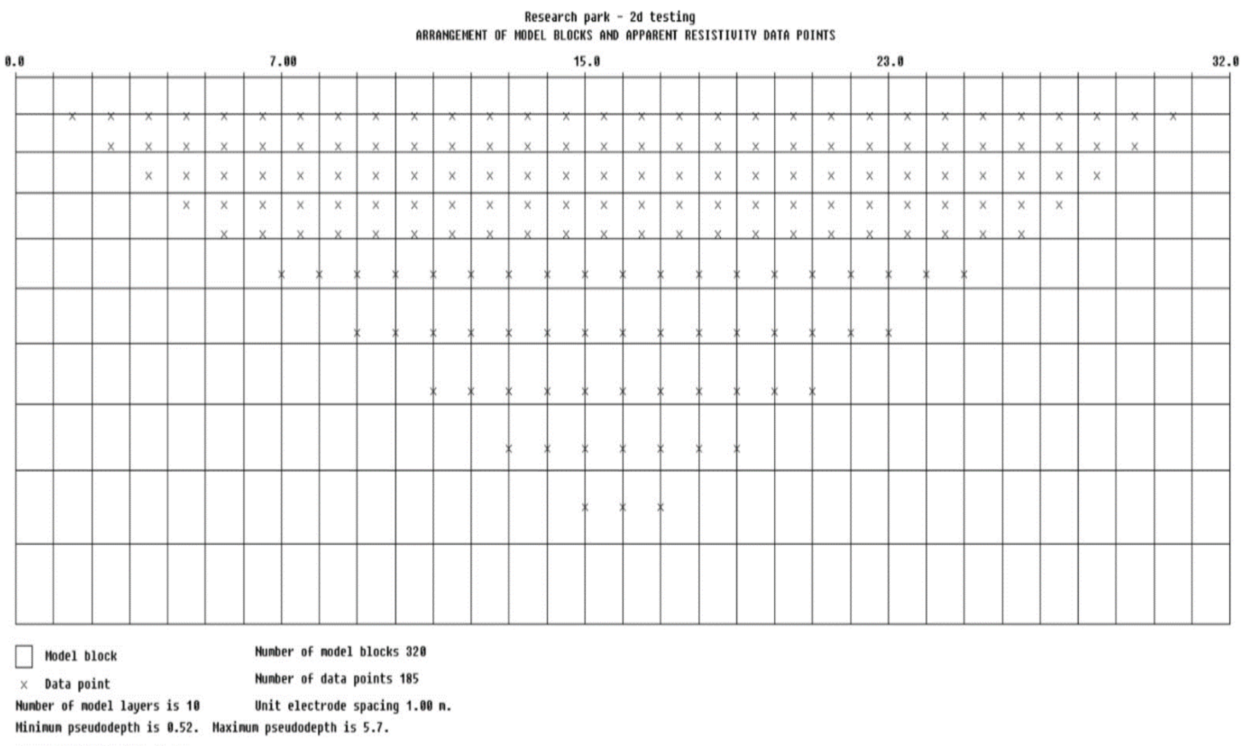


Fig 6. Arrangement of model blocks and apparent resistivity data points

3.5.4 RESULTS - 2D TOMOGRAPH OF SUBSURFACE

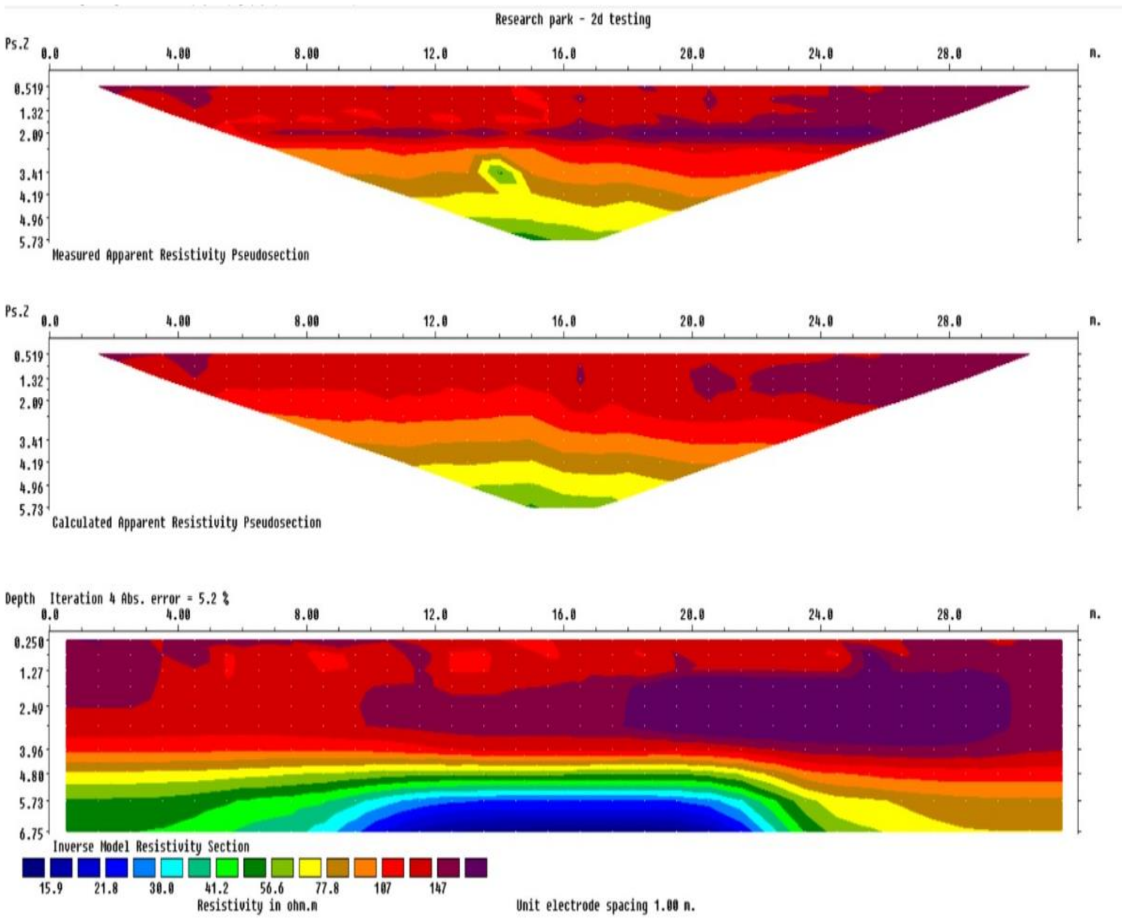


Fig 7. Resistivity Section after inversion

From the above figure, the location for the 185 datum points were represented in the white color dots. The smoothness least square constrained method was used for the inversion process and gauss newton procedure was applied for the reduction of errors. From the analysis, the RMS error calculated is 5.2 % after 4 iterations. The depth of investigation for the Schlumberger array is 1/5th of the maximum distance between the current electrodes. In our case, 1/5*(30) = 6m. The depth obtained from the tomography after inversion is around 6.75m. Thus, the thumb rule is satisfied.

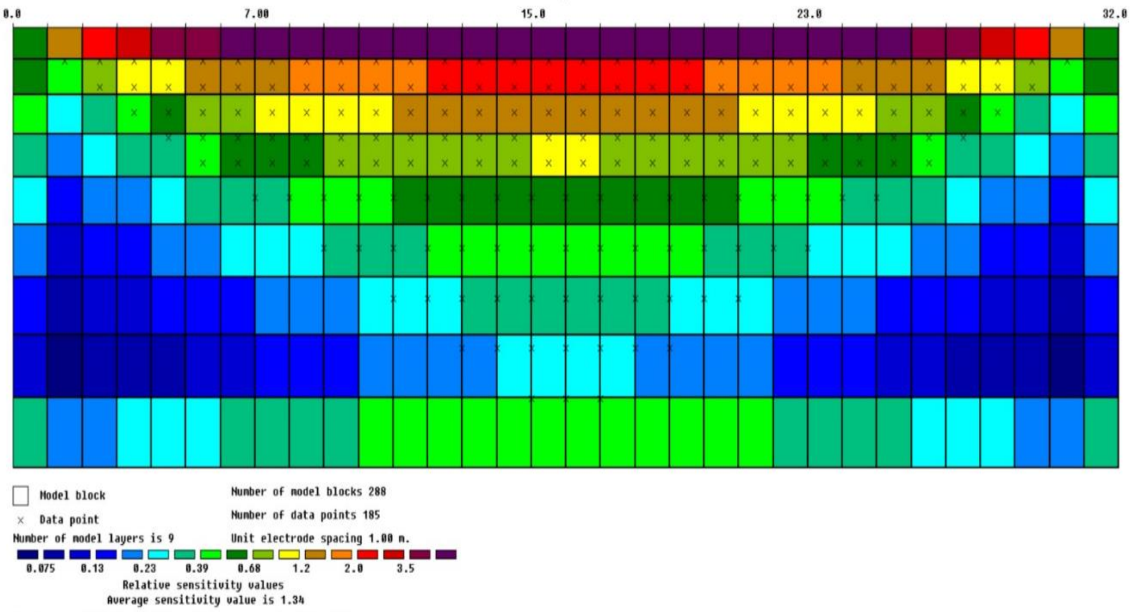
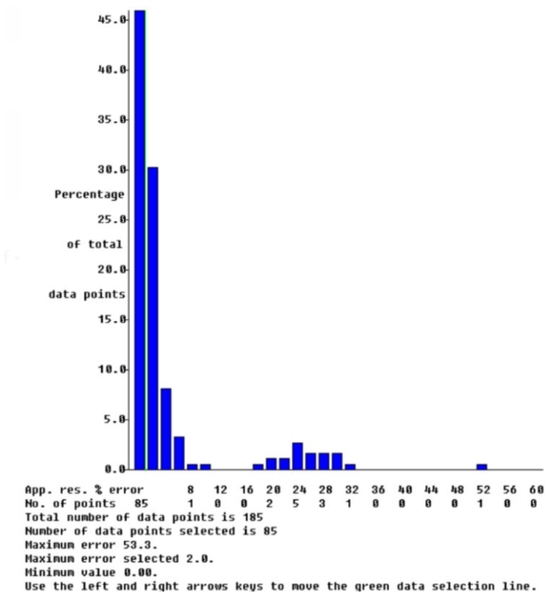


Fig 8. Resistivity Sensitivity of model blocks for the above analysis

3.5.5 Error Analysis



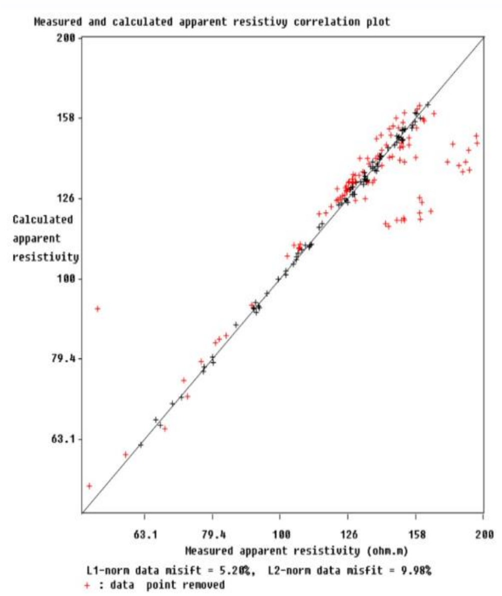


Fig 9. a) Error % vs % of datum points *b)Misfit correlation plot*

4. VALIDATION OF RESULTS FROM LABORATORY SAMPLE TESTINGS

Soil testing is a scientific tool to assess and analyze the inherent physical and engineering properties of the soil and its bearing capacity. Resistivity value is important in interpreting the subsurface tests serve one another and this enhances the experience of locating the groundwater. In these methods, the utilization of electrical properties was applied to the intended subsurface and an electric charge will pass through the area. Thus, the results of the resistivity will be affected by the grain size of the particles, density, porosity, moisture content, type of minerals involved, mobility of ions within pore fluid, amount of surface area and the interaction between solid surface and fluid. In this report we have described the effects of particle size, density & moisture content on the resistivity.

a) The grain size of soil significantly influences its resistivity, with a general trend of decreasing resistivity as fines increase.

1. Size of pore spaces-: Smaller grain sizes typically increase the contact area between grains. Pore spaces are decreasing in size. This enhanced contact area can reduce the overall resistance because the electrical current has more pathways through which it can travel. Conversely, larger grains tend to have fewer contact points, which increases resistance.

2. Pore Space and Moisture Retention: Soil with smaller grain sizes has greater pore space relative to its volume, which allows it to retain more water. Since water is generally a good conductor (especially when it contains dissolved salts), soils with smaller grains and higher moisture content tend to have lower resistivity. Larger grain-sized soils, like sands and gravels, drain more quickly and may retain less moisture, resulting in higher resistivity.

3. Path for Electrical Current: The path through which electrical current flows is also influenced by grain size. In finer soils, the tortuous paths created by numerous, closely-packed grains can increase the distance electrical current must travel, which might increase resistivity. However, the presence of moisture often offsets this effect.

b) Water content significantly affects the resistivity of soil, with a general trend of decreasing resistivity as water content increases.

1. Conductivity of Water: Water itself is a conductor, especially when it contains dissolved salts and minerals, which are common in natural environments. The presence of ions in water facilitates the flow of electrical current through the soil. As the water content in the soil increases, it provides more conductive pathways, reducing resistivity.

2. Saturation Level: At lower moisture levels, water tends to adhere to the surfaces of soil particles, particularly in clayey soils where capillary forces are strong. This thin layer of water on grain surfaces can help conduct electrical currents, reducing resistivity. As saturation increases, the connectivity between these water layers improves, further decreasing resistivity.

3. Formation of Continuous Pathways: When soil moisture increases to a point where the water phase becomes continuous, forming a network throughout the soil matrix, the resistivity drops significantly. This is because the water phases connect the isolated conductive patches within the soil, allowing easier current flow.

4. Pore Space and Soil Structure: The distribution and amount of water in the soil depend on its pore space and structure. Fine-grained soils, like clays, can retain more water than coarse-grained soils, like sands, due to their smaller and more numerous pore spaces. This means that in soils with smaller grain sizes, even small increases in water content can lead to large decreases in resistivity.

c) The density of soil significantly affects its resistivity

1. Particle Contact: Higher density typically means that soil particles are more closely packed together. This reduces the pore spaces between particles and increases the contact area between them, which can facilitate the flow of electrical current, thereby decreasing resistivity.

2. Moisture Content: Denser soils often retain more moisture. The presence of water in the soil decreases resistivity because water is a conductor of electricity, particularly when it contains dissolved salts and minerals which act as electrolytes.

3. Type and Size of Particles: The density can also influence resistivity through the types and sizes of soil particles. For example, clay, which can pack very densely, typically has lower resistivity when wet compared to sandy soils, which are less dense and have larger particle sizes.

4. Temperature and Compaction: Changes in soil temperature can affect its density and moisture retention, thereby influencing resistivity. Similarly, the compaction of soil (which increases density) can reduce the size and connectivity of pore spaces, affecting the flow of electrical currents.

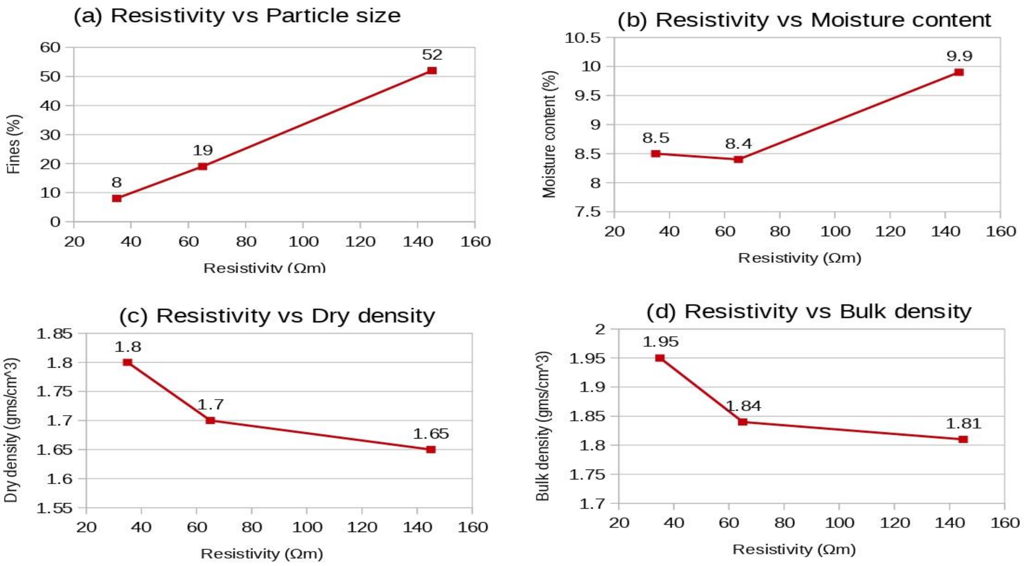


Fig 10. Correlation of Resistivity vs other soil parameters

We have collected the soil data from formerly done soil survey by the institute.

Table 4 laboratory soil sample parameters

Parameters	Size(mm) / Unit	Soil-1	Soil-2	Soil-3
Clay	< 0.002	14	0	0
Silt	0.002 - 0.075	38	19	8
Sand	0.075 - 4.75	45	42	91
Gravel	4.75 - 80	3	39	1
Cobble	80 - 300			
Boulder	> 300			
% Fines	< 0.075	52	19	8
Bulk density	gm/cc	1.81	1.84	1.95
Dry density	gm/cc	1.65	1.7	1.8
Moisture content	%	9.9	8.4	8.5
Specific gravity		2.67	2.67	2.67
Resistivity (Avg)	Ω m	145	65	35

5. DISCUSSION AND INTERPRETATION

Based on the 2D tomogram obtained, we can interpretate that

- The upper layer, extending up to 4m depth, has resistivity values ranging from 107 to 150 ohm-meters. This range is typical for unconsolidated materials like clayey or silty soils. But Between 1.5m and 3.8m,there is a high resistivity zone that starts at a distance of 10m from the origin and extends up to the full survey length of 32m. The resistivity value in this zone is greater than 150 ohm-meters. This high resistivity zone likely indicates a layer of more resistive material within the subsurface. The high resistivity could be due to the presence of a layer of dense, less permeable material such as gravel or rock, or Another possibility is the presence of a contaminant plume with higher resistivity than the surrounding soil. This could be a layer of less conductive material like clay or a contaminant like hydrocarbons. A less common but possible interpretation is the presence of a void or cavity filled with air or less conductive material. It may also show the refined nature or behavior of the soil in that zone.
- The very high resistivity zone (violet color) may indicate the presence of mineralized zones or ore bodies, which can have higher resistivity values due to the presence of metallic minerals.
- It can be seen from the tomograph, from 3.96m to 6.75m, the lithological change was observed. At 3.96m, the resistivity was around 140 ohm-meters and it is varying layer by layer indicating the transition zone of soil strata. At 6.75m the resistivity is almost around 40 ohm-meters.
- As the depth increases, the resistivity decreases. It could indicate a deeper groundwater table and upcoming saturated zone. It can be seen from the tomograph that soil strata is moving from partial saturated zone (high resistivities) towards saturated zone (relatively low resistivities).

Based on the laboratory soil sampling test, we got two anomalies that the % fines decrease with depth and resistivity also decreases with depth. Again, resistivity is not proportional to the moisture content. So, it may be affected by density of soil and same we got from the data also, with increase depth density increase and resistivity decreases. It is because denser soils usually have lower resistivity due to increased particle contact and moisture content.

Also, denser soils generally have lower permeability. This means that water moves through them more slowly, increasing the duration that water remains in the soil. Slower drainage allows for more water to be held in the soil for longer periods, which can be beneficial for plant growth but may also lead to issues like water logging in some cases.

Here we need a detail study of soil (percentage of organic matter and composition of soil particularly soil matrix) to know more about this anomaly. Although denser soils are often thought of as having fewer organic components, the presence of organic matter can influence moisture retention. Organic matter can help in maintaining a somewhat porous structure even in denser soils, thereby affecting how water is held in the soil matrix. Another anomaly we got is Bulk density of soil is higher than dry density it is may be due to soil contains moisture and compacted the overall mass of the soil sample increases due to the added weight of the water, while the volume may not change significantly. This scenario is particularly relevant in soils with high moisture retention capabilities, like clays or organic-rich soils.

6. CONCLUSION

Electrical resistivity value was relatively influenced by the variation of basic geotechnical properties related to soil moisture content, grain size fraction, porosity, density, etc. Hence, this study has shown that the application of field electrical resistivity method together with supported basic soil properties data was applicable to identify type of soils which efficient in term of cost, time, and more data coverage. The study provides valuable insights into the role of electrical resistivity in soil characterization and highlights its effectiveness when coupled with basic geotechnical properties data. By harnessing the complementary strengths of both approaches, researchers and practitioners can enhance their understanding of subsurface conditions, ultimately contributing to more informed decision-making and sustainable land use practices.