EXPLORATION OF GROUNDWATER AND CHEMICAL ANALYSIS OF WATER SAMPLES FOR DRINKING PURPOSE IN ASHIANA-E-IQBAL HOUSING SCHEME, BURKI ROAD, LAHORE, PAKISTAN

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ABSTRACT: *The groundwater exploration in the project area was carried out by the means of electrical resistivity survey, which is used to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface has been estimated which further interpreted to explore the aquifers. The chemical analysis of water samples taken within the project area has also been done to decipher the quality of water for drinking purpose.*

INTRODUCTION

The construction plan of new housing schemes for inhabitants under the Ashiana Housing Scheme has been initiated in the Lahore city. One of the sites selected under this scheme is located on Burki Road Lahore, named as Ashiana-e-Iqbal Housing Scheme.

In order to investigate the subsurface lithology and quality of the groundwater in the proposed housing project site, it was proposed that electrical resistivity survey would be conducted to locate the zones of better quality groundwater up to about 150 meters depth. The purpose of the groundwater studies was to locate favorable sites for installation of tubewell with better quality of groundwater.

The Geophysical fieldwork for electrical resistivity survey was conducted from 23-24th of July, 2012. A total of four (04) vertical electric soundings (VES) were performed within the proposed site. For the chemical analysis, three (03) water samples at the depth of 25-30 m were taken by hand pumps of different locations within the project site.

Principles of Electrical Resistivity Survey

Among the various geophysical methods of subsurface exploration, the electrical resistivity method is successfully employed for groundwater investigations particularly where electrical resistivity contrast exists between the water bearing formation and surrounding soils or rock [1].

The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock / soil. Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations. More recently it is also used for environmental issues as well [2].

Considering the variable electrical properties of the subsoil, the technique of electrical resistivity survey makes use of measuring the current and potential differences of various subsoil materials at the surface. In general, current is conducted electrolytically in the soils containing interstitial fluids. The resistivity is controlled by porosity, water content as well as the quantity of dissolved salts. Clay minerals, however, are capable of storing electrical charges and current conduction in clay minerals is electronic as well as electrolytic. Thus the resistivity of soils depends directly on the amount of contained electrolyte and clay minerals and is inversely related to the porosity and degree of saturation of the formation. Therefore, resistivity of soil varies considerably not only from formation to formation, but also within the same layer [3].

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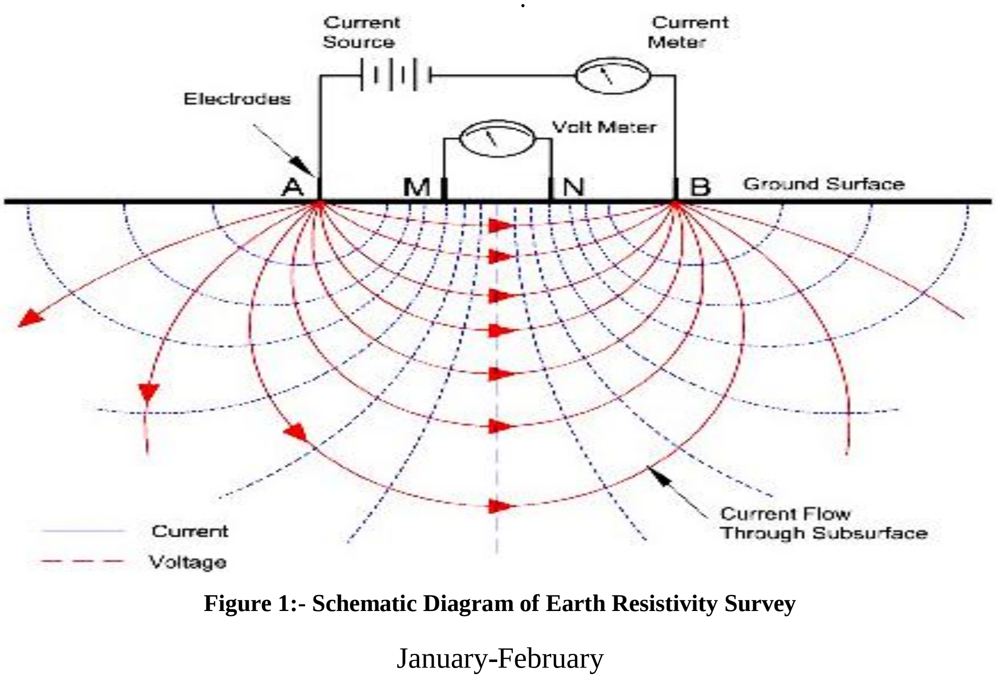

Figure 1:- Schematic Diagram of Earth Resistivity Survey

In particular, the resistivity variations can be large in unconsolidated sediments. It has generally been observed that the resistivity increases progressively from fine grained to coarse grained material in the order of clay, silty clay, clayey silt, silt, sandy silt, silty sand, sand, gravel and boulder.

During the resistivity survey, commutated direct or very low frequency (less than 1 Hz) current is induced into the ground through two current electrodes ‘A’ and ‘B’ inserted in the ground surface as shown schematically on Figure 1The potential electrodes ‘M’ and ‘N’ are inserted in the ground between the outer current electrodes ‘A’ and ‘B’ such that all the electrodes are aligned along a straight line. The potential difference is measured between the two potential electrodes.

By measuring the current (I) flowing between the two current electrodes ‘A’ and ‘B’ and the associated potential difference (V) between the potential electrodes ‘M’ and ‘N’, the resistivity (R) is computed by the following well-known Ohm’s law [4];

$R = K \times (V / I)$

where

K = Geometric factor of the electrode arrangement

V = Potential difference in milli volts

I = Current passing through ground in milli amperes

In homogeneous subsurface conditions, the above relation gives the true resistivity of the subsurface material, but in anisotropic and inhomogeneous conditions, it represents weighted average resistivity of the formations through which the current passes. Since the subsoil is normally inhomogeneous and anisotropic, the resistivity value computed from the above equation is called apparent resistivity and is denoted by (ρa).

Therefore

$\rho a = k \times (V / I)$

The apparent resistivity values are obtained for various depths below the surface by expanding the current and potential electrodes from its centre along a straight line, while spacing between the electrodes is maintained.

Schlumberger electrode configuration is commonly used for groundwater prospecting. In this configuration, distance between the current electrodes is very large compared with the distance between the potential electrodes. In this configuration, lateral inhomogeneities are easily identified. Moreover, this configuration requires lesser electrode spacing at the surface to achieve the required depth of investigation as compared with other configurations [5].

Following are the technical requirements for carrying out the resistivity survey:

- Electrical resistivity contrast should exist between the formations under study.
- While carrying out the electrical resistivity survey using Schlumberger configuration, about two times the space along a straight line is required to achieve the estimated depth of investigation.
- Resistivity values of the alluvial strata and bedrock in an area could be established if the subsurface lithology through at least one test hole or tubewell is known in or around the area having similar geological conditions.
- If the soil consists of thin alternate layers, the resistivity obtained at the surface would be the average effect of these alternate layers [6].

Instrumentation and Field Procedure

The electrical resistivity measurements of the subsurface material were taken in the field by resistivity measuring instrument Terrameter SAS 1000 of ABEM, Sweden and using the Schlumberger electrode array. The Terrameter directly records the value of V/I in ohms. In order to study the variation of resistivity with depth, Vertical Electric Sounding (VES) technique was employed. In this technique, apparent resistivity values are obtained for various depths by increasing the current electrodes spacing at the ground surface, keeping the centre of electrode array fixed at the observation point.

Vertical electric soundings were conducted at 4 observation points within the proposed site area. These resistivity observation points are designated as following:

VES-1 (450596, 3489111)

VES-2 (450259, 3488959)

VES-3 (4449869, 3488877)

VES-4 (449988, 3489545)

At each observation point, the maximum depth of investigation of 150 meters was achieved.

Interpretation and Evaluation of Resistivity Data

The apparent resistivity values obtained in the field versus depth were plotted on the logarithmic scale. The interpretation of resistivity sounding makes use of the method of curve matching in which the field curve is compared with a set of standard curves or with the curves plotted with a computer programme. The standard curves as well as computer curves correspond to a system of subsurface layers and their specific electrical resistivity, which could be correlated with the hydrogeological characteristics of the subsoil of a particular area [7]. The final interpretation makes use of the available local hydrogeological data of the tubewells.

Table 1:- Generalized Results of Four Observation Points of Resistivity Survey

Resistivity Range (Ω-m)	Resistivity Zone	Interpreted Lithology
< 20	Low	Predominantly finer material clay or silty clay
20 – 100	Medium	Predominantly fine to medium sand with some silt/clay layers
> 100	High	Predominantly medium to coarse sand with some cementation

The results of the resistivity survey obtained at four (04) observation points takenin the proposed site area are presented in Table 2.

Table 2:- Interpreted Lithology of Four Observation Points of Resistivity Survey

Probe No.	Depth (m)	True Resistivity (Ω-m)	Interpreted Lithology
VES-1	0.0 - 3.3	13.4	Silty clay surface material.
	3.3 - 19.8	69.6	Predominantly fine to med. sand with some clay layers.
	3.3 - 19.8	69.6	Predominantly fine to med. sand with some clay layers.
	19.8 - 33.8	40.3	Predominantly fine to med. sand with some clay layers.
	33.8 - 71.2	291	Predominantly med. to coarse sand with some cementation.
	71.2 - 150.0	42.7	Predominantly fine to med. sand with some clay layers.
VES-2	0.0 - 4.1	76.0	Silty clay, hard surface material.
	4.1 - 16.4	29.2	Predominantly fine to med. sand with some clay layers.
	16.7 - 72.7	140.9	Predominantly med. to coarse sand with some cementation.
	72.7 - 150.0	35.4	Predominantly fine to med. sand with some clay layers.
VES-3	0.0 - 5.9	35.1	Silty clay surface material.
	5.9 - 18.4	53.9	Predominantly fine to med. sand with some clay layers.
	18.4 - 34.5	39.4	Predominantly fine to med. sand with some clay layers.
	34.5 - 71.4	11.7	Predominantly fine grained material clay/silty clay.
	71.4 - 150.0	118.8	Predominantly med. to coarse sand with some cementation.
VES-4	0.0 - 2.6	119.6	Silty clay, hard surface material.
	2.6 - 8.4	570.2	Predominantly med. to coarse sand with some cementation.
	8.4 - 26.6	51.3	Predominantly fine to med. sand with some clay layers.
	26.6 - 66.9	222.7	Predominantly med. to coarse sand with some cementation.
	66.9 - 150.0	25.7	Predominantly fine to med. sand with some clay layers.

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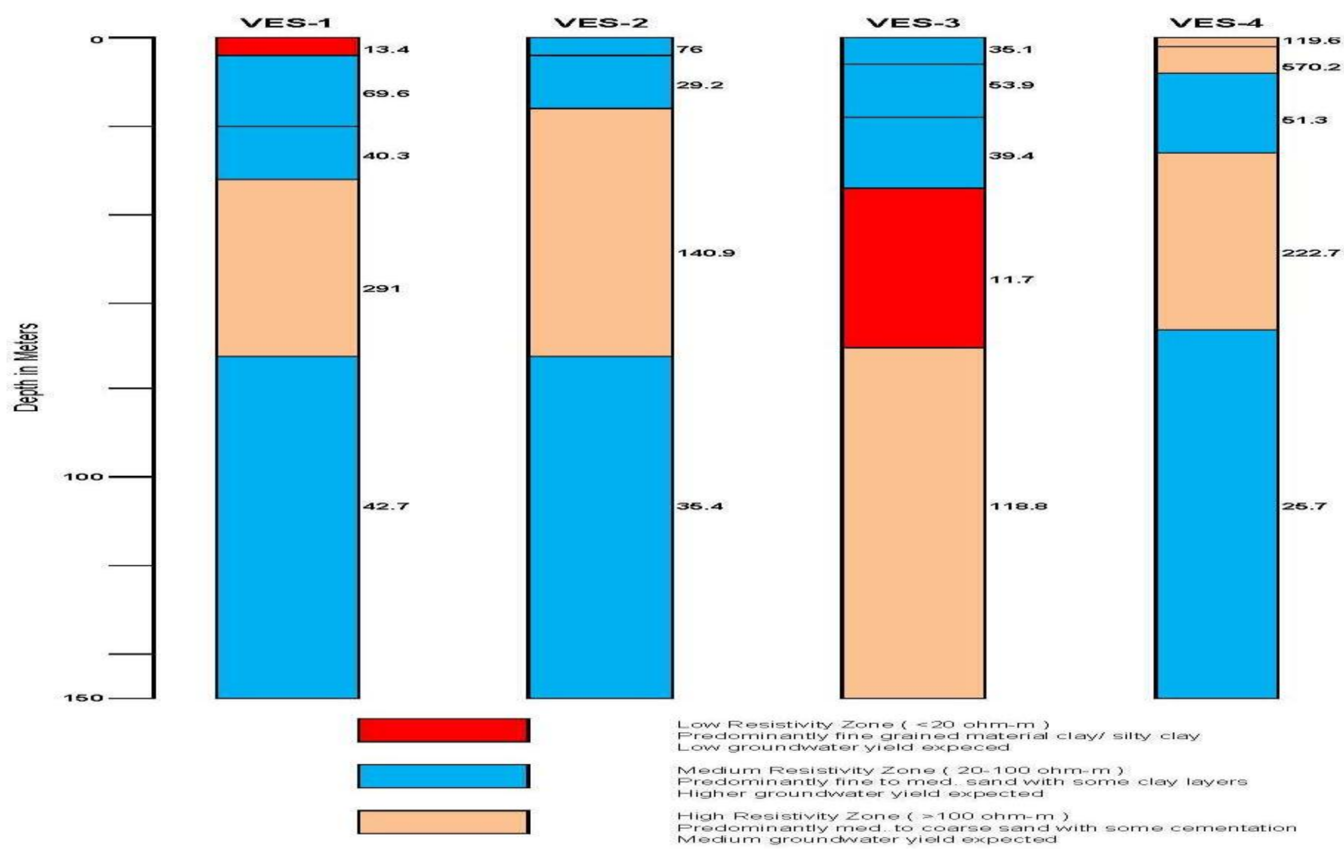

Figure 2:- Subsurface Columnar Sections Interpreted by Resistivity Survey

A subsurface columnar section has also been prepared to depict the lateral variation of subsurface hydrogeological condition and is presented in Figure 2

The results of the electrical resistivity survey show the presence of alternating layers of low resistivity fine grained material and medium to high resistivity sandy material up to investigated depth of 150 meters.

The low resistivity layers representing fine grained material are present at VES-1 and VES-3. At VES-3, a thick layer of low resistivity material is present at intermediate depth. Due to low permeability, the fine grained material is not expected to yield appreciable quantities of groundwater.

Due to predominance of sandy material, the medium resistivity material is expected to get appreciable quantities of fresh groundwater.

The high resistivity material is interpreted to represent medium to coarse sand with some cementation, therefore it is expected to give medium groundwater yield.

Appreciable thickness of medium to high resistivity material is present at all the four observation points. The greater the resistivity value in medium resistivity zone, the better is the expected groundwater quality.

Chemical Analysis of Water Samples

For the purpose of chemical analysis, three (03) water samples were taken at depth of 25-30 m from the hand pumps of different locations within the project site. The results of the samples are given as followings in Table 3:

Table 3:- Chemical Analysis of Water Samples of the Project Area with WHO Limits [8]

Parameters	Results (mg/l)			WHO Limits (mg/l)
	Sample 1	Sample 2	Sample 3	
Conductivity	670	634	643	700
Total Dissolve Solids	430	451	462	1000
Total Hardness	268	265	274	-
Calcium Hardness (Ca^{+2})	51	48	54	75
Magnesium Hardness (Mg^{+2})	34	39	37	50
Sodium Hardness (Na^{+1})	22	20	24	200
Potassium Hardness (K^{+1})	03	02	04	50

The Table 3 clearly decipher that the parameters of all the water samples at depth of 25-30 m are within the limits of World Health Organization (WHO) [9]. So according to the above table, the water is fit for drinking purpose. Furthermore, after drilling for installation of tubewells (recommended by interpreted results of resistivity survey) the water should be further tested to determine its quality at that particular depth for any risk of contamination as well [10].

CONCLUSIONS & RECOMMENDATIONS

From the results of electrical resistivity survey carried out for groundwater investigations and location of tube wells in the proposed site area of Ashiana-e-Iqbal Housing Scheme on Burki Road, Lahore, it is concluded that:

- The subsurface consists mainly of medium to high resistivity material, representing coarser material with good quality groundwater. At VES-3 location, a thick layer of low resistivity material representing finer material with low groundwater yield is interpreted to be present.
- Appreciable thickness of medium to high resistivity layers representing predominantly fine to coarse sand is present at VES-1, VES-2 and VES-4 locations.
- On the basis of resistivity survey, the locations of resistivity observation point VES-1, VES-2 and VES-4, which shows predominance of sandy material with better quality groundwater, are very favourable for the installation of tubewell up to more than 150 meters depth yielding good quality water. These three locations are suitable for test drilling and are therefore recommended for installation of tubewells up to 150 meters depth.
- It is also recommended that drilling should be conducted under the supervision of a hydrogeologist and before installation of tubewell, geophysical well logging should be carried out for proper design of the tubewell assembly.
- The water is fit for drinking purpose at depth of 25-30 m in the area. However it needs to further chemical testing at depth of installing tubewells due to probability of any contamination at that depth.

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