Electrical Resistivity Survey for Groundwater Investigations and Evaluation of the Granite –Basalt formation around Narayankher, Medak District, Telangana State, India

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Abstract: This study is concerned with the identification and delineation of aquiferous zones for potential groundwater development around Narayankher area and the constraints to effective and sustainable management of underground water in the study area. Traditionally, this has been done by using vertical electrical sounding (VES) surveys. The VES surveys provide comprehensive information for interpreting the structure and extent of subsurface hydro-geological features. The study area water supply for irrigation and domestic uses are mostly from dug wells, of 10 to 15 m depth penetrating the top weathered/fractured zones. Most of the dug wells dry up in the beginning of summer, causing enormous damage to the crops. Increasing demand of water supply can be met from deeper aquifers. In the present study the electrical resistivity method has proved to be useful for identifying deeper aquifers, and each VES sounding extend among 120 m to 150 meters, it is clearly that 40 VES soundings were carried out to cover the total study area. All these soundings are conducted using Schlumberger configuration with a maximum half-distance of current electrode separation (AB/2) equal to 150 m until the sounding curve attained, which is an indication of establishment of contact of volcanic rock with the granite basement. Initially the VES data has been interpreted with master curves and later the interpretation is redefined by using IPI2Win software. These methods provided a more precise hydro-geophysical model for the study area compared to the traditional VES. The results from this study are useful for technical groundwater management as they clearly identified suitable borehole locations for long term groundwater prospecting.

Keywords: Vertical Electrical Sounding; Groundwater; Geoelectric Section; Aquifer; Resistivity

I. INTRODUCTION

Groundwater is one of the most valuable natural resources, and supports human health, economic development and ecological diversity. Due to its several inherent qualities (e.g. consistent temperature, widespread and continuous availability, excellent natural quality, limited vulnerability, low development cost and drought reliability), it has become an important and dependable source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries [1].

The present study has been carried out to evaluate hydrogeological characteristics of groundwater of the granitic and basaltic aquifers in Narayankher Mandal, Medak district. The study area is situated at distance of 120 kms from Hyderabad, Telangana state. The study area in Medak district lies between North latitudes $18^0 2'$ and East longitudes $77^0 46'$ and is included in Survey of India topo sheet no's 56F/12 and 56F/16. It has an average elevation of 610 meters above mean sea level (Figure 1). The area comprises of several villages Malkapur, Baddaram, Shankarampet, Kamalapuram, Venkatapura, Kamalapur 'X' road, Tenkati, Nizampet, Bachupalli, Mirkampet, Raparthi, Ankampalle, Krishnapuram, Kanapur, Narayankher, Thimmapur above villages are Granitic terrain. Kajapur, kadpol, Sirgapur villages are Granites-Basalts contact Rakal, Thurkapalle, Kondapur, Mansurpur, Gadidi Villages are having Basalts. Hukran, Abendda, Sheligera 'X' road villages are having Intratrappeans and in and around Narayankher town covering approximately 343.47 sq. kms. The area is significant due to the presence of fractured volcanic deposits and Precambrian crystalline basement rocks associated with the groundwater. Availability of groundwater in unconfined aquifers underlain by impermeable crystalline igneous rocks is often controlled by the development of secondary porosity and permeability from weathering and fracturing.

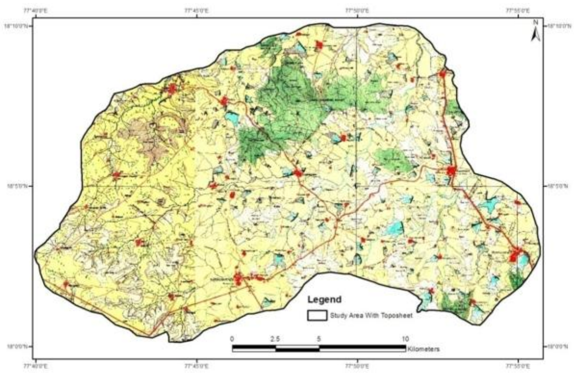

Figure 1 Topographic map of the study area

II. GEOLOGYAND GEOMORPHOLO-GY OF THE STUDY AREA

The geological formations encountered in the region are Archaean Group. The Archaean or Peninsular gneisses occur all over the district in 6, 86,853 ha area (70.7%) (Figure 2) [2], they are partially metamorphosed igneous rocks. They remained stable as a "Shield" area for a very long time. The rocks are composed of grey or pink feldspars, quartz and muscovite mica. The pink, granite together with its pegmatite and quartz veins was a later intrusion than the grey granite, as indicated by the presence of enclaves of the latter in the former and also the intrusive relation of the former with the latter. The dark minerals of granite include biotite mica and hornblende and other minerals like apatite, zircon etc., and the important rock types are granites, grano-diorites and banded gneisses. In some areas, the peninsular gneisses are traversed by a number of dolerite dykes which represent the last phase of igneous activity of the Archaean period [3].

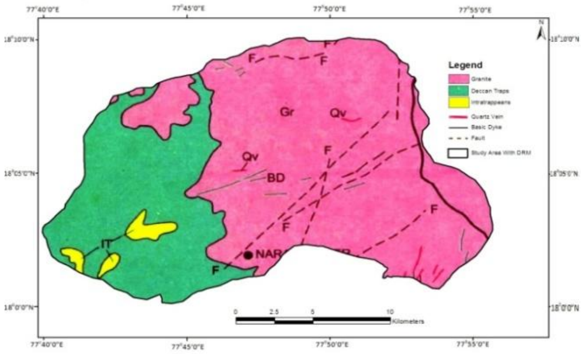

Figure 2 Geological Map of the Study Area

Deccan traps occur in parts of Medak, Adilabad, Ranga raddy, Mahaboobnagar and Nizamabad districts with a total aerial extent of 10,000 Sq. Kms. The Deccan trap basalts in Peninsular India are the result of fissure eruptions of molten lavas which flowed to long distances covering hundreds of kilometers of the country to form extensive flows. These rocks are generally horizontal and layered and each layer ranges from a few meters to 40 meters in thickness. The Basalts, though generally uniform in composition, show variation in colour, texture and mode of weathering. The study area is represented monotonously by a single formation known as Granites and Deccan basalts and Infra-trappans formations comprising nearly horizontal lava flows. These flows have been considered to be a result of fissure type of lava eruption during late Cretaceous to early Eocene period. The Deccan traps appear as step like terraces or plateaus occupying large areas. They are exposed between the elevations of 512 to 627 meters in the study area they show spheroidal weathering and columnar joints Basalts are highly weathered and are decomposed resulting in the formation of laterites which are seen to occur as capping on top levels and also along the slopes of the hillocks and as red loamy soil in low lying areas while the out crops of the bed rock are seen exposed in deep gullies. It is well established that geology plays a vital role in the distribution and occurrence of groundwater, [4].

A. Granites and gneisses

Figure 3 Granite and Quartz vines near Shankarampet

The Archaeans are consisting mainly of pink and grey granites. The granites are massive and intruded by dolerite dykes, pegmatites and quartz veins. The grey-granites are generally traversed by NW-SE joints [5]. The pink granites and grey granites are so closely associated with each other that it is difficult to map them separately. The pink granite is generally porphyritic with large phenocrysts of pink orthoclase feldspar. Biotite, Chorite and hornblende are the major mafic minerals while epidote and tourmaline occur as accessories. The pink granites are more susceptible to weathering than the grey granites. The characteristic feature of these granites is the occurrences of nodular calcareous near the surface containing abundant quartz pebbles (Figure 3).

B. Basalts

Basalts were formed from the eruption of volcanic flows from upper cretaceous to Eocene period. These are horizontal flows trapping the older rocks and are mostly confined to the Deccan parts and hence they are known as Deccan traps or Deccan basalts. Basalts exhibit both vesicular and non-vesicular form. Vesicular forms are very porous and soft, while the non-vesicular forms of basalts are very compact and hard. In fact, it was the vesicular type of basalts is highly altered to give rise to laterites.

The Deccan traps which basaltic in composition, are the parent rocks of laterite. In the study area there were 9 flows of Deccan traps according to [6] [7], of which the first seven flows are not weathered and still they appear as basaltic in composition, whereas the 8^{th} and 9^{th} flows have been completely weathered and altered to laterites (Figure 4). Thus the laterites under the description are the part of the ninth flow. A red or grey indurate earth of white marl with lamine of tuff indicating sub-aerial weathering separates the flows from each other.

Figure 4 Basalts outcrop in the study area at Narayankher

C. Deccan traps

Major portion of the area is occupied by basalts with a general N-S to NW-SE trend. The basalts lie uncomformably over the granites except north of Kajapur. The lowest basalt flow shows undulating contact with underlying formations, while the subsequent flows are nearly horizontal (Figure 5). The Basalts of Narayankher and surrounding areas are sub-aerial pahoehoe lavas, characterized by smooth undulating or rolling surface and vesicularity towards the top base with spheroidal vesicles, partly elongated and coalescing and filled with secondary minerals [8].

Figure 5 Deccan traps in study area

At a number of places vesicular flows occur and often the vesicules are filled with secondary minerals like silica and zeolites. These are mostly medium grained and are light to dark-grey in colour. Some of the rocks show spheroidal weathering and irregular joints. According to [9], the Deccan trap is a unique continental basaltic province with more or less uniform chemical nature.

D. Infra-trappean beds

These beds are mainly composed of clays and occur in between the basalt flows (Figure 6). These are considered to have been formed due to the deposition of some volcanic ash or sediments of lacustrine or fluviatile origin during the period intervening between the eruptions of two lava flows. The lateral extents are usually 1 to 3m thick and not exceed 5 to 7 sq.km [10].

Figure 6 Geological formations in the Abbanda village

III. OCCURRENCE OF GROUND-WATER

A. Granites

Secondary porosity and permeability are imparted to these crystalline rocks by weathering and fracturing. The thickness of the weathered zone may range from feather edge near outcrops to more than 100m [11] [12]. The aquifer tests in granites [13] indicate a decrease in porosity and specific yield with depth. The depth to the water table varies widely in granite rocks generally due to undulating topography (Figure 7).

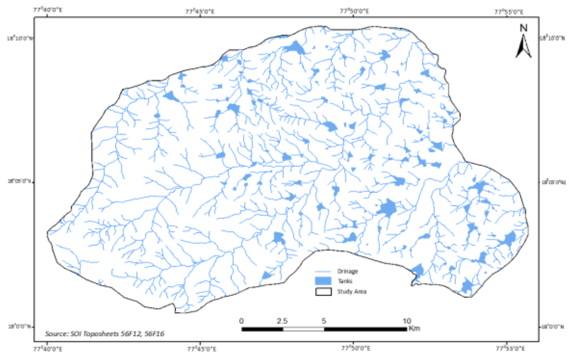

Figure 7 Drainage map of the study area

Data from many regions show that wells in granite rocks achieve 0 to 50 percent of their total yield within the first 10 to 20m below the water table and within a depth of 60m mainly from the weathered and semi-weathered zones [14][15][12][13]. The contribution to well yield below a depth of 90m is comparatively negligible in a majority of the cases, although rarely well yield may be wholly derived from deep-seated fractures at depths of 200m or more [16].

B. Basalts

Groundwater occurrence and movement in basalt rocks are controlled by (1) vertical and horizontal porosity and permeability owing to fractures and interconnected vesicular interstices which permit storage and movement of ground water, (2) occurrence of impervious layers and presence of dykes and sills which retard movement of ground water and (3) presence of pervious and permeable inter beds between lava flows [17].

The distinctive hydro-geological feature of basalt rocks is the significant primary porosity in the form of interstices in vesicular and pillow lavas, lava tubes and occasional tunnels. Secondary porosity is introduced by weathering, brecciation, shrinkage cracks and joints and fracture systems developed due to tectonic disturbances [18]. The maximum secondary porosity in lava is introduced by weathering (up to 35percent) and fracturing imparts up to 15percent.

IV. FIELD INVESTIGATIONS

In general, electrical investigations particularly vertical electrical soundings, conducted to determine the sources of groundwater potential zones and to identify fresh groundwater sources. Some of the significant applications are lateral differentiation of permeable formations from impermeable or less permeable formations, vertical distribution of various layers. Electrical resistivity and self potential surveys. Self potential (SP) method is applied to identify plumes of contaminations, integrating the SP anomaly with electrical resistivity and water quality data.

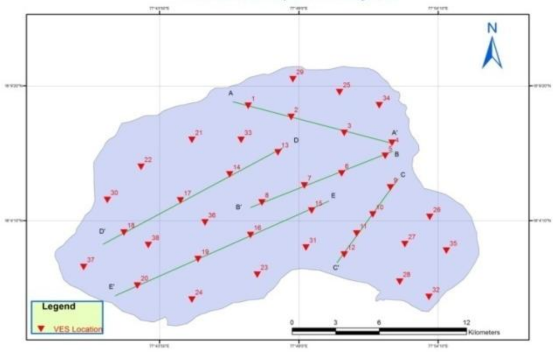

Figure 8 Location map of the VES soundings

A total of forty vertical electrical soundings (VES) were carried out at selected locations (Figure 8). In and around the study area in order to infer the subsurface conditions along the Profiles, soundings were carried out using IGIS make Resistivity meter wherein the current and potential readings are displayed for calculating the resistance. Accessories are metal electrodes, measuring tape, labelled tag (used in locating station position), hammers (used in driving the electrodes into the ground), compass, and connecting cables. Cast iron stakes as current electrodes and carbon filled porous pots as potential electrodes were used to improve the ground contact. The entire VES were carried out with a maximum current electrode separation (AB/2) as started with 1.5 to maximum depth of 120 m to 150 m covering an area of 8.58 sq. km. The locations of VES were chosen such a fashion to cover the entire study area uniformly with closer to longer in meters within the study area and in kilometers around the study area distance between soundings and as per the availability of space for carrying out surveys [19].

The induced current passes through progressively deeper layers at greater electrode spacing. Apparent resistivity values calculated from measured potential differences can be interpreted in terms of overburden thickness, water table depth, and the depths and thicknesses of subsurface strata [20]. For this study, the Schlumberger configuration was used to acquire VES data at five (4) sounding points, one along each traverse. The electrode separation (AB/2) varied from 1.5 to maximum depth of 120 m to 150 m in the study area. Current was passed into the ground through the current electrodes, and the resulting potential was measured through the potential electrodes, and was converted to resistance [21].

V. RESULTS AND DATA INTERPRE-TATION

The study area partly covered by Precambrian crystalline rocks and by Deccan traps below a thin soil cover which is produced by weathering of the traps. In some places at a higher elevation, highly weathered/massive basalts are exposed. The soil-covered area constitutes about 70% of the total area [22] and is being used for agriculture and development of plantations. The remaining area is wasteland. Below the soil layer is the weathered/fractured basalt layer. Groundwater of limited quantity occurs in this weathered/fractured mantle at shallower depth under unconfined conditions [23].

This zone is the main source of groundwater supply to the dug wells. Below this zone lie the lava flows. Each lava flow consists of an upper vesicular sub-unit and a lower massive sub-unit which may or may not be fractured. Two lava flows are separated by intertrappean beds, which together with the underlying vesicular basalt layer form a potential groundwater zone between two compact basalt layers at a deeper level. Groundwater occurs in confined conditions in this composite unit of intertrappeans and vesicular basalt layers, and in the joints and fractured zones of massive basalts at a deeper level. At places clay-rich bole beds occur between lava flows. Bole beds are poor aquifers because of their clayey nature. In this region water supply for irrigation and domestic use is mostly from dug wells of 10 to 15 m depth penetrating the top weathered/fractured zones. Water available in the dug wells is inadequate to meet the present demand for irrigation and domestic use. Most of the dug wells dry up in the beginning of summer, causing enormous damage to the crops. Increasing demand of water supply can be met from deeper aquifers. In the present study the electrical resistivity method has proved to be useful for identifying deeper aquifers in the form of fractures, faults, joints, intertrappeans and infratrappean formations.

Geologic interpretation of the resistivity data was done in accordance with published reports. As per CGWB, the region is underlain by crystalline rock formations. A resistivity range of 0 to 15 Ω-m represents clay layer; a range of 15 Ω-m to 25 Ω-m represents weathered; a range of 25 Ω-m to 35 Ω-m represents semi-weathered to fractured granite; a range of 35 Ω-m to 120 Ω-m represents fractured granite; and a resistivity of more than 150 Ω-m represents hard granite that forms the bed rock [24].

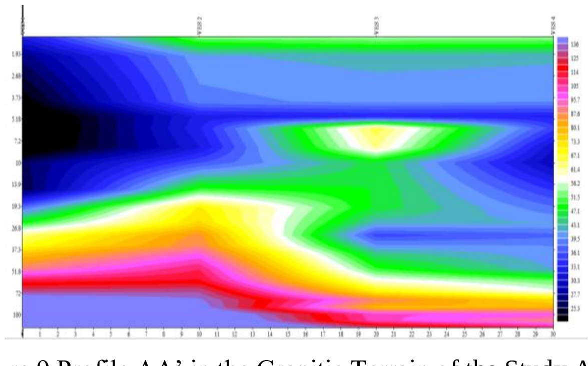

Figure 9 Profile AA' in the Granitic Terrain of the Study Area (Resistivity values in ohm-m)

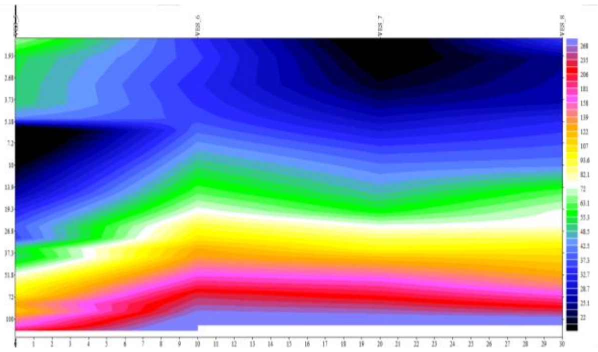

Figure 10 Profile BB' in the Granitic Terrain of the Study Area (Resistivity values in ohm-m)

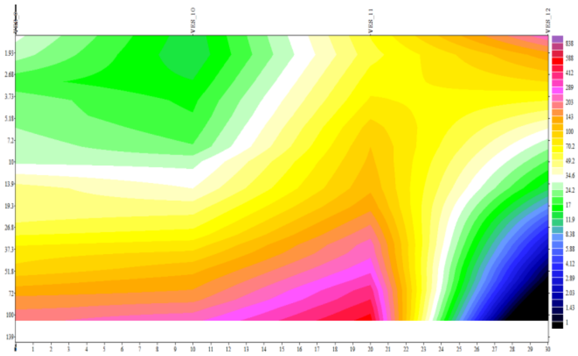

Figure 11 Profile CC' in the Granitic Terrain of the Study Area (Resistivity values in ohm-m)

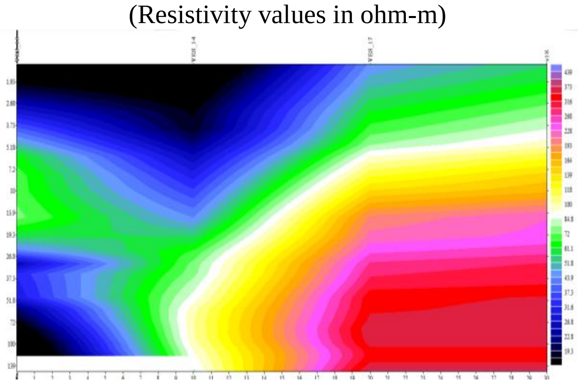

Figure 12 Profile DD' in contact between Granitic Terrain and Deccan Traps of the Study (Resistivity values in ohm-m)

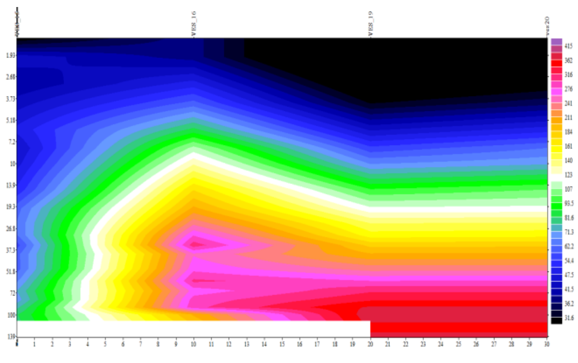

Figure 13 Profile EE' in contact between Granitic Terrain and Deccan Traps of the Study Area (Resistivity values in ohm-m)

Locations of the sites are shown in (Figure 8). The profile AA' (Figure 9), BB' (Figure 10) and CC' (Figure 11) the study area are located in the Precambrian crystalline granitic gneisses and the profiles DD' (Figure 12) and EE' (Figure 13) are in contact between the granites and basalts extended exclusively towards NNW and SSW of the study area. Information from a total of

VES 1 to VES 12 stations was used to generate the hydrogeologic profiles along AA', BB' and CC' are taken in the granitic terrain (Figure 14) along the assumed sections. Each cross-section has at most four hydrogeologic layers namely: Top soil (consisting of clay and highly weathered rocks); Un-saturated zone (consisting of weathered granite); Aquifer zone (consisting of fractured granite); and Bed rock zone (consisting of hard granite). Along with, ground surface profile was demarcated for each cross section. Since the cross sections were developed using linear interpolation between VES stations, uncertainty in the interpreted geologic layer increases with the distance from the VES station. A high thickness of layer 3 (aquifer zone) at any location may suggest an aquifer of appreciable depth. The top two layers act as an un-saturated zone, allowing the downward passage of water and contaminants to the aquifer. The aquifer zone is primarily un-confined, and hence, the availability of water largely depends on the aerial recharge.

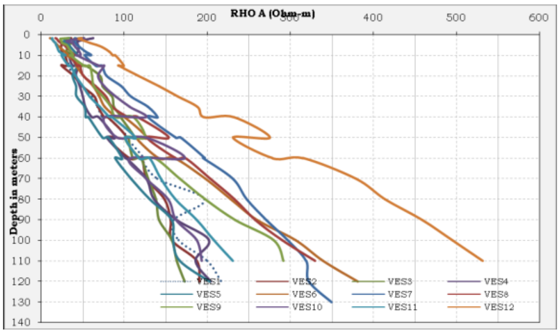

Figure 14 Vertical Electrical Soundings carried in Profile AA', BB' & CC' of the Study Area in Granitic Terrain

Groundwater table is relatively flat, except at the pumping regions. Referring to the aquifer demarcation maps, a structurally closed groundwater basin (It implies that it is a confined aquifer in the basin and is enclosed without any leakages to the surrounding regions) (aquifer zone) is identified along the section C-C'. However, the remaining sections are either leaking the groundwater to the adjacent regions, or, not containing aquifer of appreciable thickness. Information from soundings VES 13, VES 14 and VES 17 and VES 18 along the profile DD' of VES stations was used to generate the hydrogeologic profiles (Figure 15) along the assumed sections. Each cross-section has at most four hydrogeologic layers namely: Top soil (consisting of clay and weathered rocks; Un-saturated zone (consisting of weathered granite; Aquifer zone (consisting of fractured granite; and Bed rock zone (consisting of granite) along VES 13 and VES 14 of the profile. Along with, ground surface profile was demarcated for each cross section. Since the cross sections were developed using linear interpolation between VES stations, uncertainty in the interpreted geologic layer increases with the distance from the VES station. A high thickness of layer 5 (aquifer zone) at any location may suggest an aquifer of appreciable depth. The top two layers act as an un-saturated zone, allowing the downward passage of water and contaminants to the aquifer. The aquifer zone is primarily un-confined, and hence, the availability of water largely depends on the aerial recharge. Groundwater table is relatively flat, except at the pumping regions. Referring to the aquifer demarcation maps, a structurally closed groundwater basin (It implies that it is a confined aquifer in the basin and is enclosed without any leakages to the surrounding regions) (aquifer zone) is identified along the contact between Granite and Basalt along the profile section D - D' and E -E' (Figure 15).

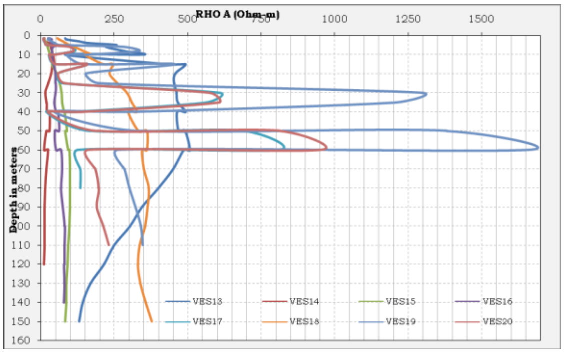

Figure 15 Vertical Electrical Soundings carried in Profile DD' & EE' of the Study Area in contact between Granite and Basalt

CONCLUSIONS

The picture that emerges from this study has shown that there is large spatial variability of ground water potential while the most promising potential zone in the area is related to volcanic rock of which is affected, by secondary structure and having interconnected pore spaces, with gentle slope and less drainage density. It can also be inferred that most of the zones with low to poor groundwater potential lie in the massive basements unit which is far from lineaments. Areas close the sewer drainage system should be avoided or buffered to prevent contaminated water.

It can also be concluded that parts of the area that are characterized with surface expression of lineament are considered to be hydrogeological insignificant due to high slope and hence constitute the poor groundwater potential zone for the area. The low drainage density areas cause more infiltration and result in good ground-water potential zones as compared to high drainage density areas. It must, however, be added that the results of this study is qualitative, hence, it is recommended that more quantitative investigations involving geophysical technique(s), borehole drilling be carried out to fully understand the prospect of the groundwater resources of the area and consequently design a model for the effective groundwater use and management in the area.

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