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Research Article

Investigation of Ground Water Potential using Electrical Imaging Method in Assosa Town Benishangul Gumuz Region Western Ethiopia

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ABSTRACT

Assessing groundwater potential could be aid by different geophysical methods. Electrical imaging techniques are used to investigate subsurface geology based on the resistivity in the earth's field resulting from the resistivity properties of the underlying rocks. To assess the groundwater potential Zone of Assosa town, electrical imaging methods were used. Geographically, Assosa town is bounded between 34°31'00"-34°33'24.2"E and 10°02'37.3"-10°04'00"N that covers a total area of 610.8 Km^2. The resistivity of rocks is extremely variable depending on the type of rock, the presence of conductive materials, salinity, and abundant pore spaces. The geology of the area contains a Precambrian deposit and is dominantly covered by granitic rocks. The hydrogeological units of the area include alluvial deposits, which show permeability, fractured, and weathered granite. 2D electrical imaging using the Schlumberger configuration array was conducted to assess the geo-electric properties of the subsurface to determine the apparent resistivity, thickness, and depth of the subsurface formation. Generally, the resistivity of the area increases downward, this reveals that the top part of the study area is saturated and highly fractured than the bottom part, which is below 50 m depth.

Keywords: Groundwater; Permeability; 2D electrical imaging; Schlumberger array

INTRODUCTION

Background

Accessibility of groundwater in unconfined aquifers underlain by impermeable metamorphic rocks is often controlled by the presence of porosity, permeability, and fracture. Groundwater is water that occurs in the subsurface where the pores are saturated with water and usually stored in the aquifer. Groundwater is a critical source of freshwater throughout the globe [1]. Several geophysical techniques can be used for hydrogeological characterization. For this study, an electrical resistivity survey mainly 2D imaging with Schlumberger array was applied. Groundwater potential in Ethiopia is low as compared to surface water resources. Current estimates put the available groundwater resources in the country to be about 2.6 billion m^3 [2]. Assessing groundwater requires detailed hydrogeological and geophysical exercises that can evaluate the aquifer layer and groundwater potential [3]. The electrical resistivity method has been a very significant instrument employed in exploring the earth for groundwater [4]. Electrical resistivity is used to obtain information about the subsurface layers and the location of groundwater [3,4]. The contrast in the electrical resistivity of various lithological sequences in the subsurface reveals the subsurface layers and is used to assess the groundwater prospect of the area [5]. Generally, the study area is underlain by basement rocks and found within the Abay basin where intermittent and ephemeral streams are most common. The local hydrogeology of the study area is mainly influenced by the topography and geology of the area, due to this groundwater potential in the volcanic and basement rocks are contained in the weathered, fractured and thick unconsolidated sediments. The groundwater recharge of the study area depends on annual precipitation, surface runoff, and seasonal rivers.

Description of the study area

Location and accessibility: The study area is found in Benishangul Gumuz regional state, the Western part of Ethiopia, which is some 675 km away from Addis Ababa. Geographically, Assosa town is bounded between 10°02'37.3"10°04'00"N and

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34°31'00"34°33'24.2"E respectively, with an average elevation of 1570 m m.a.s.l. This study covers a total area of 610.8 Km^2. As shown in the Figure 1 Assosa town is surrounded by resettlement villages: in the North by Amba 8, in the South by Amba 38 and Amba 3, in the East by Amba 4, and in the West Komosha town. Generally, the area is accessed through asphalted and graveled road.

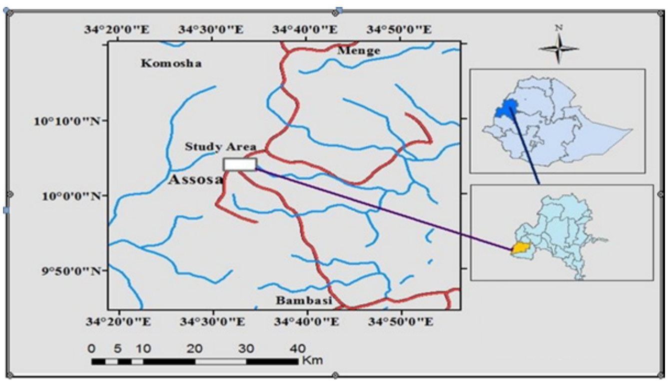

Figure 1: Location map of the study area. Note: (Rivers; (Roads; ( ) Study Area

Climate and vegetation cover

According to the National Meteorology Agency, the cumulative Mean Annual Rainfall (mm) of the study area ranges from 800 mm to 1999 mm. The main rainy season is between June and September. The highland part of the study area is covered by a deciduous leaf forest. The tree cover decreases in the low land areas, where scattered trees and especially bamboo may be encountered. Some dense vegetation is found along with stream and river courses.

Physiography and drainage

The geomorphology of the area is generally an outcome of repeated tectonism, with associated intrusion and erosion. The elevation of the study area ranges from 1500 m to 1550 m above sea level and the topography is moderately undulating with flat plain. The drainage density and pattern are also partly or wholly controlled by the tectonic activity and geological variation in the area. Most of the young lineaments serve as river channels.

METHODOLOGY

Several different geophysical techniques can be used for hydrogeological characterization. In this study, an electrical resistivity survey, mainly 2D imaging with Schlumberger array was applied. Using the ABEM Terrameter-LS instrument, an automatic electrical resistivity imaging system for automatic measurement (4cables with 21 takeout's each) having 61 electrodes for data acquisition has been used. 800 m length cables were extended from West to East or North to south direction, which can be used to point out the start point for data analysis. The Center for the analysis is just 400 m from each direction where the instrument was fixed. These methods measure earth resistivity by passing an electrical current into the ground and measure the resulting potentials created in the earth. This method involves the supply of direct current or low-frequency alternating current into the ground through a pair of current electrodes and the measurement of the resulting potential through another pair of electrodes called potential electrodes [6]. Data interpretation can be done by 2D Resistivity Inversion Software (RES2DINV). The inversion result provides information in both vertical and horizontal directions. Hence, based on the inversion result with a minimum error rate of resistivity profile in both directions, the depth of expected geological structures and expected geological contact layers can be estimated for proposed groundwater exploration.

Abem terrameter LS System

Terrameter-LS (Lund system) are a state of the art data acquisition system and can be used for Resistivity, Induced Polarization (IP), and Self Potential (SP) surveys. The Lund system is an automatic electrical resistivity imaging system for automatic measurement (4 cables with 21 takeouts each). 2D resistivity Imaging (Tomography) is one of the most popular geophysical methods mainly due to its time efficiency without the limitations of sounding or profiling and has a wide range of applications. Resistivity variation in both horizontal and vertical directions is determined. The method is the combination of electrical sounding and profiling because surveys are done along with the profile with increasing depth of investigation. In this method, it is not necessary to move electrodes. Before starting measurement information about array type, the smallest electrode spacing to be used, station spacing, profile length, and other parameters of the survey are input for the equipment. The equipment also checks if the electrode has good contact with the ground (if it is properly grounded).

Geological and structural setting of the study area

Regional geological setting of the study area: In general, the geology of Western Ethiopia has a complex geological history. Regionally, the geology of the Precambrian basement rocks can be divided into three litho-structural domains based on lithological associations, the style of deformation, and metamorphism [7]. Regionally, the basement has been divided into three major domains showing differences in lithology, structure, and metamorphism in Western Ethiopia. A central low-grade domain lies between western and eastern domains it consists of high-grade gneisses and covers the majority of the Assosa-Kurmuk area. Gneisses of middle to upper amphibolite facies are migmatitic and are thought to be Archean or early Proterozoic in age. These rocks outcrop in the westernmost part of the Assosa-Kurmuk area. This gneissic unit borders (in the east) a large outcrop of felsic to mafic meta-volcanic with intercalated meta-sediments and occurrences of altered ultramafic bodies of upper greenschist to lower amphibolite facies. They are thought to be late Proterozoic in age. The contact between these two units is of tectonic origin. Both units have been intruded by a succession of plutons ranging from early, foliated mafic to felsic intrusions to post-massive tectonic bodies. These massive rocks were exposed around the southern part (Enzi) of Assosa town, which is overlained by granitic rocks exposed on a small session of Enzi ridges and elongated to the western direction of Assosa. Massive intrusive rock like granite is extensively covering the majority of the area. Gimbi-Assosa area, the Tulu Dimtu Belt consists of a variety of moderate to high-grade gneisses and low to moderate grade meta-Sedimentary rocks intruded by deformed and undeformed ultramafic, mafic, intermediate and felsic igneous bodies [8]. The bedrock of the study area is generally, covered with remnants of presumably Mesozoic sandstone and Tertiary volcanics. Alluvial, diluvial, and colluvial sediments cover extensive areas along the lower reaches of the Dabus and Abbay rivers and at the confluence point of the Abbay with the Belles. The general structural and tectonic features are trending towards E-W, N-S, N-W, and N-E of the study area.

Structural settings of the study area: Two sets of lineaments are prominent in the area. These are northwest to north-northwest set and northeast to north-northeast set. The majority of the stream and river courses are parallel to these lineaments. The sheared zones, often running N-S, are usually 50 to 500 m wide and contain highly strained rocks Numerous E-W trending lineaments traverse the area. They displace the N-NE trending lineaments. Both lateral and vertical movements are thought to have taken place along the Kurmuk fault that separates the Kurmuk plain to the west from the uplifted Ethiopian plateau to the east. At the southwestern edge, the gneissic rocks are bounded on both sides by major N-NE trending faults. Springs and marshy areas found east of Agubella village lie along with one of the above faults. A narrow shear zone is present in the west-central part of the map area. It extends from east of Oura village northward, swinging northwest. The rocks affected by it are highly strained and range from mylonite to Augen gneiss.

Data processing and presentations

Using the ABEM Terrameter-LS instrument, an automatic electrical resistivity imaging system for automatic measurement (4cables with 21 takeouts each) having 61 electrodes for data acquisition has been used. 800 m length cables were extended from west to east direction (that can be used to point out the start point for data analysis). The Center for the analysis is just 400 m from each direction where the instrument was fixed. But for 400 m total cable extension, the center will be at 200 m. Data interpretation can be done by 2D resistivity inversion software (RES2DINV). The inversion result provides information in both vertical and horizontal directions. Hence, based on the inversion result with a minimum error rate of resistivity profile in both directions, the depth of expected geological structures and expected geological contact layers can be estimated for proposed groundwater exploration.

RESULT AND DISCUSSIONS

Interpretation of 2D resistivity of Amba-1(near Hoha river)-1

As shown in the Figure 2, the resistivity values vary from low, medium to high resistivity anomaly. This profile is located at Amba 1 near Hoha River. The interpretation of the resistivity model and the well log data shows different geological formations. The first layer formation shows resistivity of low to medium anomaly and could be associated with laterite and silty soil. The second layers hows medium to high resistivity anomalies and could be associated with weathered basalt. The second and the third layer show medium to high resistivity anomalies and could be associated with weathered and fractured basalt. The fourth layers represent moderately fractured granite and the bottom part constitutes massive granite. The 2D inverse resistivity model revealed weakness zones that can be interfered with potential and productive groundwater zones. Geological structures such as fractures and faults are mapped in the figure (black dash line).

Interpretation of 2D resistivity of map Amba-5(down stream)

The 2D inverse resistivity model at Amba 5 as depicted in Figure 3. The top layer of the study area reveals low resistivity anomaly that vary from 0-70 Ohm.m. This layer appears as conducting and is indicative lateritic and clay soil that ranges in depth from 0-25 m. Later, it is followed by an increase in resistivity with depth which represents slightly weathered to highly weathered granite. Above 100 m depth, the high resistivity values indicate massive granite rock, which indicates no tectonic fracture showing no sign of prospect hydrogeological condition. The 2D inverse resistivity model revealed weak zones that can be interfered with potential and productive groundwater zones. These zones are located between 40 m to 65 m and are considered as deeper groundwater potential zones.

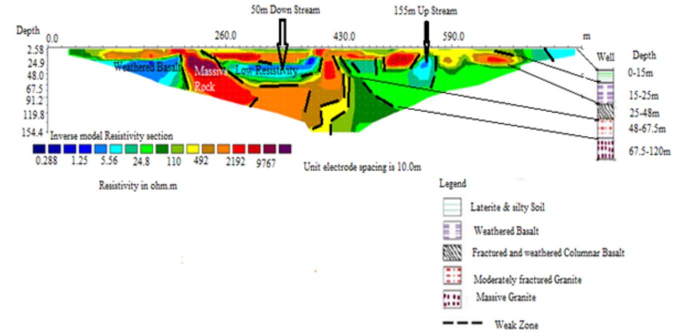

Figure 2: 2D imaging profile section of Amba-1(Hoha river above the bridge).

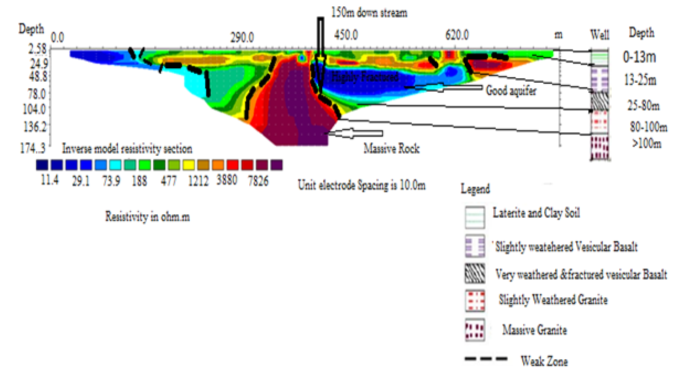

Figure 3: 2D Inverse resistivity imaging profile section of Amba-5 downstream.

Interpretation of 2D resistivity imaging of Amba-1(Hoha river downstream) area

As shown in the Figure 4, the resistivity values vary from low, medium to high resistivity anomaly. The analysis of the results from the geophysical survey enables us to identify five different geological formations. The formations encountered from the surface to the depth were intercalated gravel and laterite soil at the top then weathered and fractured granite and basalt at the middle and massive granite at the base. The 2D inverse resistivity model revealed fracture zones that can be interfered with potential and productive groundwater zones. On Figure 4 these zones are located at 0-45 m depth and are considered as a good groundwater potential zone.

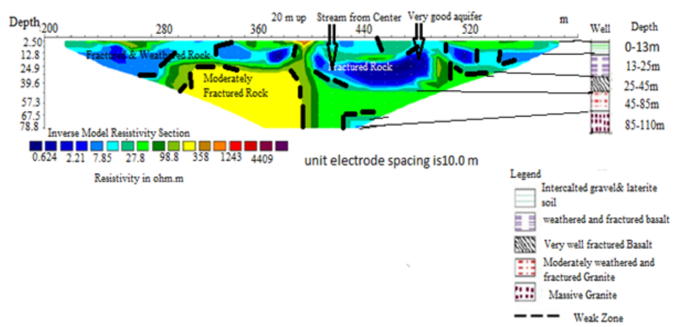

Figure 4: 2D Inverse resistivity imaging profile section of Amba-1(Hoha river downstream).

Interpretation of 2D resistivity imaging of Assosa town behind new high school

The Figure 5 shows the 2Dinverse resistivity map of the study area generally, the resistivity map of the study area shows high resistivity zones from the center to the right side (after 400 m) and near the source point (0-400 m) the resistivity value is characterized by low to medium resistivity anomaly. After 400 m from the center, the resistivity increases downward, and this reveals that the rock below 30 m is denser than the top. Based on Figure 5 the apparent resistivity map depicts, generally, the top part is characterized by low to very low resistivity. This reveals that the top part of the study area is lateritic and with a resistivity range of 0 to 50 Ohm.m. This is followed by weathered and fractured basalt showing resistivity of the order of 50 hm.m. to 120 Ohm.m.

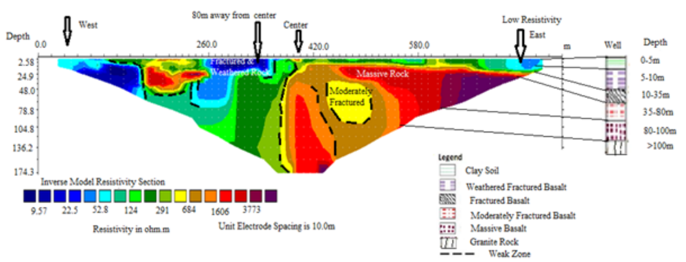

Figure 5: 2D Inverse resistivity imaging profile section of Assosa town behind the new high school at the bank of Selga river.

Interpretation of 2D resistivity imaging of assosa stadium

Based on the apparent resistivity Figure 6 the resistivity of Assosa Stadium increases downward, this reveals that the rock below 35 m is denser than the top part. As shown on the Figure 6, generally, the top part is characterized by low to medium resistivity. This depicts that the top part of the study area is highly saturated and the rocks are more fractured and weathered. At the center (380 m to 420 m), the resistivity is lower than the right and left sides of the stadium site. This depicts the area have good groundwater potential.

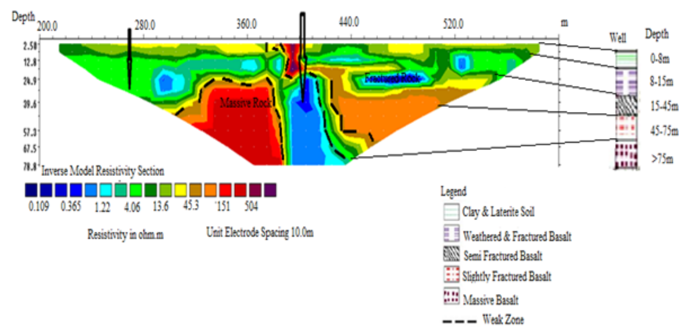

Figure 6: 2D Inverse resistivity imaging profile section of Assosa town near Assosa stadium.

Interpretation of 2D resistivity imaging of assosa management site

The apparent resistivity map, which is observed in Figure 7, is characterized by low, medium, and high resistivity values. The high resistivity zone is bounded between 5 to 40 m depth; this reveals that the rock is less fractured and less saturated. The apparent resistivity map of Figure 7 decreases downward hydro- geologically, it reveals that the area is more saturated than the top part, and the rock is more fractured and weathered. Generally this layer is inferred as a good source of groundwater potential due to intense weathering/fracturing of rock layers are a significant source for groundwater potential.

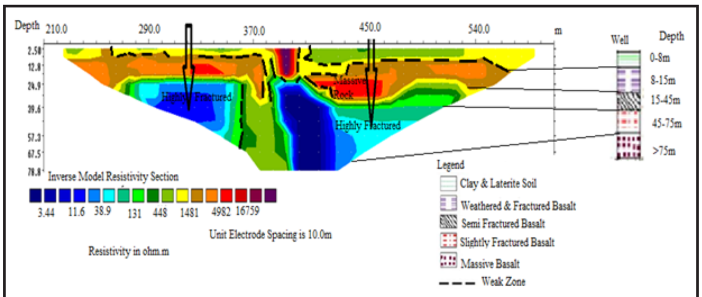

Figure 7: 2D Inverse resistivity imaging profile section of Assosa management institute, site 1.

CONCLUSION

The geomorphology of the area is an outcome of a repeated tectonism, with associated intrusions and erosion, and the main geomorphologic features are Volcanic Plains, ridges, and isolated hills. The Precambrian rocks are a dominating area. However, due to the absence of more secondary structures that govern infiltration to make groundwater, the area is not a good water-bearing zone, for this reason, these units ranged from the low fissured aquifer to aquitards/aquicludes in the area. In the area, groundwater discharge is mainly due to moderate depressions, especially in the highlands, while its flow direction is controlled by geological structures and geomorphology. The electrical resistivity imaging survey carried out in Assosa town has provided information on the subsurface geoelectric layers, the structural disposition of the basement rock and the groundwater potential of the area. Based on quantitative data analysis and interpretations that are recorded from each imaging survey, the top part of the study area is generally characterized by low to medium resistivity and the bottom part which is below 50 m shows a high resistivity anomaly. These depict that the bottom part is massive and less fractured than the top part of the study area.

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