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GEOELECTRIC METHODS FOR GROUNDWATER EXPLORATION IN THE FOOD ESTATE AREA OF CENTRAL SUMBA REGENCY, EAST NUSA TENGGARA, INDONESIA

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ABSTRACT
Groundwater is one water source to meet the needs of humans, animals, and plants. The groundwater potential of an area is usually difficult to determine because it is below the [1]surface. The Indonesian government has a program to develop a food estate in Central Sumba Regency; however, the availability of surface irrigation water is limited. Therefore, the assessment of groundwater potential was conducted. In this study, the evaluation of groundwater potential was carried out using geophysical methods and a hydrogeological survey. The resistivity of subsurface rocks was measured in 20 VES points by Schlumberger configuration. The area of the food estate in Central Sumba is mainly composed of limestone that forms a karst landscape. The groundwater level from the existing well is around 2-16 meters from the surface. The potential of rock as an aquifer is limestone with a resistivity value between 34 -7013 Ωm. There are two types of aquifers in the study area: unconfined and confined aquifers. Unconfined aquifers are found at a depth of 2-7 meters, while confined aquifers are found at depths of 11-120 meters. The distribution of aquifers is more in the western part of the study area.

Keywords : Geolectrical Methods; Groundwater; Food Estate

1. INTRODUCTION
Water is one of the fundamental things needed for humans, animals, and plants. One of the most widely used water sources is groundwater, and many countries use groundwater extensively. Groundwater is generally the main drinking water source and contributes significantly to irrigation, thereby increasing food security in arid and semi-arid areas. Therefore, groundwater is an important component of the water economy (Margat and Van Der Gun, 2013).
The research area is located in the Food Estate Area, Central Sumba Regency, East Nusa Tenggara Province. The study area is part of the Waikabubak formation, which is dominated by limestone, clayey limestone, marl inserts, sandy marl, tuffaceous marl, and tuff (Effendi and Apandi, 1993). The research area is composed of limestone that forms a karst landscape. Groundwater in karst areas has been a very important water source for thousands of years. Even 25% of the world's population uses karst groundwater as the main source of drinking water (Ford and Williams, 1991)(P. Wu *et al*, 2009). Groundwater in the research area is not only used for raw water but also irrigation water.

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The potential of karst groundwater as a source of irrigation water must meet the required quantity throughout the year.

The geoelectric method is the most widely used method for groundwater exploration (Rolia and Sutjiningsih, 2018) (A. Ferhat *et al,* 2022) (Wilopo *et al,* 2020) (Chikabvumbwa *et al,* 2021) (M. AL Deep *et al,* 2021) (Raji and Abdulkadir, 2020) (Bahammou *et al,* 2021). The geoelectric method using the concept of subsurface determination provides information about the structure, composition, and subsurface conditions (Lesmes and Friedman, 2005). Besides that, it can also be used to determine aquifers' location and distribution (Rolia and Sutjiningsih, 2018). The measurement of rock resistivity with the geoelectric method is by injecting an electric current and reading the potential difference on the surface. One of the geoelectrical methods used in this research is Vertical Electrical Sounding (VES) 1D. VES is applied to horizontally layered or horizontally inclined soils (R. Kirsch, 2009). The result of VES is in the form of resistivity (ρ) in ohmmeter (Ωm) (Goldscheider and Drew, 2008).

Several studies used the geoelectric method for groundwater exploration in Indonesia, such as in the karst area (A. Ferhat *et al,* 2022) and the alluvial deposit (Wilopo *et al,* 2020). Research using the VES geoelectric method carried out outside Indonesia, among others, was carried out in the Linthipe sub-basin, Malawi, to determine the potential of groundwater to be used as irrigation water (Chikabvumbwa *et al*, 2021) in Abha, Saudi Arabia, for exploration in fractured basement rock (M. AL Deep *et al,* 2021) and Nile Valley, Egypt (Mohamaden *et al,* 2019).

Besides, knowing the value of the permeability of an aquifer is also important in groundwater research. Parameters related to permeability are hydraulic conductivity and transmissivity (R.J. Sterrett). Karst groundwater has unique properties and behavior compared to groundwater in other rocks. For example, it has diverse permeability and conductivity values (Goldscheider and Drew, 2008) (Romanov *et al,* 2003). There are two methods to determine the conductivity value in an aquifer: laboratory and field tests. A pumping test is a more recommended field test method because the results represent the actual values in the field (K. Sun, 2018).

Research on the potential of groundwater in the study area is still limited considering that the majority of water sources used for community needs for daily needs come from groundwater. Therefore, there is a need for research to determine the potential of groundwater in the research area using a geoelectric survey.

2. STUDY AREA

The research area is located in the Food Estate Area, Central Sumba Regency, East Nusa Tenggara Province, as shown in Figure 1. The food estate area of Central Sumba is a plain in the form of settlements, rice fields, plantations, savannas, and forests with a relatively gentle slope with an average height of the study area of 300-500 m above sea level.

The geological condition of the study area is the Waikabubak formation of tertiary age which is dominated by limestone, clayey limestone, marl inserts, sandy marl, tuffaceous marl, and tuff (Effendi and Apandi, 1993) which can be seen in Figure 2. Based on the Hydrogeological map of Sheet Sumba (Meiser *et al,* 1965) the study area contains aquifers. With the productivity of the aquifer is 0.5 liters/second.

3. RESEARCH METHOD

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The geoelectric method is used to determine the resistivity of underground structures. Measurement of rock resistivity by injecting an electric current and reading the potential difference on the surface. Geoelectric measurements using the VES geoelectric method and performed with the Schlumberger configuration. Resistivity measurement requires four electrodes. Two electrodes, A and B, are used for current injection, while the other, M and N, are used to measure potential difference (Kirsch, 2009)

Data acquisition was carried out at 20 points covering the research area, as shown in Figure 1. The coordinates of each point were recorded using GPS (Global Positioning System). Data acquisition cannot be carried out ideally because of the condition of the land that has been built with asphalt roads; the conditions of the roads are potholes and waterlogged and limited access roads that cannot be passed. The instruments used in this research are a resistivity meter, four electrodes, and an electrode connecting cable. Measurements are made with a cable span of 400 meters so that it can read data up to a depth of 130 meters.

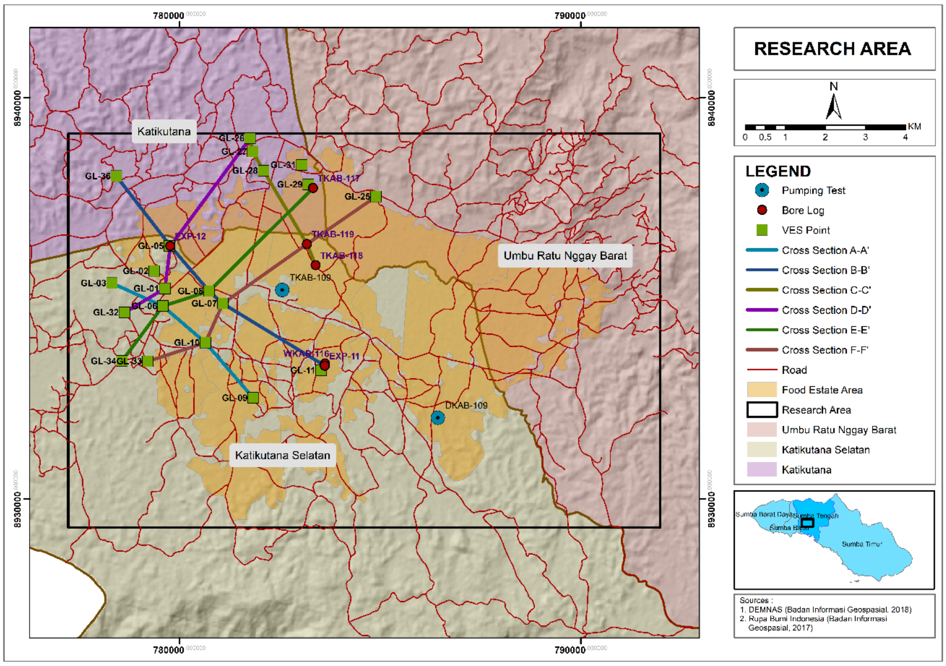


Figure 1. Research Area (Badan Informasi Geospasial, 2018)

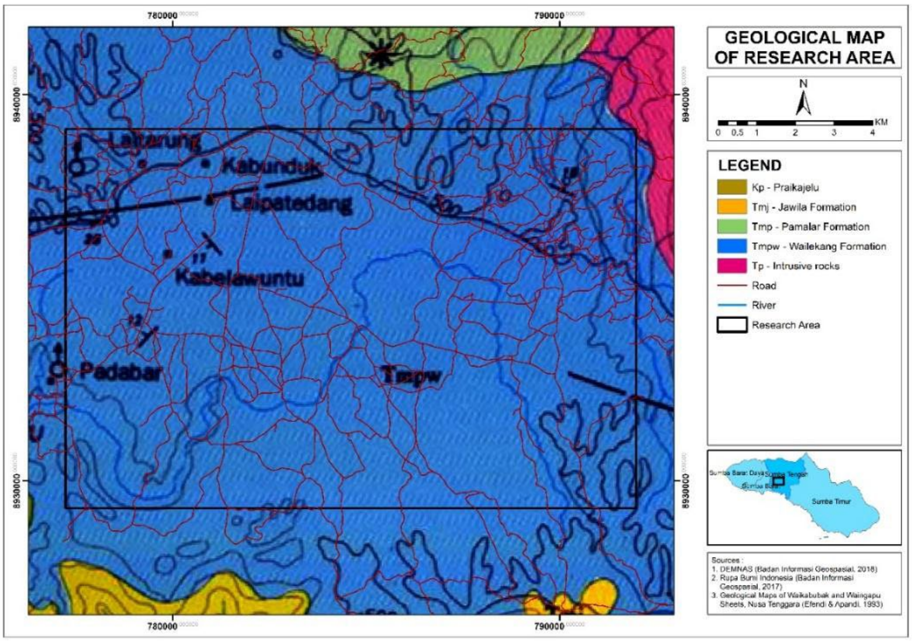


Figure 2 Geological map of research area (Badan Informasi Geospasial, 2018)

Measurement of Vertical Electrical Sounding (VES) produces electric current (I) and potential difference (V). The apparent resistivity (ρ_a) value can be calculated based on the electric current value and potential difference using equation 1 below.

$$\rho_a = K\frac{\Delta V}{I} \tag{1}$$

The resistivity values obtained from measurements at 20 points can then be processed with the help of IP2win software. The IP2win software converts the apparent resistivity value into the actual resistivity value of the material. Then it will perform several iterations and estimate the number of layers, resistivity, thickness, depth of each layer, and the RMS value. The maximum allowed RMS value is 10%. The resistivity value from the processing is then interpreted based on Telford's table of material values, shown in Table 1. Geological and hydrogeological maps are also needed to interpret a rock's lithology.

Table 1 Resistivity values of sedimentary rocks
(Telford *et al, 1990)*

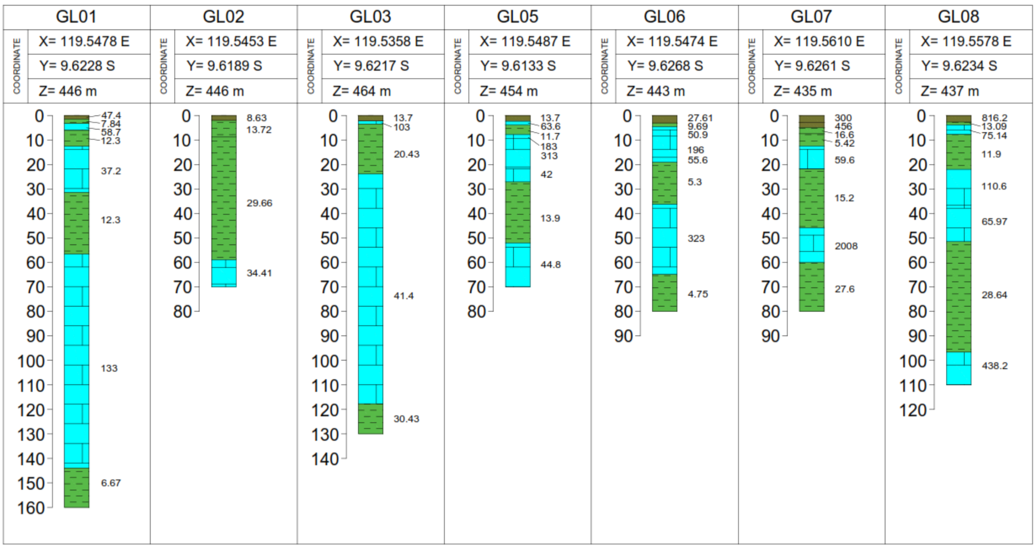
No	Rock type	Resistivity value (Ωm)
1	Sandstone	$1 – 6.4x10^2$
2	Limestone	$50 - 10^7$
3	Dolomite	$3,5x10^2 – 5x10^3$
4	Claystone	1-100
5	Alluvium and sand	10-800
6	Marls	3-70

The value of hydraulic conductivity is a factor that determines the transport of water in the soil. The hydraulic conductivity (K) value is one of the most important hydraulic parameters. The hydraulic conductivity of the soil can be determined using the correlation method or the hydraulics method. Hydraulics methods include laboratory methods and field methods (in situ) (J. Stibinger, 2014). One of the field methods with a large scale is the Pumping Test.

4. RESULT AND DISCUSSION

In this study, 20 points of geoelectric data have been acquired. The geoelectric data can be processed using IP2win software, and the outputs are rock resistivity values in each layer, thickness, and depth of rock layers, as seen in Figure 3. The geoelectric point analysis must have a root mean square (RMS) value of less than 10%. The data processed using IP2win software can be combined with bore-log data to interpret subsurface lithology.

Based on the bore-log data and field mapping, the lithology in the study area consists of marl and limestone, as shown in Figure 3. Figure 4 shows the outcrop of limestone and marl in the field. The resistivity value between 1-34 ohmmeters (Ωm) is indicated as marl and the resistivity value of 34-7013 ohmmeters (Ωm) as limestone. The result of the analysis and interpretation of each geoelectrical data can be correlated to develop the two-dimensional cross-sectional profile. Geoelectric point correlation is done by connecting some geoelectric points. In this study, six geoelectric cross-sections will be carried out, which can be seen in Figure 1. Figure 5 below shows the correlation results for cross-section A-A', cross-section B-B', cross-section C-C', cross-section D-D', cross-section E-E', and cross-section F-F'. Figure 6 shows the 3D model of the analysis and interpretation of geoelectric data and bore log data in the study area.



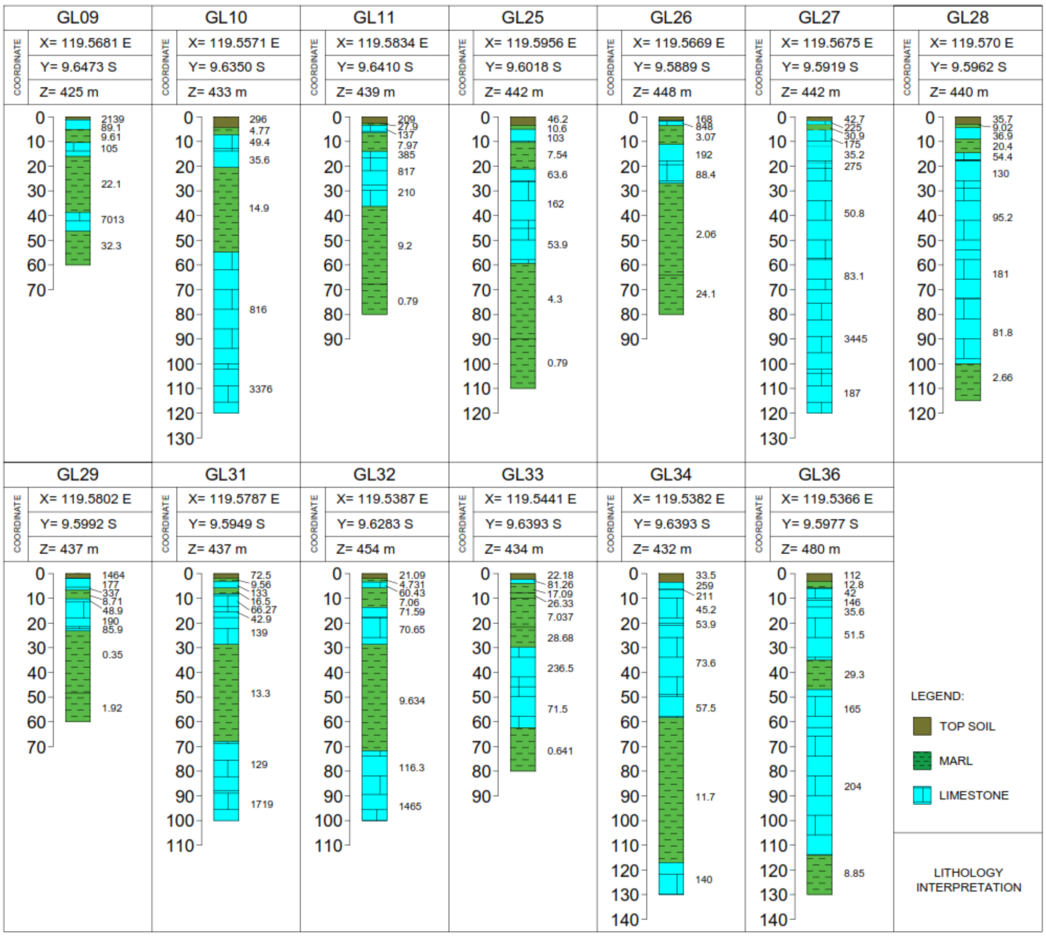


Figure 3 Interpretation of VES data

Groundwater potential can be estimated based on the permeability of the rock. Based on the correlation results in Figure 5, it can be estimated that the groundwater potential in the food estate area of Central Sumba Regency is as follows:

a. Marl layer can be interpreted as an aquiclude. The distribution of the marl layer is spread in the research area, and the thickness is between 0.5-30 meters. The pumping test was carried out on marl units in Tanah Modu Village, South Katikutana, and the hydraulic conductivity value was 1.82 x 10^{-7} m/sec (Ministry of Public Works and Housing, 2021)
b. Limestone layers can be interpreted as aquifers. The aquifer layer is a layer that can store and drain groundwater. Based on the surface geological survey, limestone characteristics are categorized as clastic limestones. The pumping test was carried out on limestone units at Dusun 3 KSP 2, Dasa Elu Village, South Katikutana, and acquired the hydraulic conductivity value was 6.2 x 10^{-5} m/sec ((Ministry of Public Works and Housing, 2021). There are two types of aquifers in the research area based on the geoelectrical data and field survey, unconfined aquifers and confined aquifers. Unconfined aquifers can be found at a depth of 1-7 meters, while confined aquifers can be found at depths of 11-120 meters. The thickest confined aquifer layer, 93.94 meters, was located at GL03, in Wai Lawa Village, South Katikutana District.

(a) (b)

Figure 4 (a) Marl outcrop and (b) limestones outcrop

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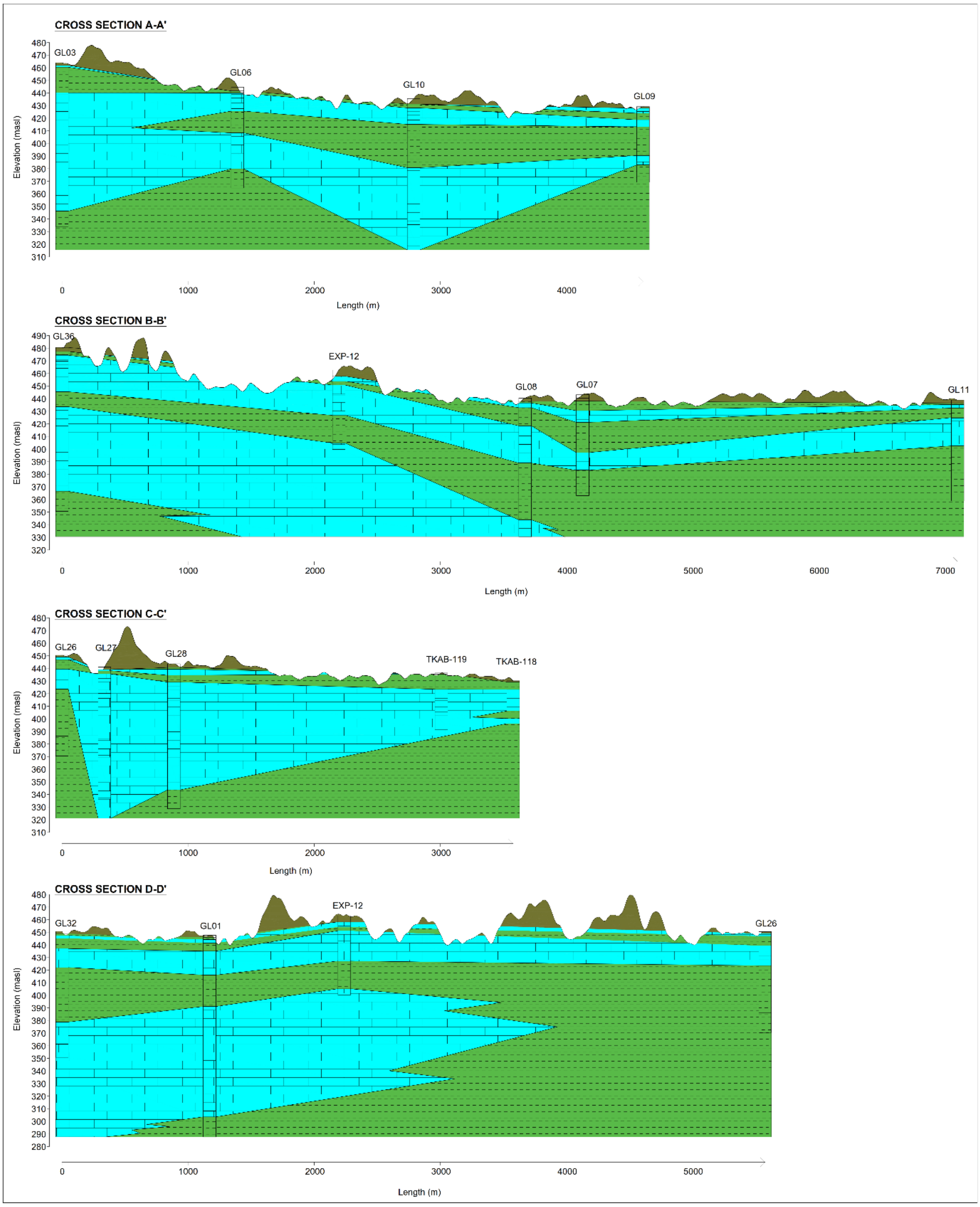

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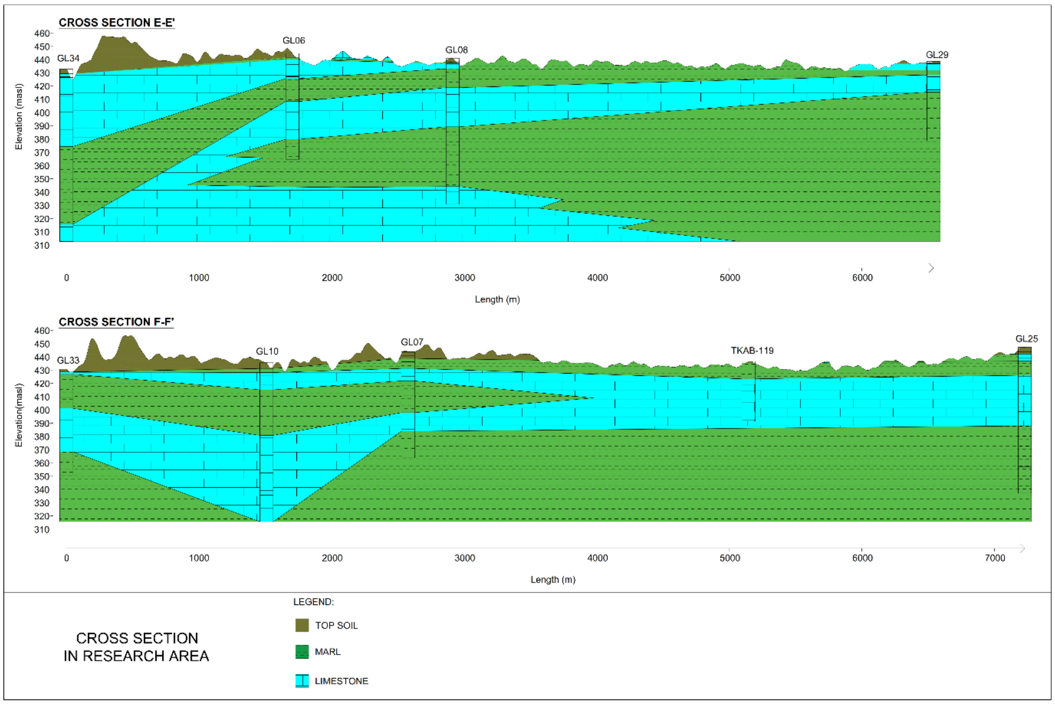

Figure 5 2D model in the research area

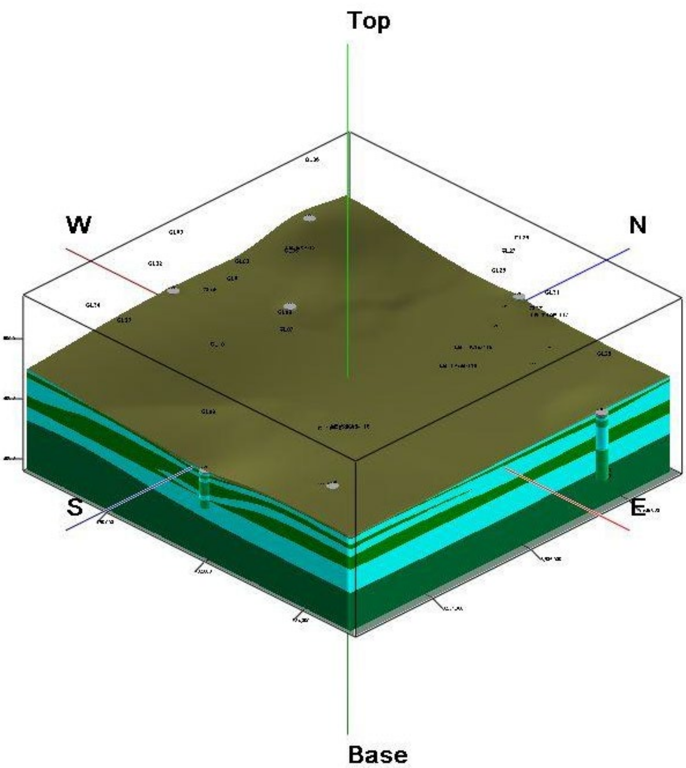

Figure 6 3D model in the research area

5. CONCLUSIONS

The groundwater exploration in this study was carried out in the food estate area, Central Sumba Regency, East Nusa Tenggara Province. The research area is in the Waikabubak formation. The result showed that based on the resistivity value and field survey, the research consists of marl and limestone. The rock layer that can be interpreted as an aquifer is limestone with a hydraulic conductivity value is 6.2 x 10^{-5} m/sec. The two-dimensional model of rock distribution shows that the study area has unconfined and confined aquifers. More aquifer layers are found in the western parts, namely in the villages of Dameka, Wai Lawa, Mata Woga, and Makata Keri. Unconfined aquifers can be found at a depth of 1-7 meters, while confined aquifers are located at a depth of 11-120 meters. The confined aquifer in Wai Lawa Village has a thickest 93.94 meters at a depth of 23.76-117.7 meters from the surface.

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