Determination Of Liquefaction Sediment Volume In Balaroa VillageUsing The Geoelectric Resistance Type Method

Asgar [a,1)*] , M. Rusydi[a,2], Rustan Efendi, [a,3] Moh. Dahlan Th Musa [a,4], Badaruddin [a,5]

[a]Faculty of Mathematics and Natural Sciences Tadulako University, Jl. Soekarna Hatta, Palu, 94118, Indonesia
email: garasgar234@gmail.com
* corresponding author

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ABSTRACT

Introduction: Research has been carried out titled "Determining the Volume of Liquefaction Sediment Using the Geoelectric Resistivity Type Method in Balaroa Village". **Methods:** This research aims to identify subsurface lithology and determine the volume of liquefaction sediment in Balaroa Village. This research uses the resistivity method Wenner configuration. **Result and Discussion:** Measurements were carried out in 4 passes with the distance between electrodes on Tracks 1 - 3 being 7 m and on Track 4 a distance of 10 m. From the results of measurements and data interpretation, it was obtained that the type resistance value was 2.98 - 436.14 Ωm with lithology in the form of clay, sand, and gravel. The calculated volume of liquefaction sediment in Balaroa Village is 370,883 m³. **Conclusion:** Clay and sand rocks are liquefaction sediments with resistance values of less than 67.86 Ωm. Meanwhile, gravel and building debris are non-liquefaction rocks with resistance values of more than 67.86 Ωm. The calculated liquefaction sediment in Balaroa Village is around 370,883 m³. The volume of liquefaction sediment increases in thickness in the eastern part, which is caused by morphological conditions that tend to be more gentle in that part.

1. INTRODUCTION

Palu City is an area traversed by the north-south trending Palu Koro Fault with a length of approximately 500 kilometers, stretching from around the Sulawesi water boundary with the Makassar Strait to the northern coast of Bone Bay. The movement of the Palukoro Fault that occurred on September 28, 2018, caused an earthquake with a magnitude of 7.4. The earthquake caused other natural disasters such as liquefaction and tsunami [4].

Liquefaction is a condition of loss of soil strength due to earthquakes [1]. One of the areas that experienced liquefaction is the Balaroa area. This liquefaction event was in a densely populated settlement with an area of 0.4 km^2 and a length of approximately 980 m, causing many destroyed buildings and casualties. The process of liquefaction is divided into several stages, beginning with strong vibrations from the Palu Koro Fault earthquake source at the foot of the slope. Second, *ground oscillation* occurs, causing surface cracks to form. Third, the stability of the slope will continue to decrease until ground motion occurs, which begins with the movement of material at the foot of the slope, which then moves to the ground pulling the upstream part, which can even pull up to about 1 km of debris [4].

Previously, it has determined the rock lithology in the Balaroa liquefaction area by conducting a *Cone Penetration Test* (CPT). Liquefaction sediment lithology consists of sand, silty sand or sandy silt, and gravelly sand [12]. In general, the conditions for liquefaction in an area if the sediment grain size is <0.30 mm in diameter [13]. Research on liquefaction potential by analyzing the relationship between grain size and rock lithology has been conducted in the Bantul area of Yogyakarta Province. The results obtained showed that the grain size has a D_{50} value of 0.314 and D < 0.005 mm by 7.347%, which is Sand-Lanau, where this area has the potential for liquefaction [8]. Determination of rock lithology can be done in many ways, including the geoelectric method. The geoelectric method is one of the geophysical methods used to determine rock lithology based on its specific resistance value [2].

Liquefaction disasters cause a lot of damage and disturbance to humans, resulting in many casualties and property losses. Liquefaction also causes changes in the topography of the land surface in the liquefaction area, thus changing the landscape/morphology of the area. These changes can be known in various ways including by analyzing the mechanism of liquefaction material displacement. The analysis obtained the measured volume of sediment transported during liquefaction. Knowing the measured volume of liquefaction sediment can be used as an evaluation and consideration of development policies related to liquefaction disaster mitigation.

Based on the description above, this research uses geoelectric methods to determine liquefaction sediments based on the value of specific resistance in the Balaroa liquefaction area. Furthermore, information on liquefaction sediments is used to calculate the measured volume of sediments transported during the liquefaction disaster on September 28, 2018.

The study area is located on the Palu Koro fault line. The study area is located in the low zone of Palu Koro fault which is filled by Alluvium and Beach Deposits. This formation is the youngest sediment in the study area consisting of sand, mud, gravel, and coral limestone. On the west side of the study site, there are Molasa Celebes Sarasin and Sarasin formations consisting of sandstone, mudstone, conglomerate, limestone-coral, and marl. In addition, there are also granite formations and Tinombo formations located on the west side of the research site which are adjacent to the Molasa Celebes Sarasin and Sarasin formations [9]. The geological condition of the study area can be seen clearly in Figure 1.

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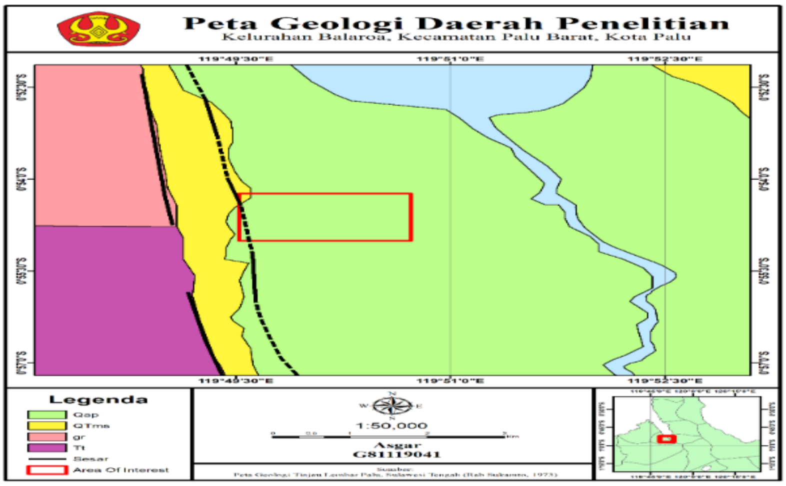

Fig 1. Geologic map of the study site and its surroundings

Liquefaction is the loss of strength of sand layers accumulated with water caused by earthquakes above the ability of local lithology to withstand earthquake vibrations [4]. Liquefaction disaster causes several events such as the drying of well water replaced by non-cohesive material, *rapid settlement,* and *differential settlement*. Liquefaction generally occurs in saturated soils so the susceptibility to liquefaction is strongly influenced by the depth of the groundwater table. As the depth of the water table increases, the susceptibility to liquefaction decreases. Liquefaction events occur along with earthquakes [3].

The liquefaction area in Balaroa Village, in the lower layer, is thought to be Mollase sediment and in the western part, there is granitic or granodioritic debris due to the formation of alluvial fans. Granitic or granodioritic debris is in the form of coarse sand to gravel material with fragments in the form of granite to boulder size, not yet solid, random position of fragments, very dense density, visually has a fairly good shear strength. In the upper layer, there are swamp deposits consisting of black silt with a little interspersion of fine sand inserts, very soft, low plasticity. The swamp sediment has a thickness of 6 m upstream of the contact with the spoil. At the bottom of the black silt is gray sand, loose to medium density, medium to fine-grained. The process of liquefaction occurs in sand material and is thought to also occur in materials that behave like sand material properties, namely low plasticity silt material [4].

The type of resistance geoelectric method is one of the geophysical methods that utilize the nature of rock-type resistance to study the inner state of the earth. The advantages possessed by the resistance geoelectric method are non-destructive to the environment, low cost, easy and fast operation, and the ability to identify the depth of the soil [7].

The working principle of the geoelectric method of specific resistance is by entering an electric current into the ground from the ground surface. Entering the current into the ground using four electrode rods with a certain distance so as to obtain a specific resistance value. The value of the specific resistance obtained differently for each material [5].

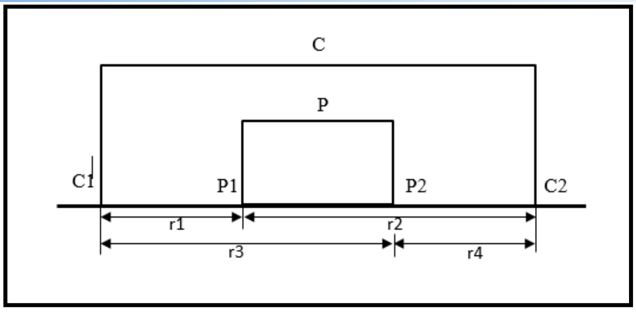

Fig 2. The electrode arrangement of Wenner Configuration

The Wenner configuration has the same arrangement and distance between the electrodes, where r1=r4=a and r2=r3=2a. The distance between the current electrodes is three times the distance of the potential electrode and the distance between the potential electrode and the sounding point is 2/a. So that the distance between each current electrode and the sounding point is 3a/2. The Wenner configuration has a target depth that can be achieved, namely a/2 [24]. The geometry factor equation (K) used in the Wenner configuration is

$$K = 2\pi a \qquad (1)$$

Based on the geometry factor value obtained, the apparent type resistance price for the Wenner configuration can be calculated using the following equation:

$$\rho_\alpha = K\frac{\Delta v}{I} \qquad (2)$$

The cross-sectional method uses the principle of making incisions in the body of rock deposits, then calculating the area of each rock deposit and determining the volume using the distance between the incisions. This cross-sectional method is divided into two parts, one of which is the cross-sectional method with the *Rule of gradual Change* modeling [6].

The cross-sectional method with *the Rule of gradual Change* modeling is one of the conventional resource calculation methods. Following the guidelines of the *rule of gradual changes* is done by connecting two points between the outermost observations and moving gradually from one incision to the next. So to determine a volume, two cross-sections are needed [6]. In this case, to calculate the volume of liquefaction sediment at the research location, the formula used is as follows

$$V = \frac{P1+P2}{2} \times L \qquad (3)$$

Where V is the volume of liquefaction sediment (m^3), P1 and P2 are the cross-sectional incision areas (m^2), and L is the distance between cross-sections (m).

2. RESEARCH METHODS

The research site is located in Balaroa Village, West Palu Sub-district, Palu City. Geographically, the research location is located at 0°54´5 "N to 0°54´35 "N and 119°50´23 "E to 119°50´50 "East. To see a clear picture of the research location can be seen in Figure 3.

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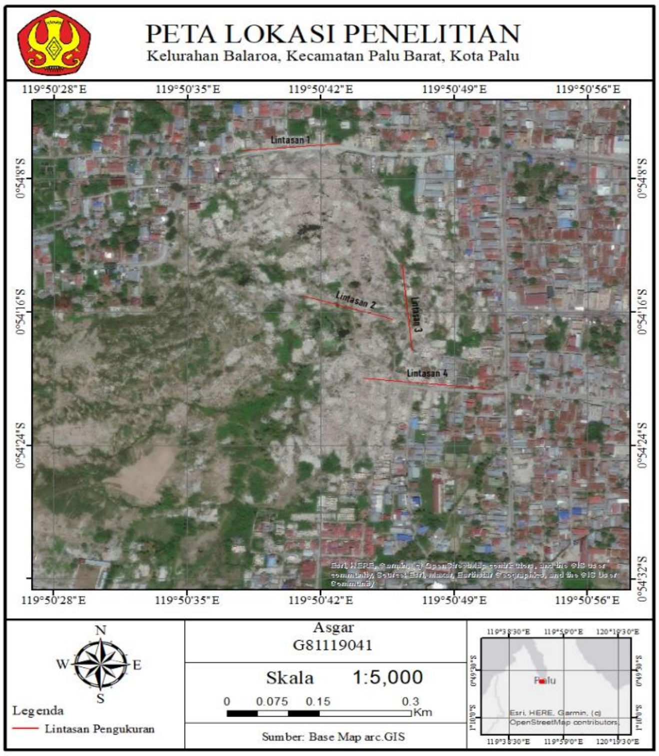

Fig 3. Map of the research location

The equipment used in this study is a set of Resistivitymeeter tools, 4 roll cables, namely 2 rolls of potential cables and 2 rolls of current cables that function to drain electricity, electrodes that function to inject current into the ground, batteries function as a source of current, *Global Position System* (GPS) to determine the coordinates and elevation of each electrode, Meter to measure the distance between electrodes, Hammer to stick electrodes into the ground, Geological compass to measure the direction of the stretch, Stationery to record measurement data and descriptions at the research location, Laptop used in processing data. *RES2DNV software* is used to process geoelectric data. Geological Map of Palu Sheet 1: 250,000 is used to make a geological map of the research location and supporting data in interpreting the data.

The calculation of the apparent type resistance value is based on equation 2 with the geometry factor that has been calculated based on equation 1, then processed in *RES2DNV software* to obtain a 2D cross-section. Data analysis and interpretation were carried out with the help of geological data from the study area. Then determining the volume of liquefaction sediment using ImageJ software will provide the area of liquefaction sediment area and the calculation of liquefaction sediment volume using the formula in equation 3.

3. RESULTS AND DISCUSSION

The number of geoelectric measurements in this study was 4 passes. The results of geoelectric measurements have been carried out to determine the lithology of subsurface rocks in the liquefaction area in Balaroa Village and the volume of liquefaction sedimentary rocks. The results of data processing obtained different specific resistance values in each cross-section, so it is necessary to equalize the 2D cross-section specific resistance values from 2.98 - 436.14 Ωm.

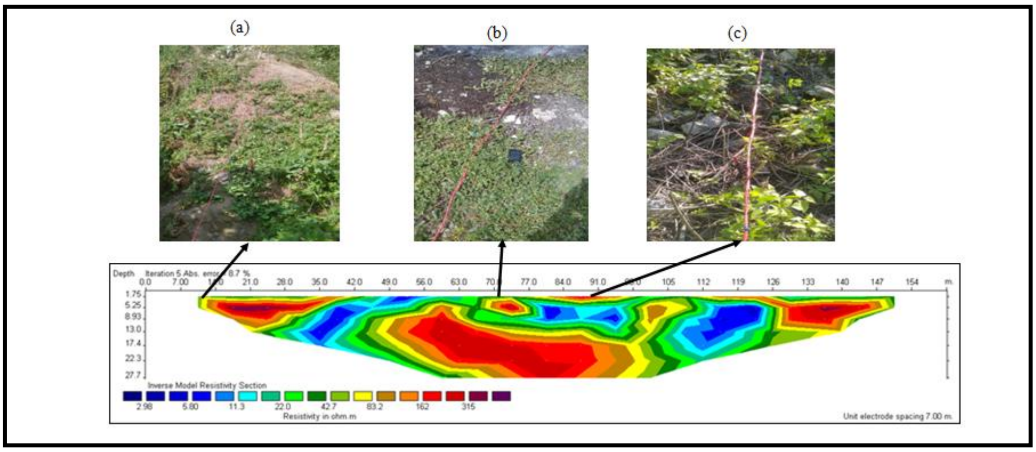

Fig 4. 2D cross-section outcrop of Track 3.

Based on the measured specific resistance value with the geological conditions of the study area, the rock layer analysis is carried out with the specific resistance value. So the rock layers in the research area at a specific resistance value of 2.98 - 67.86 Ωm are thought to be a layer of liquefaction sediments consisting of clay and sand. While the value of specific resistance > 67.86 Ωm is suspected to be a non-liquefaction sediment consisting of gravel and building debris. The interpretation results refer to previous research that examined the liquefaction phenomena conducted by [25], which obtained a low specific resistance value of <50 Ωm which is thought to be alluvia deposits.

1. Track 1

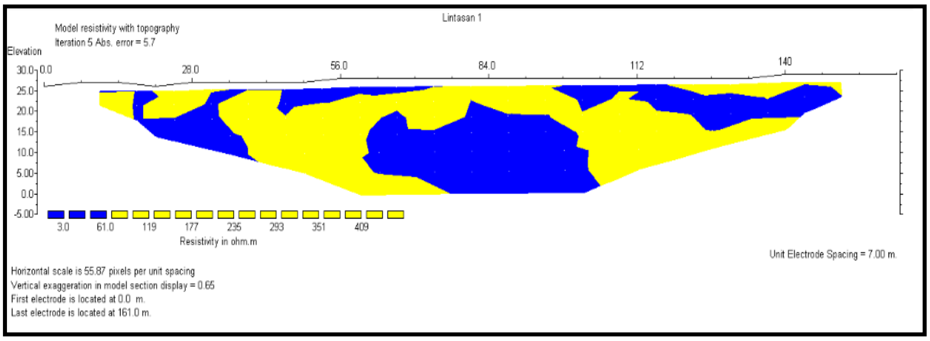

Fig 5. Cross section of liquefaction sediment type resistance of track 1

Based on the cross-section of track 1, it can be seen that the liquefaction sediment layer has an average thickness of 7 m with a dominant thickening towards the east of the track. There are also gravel and building materials which are non-liquefaction rocks. In the middle of the 63 - 105 m meter track, there are non-liquefaction rocks with a thickness of ± 7. The noncyclone rock layer is unevenly distributed.

2. Track 2

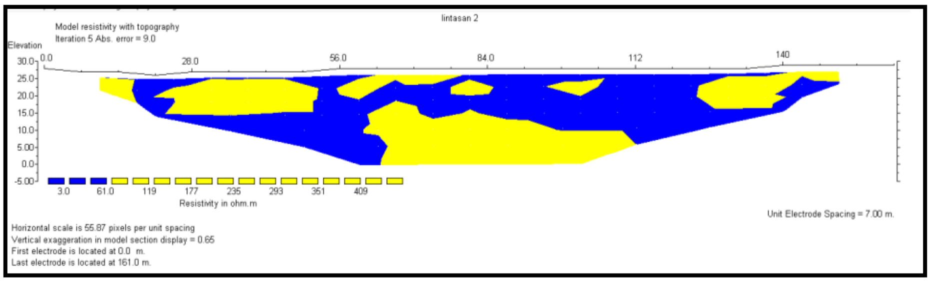

Fig 6. Cross-section of liquefaction sediment type resistance of track 2.

Based on the cross-section of track 2, it can be seen that the liquefaction sediments spread evenly with a thickness of ± 7 m and the liquefaction sedimentary rocks tend to thicken towards the East. Meanwhile, non-liquefaction rocks are scattered randomly near the surface which may be the remains of building debris.

3. Track 3

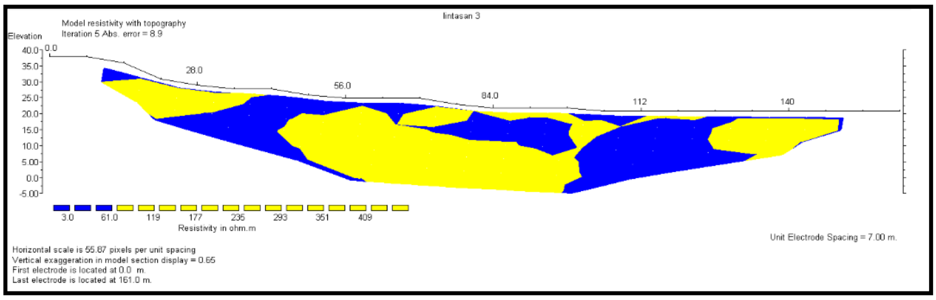

Fig 7. Cross-section of liquefaction sediment type resistance of track 3.

Based on the cross-section of track 3, it can be seen that the liquefaction sediments have varying thicknesses. In the middle of the track at meters 56 - 98 m, the liquefaction sediments have a thickness of ± 5 m. Liquefaction sediments tend to thicken towards the south. There are non-liquefaction rocks that tend to accumulate in the middle of the track, namely from 56 - 98 m meters.

4. Track 4

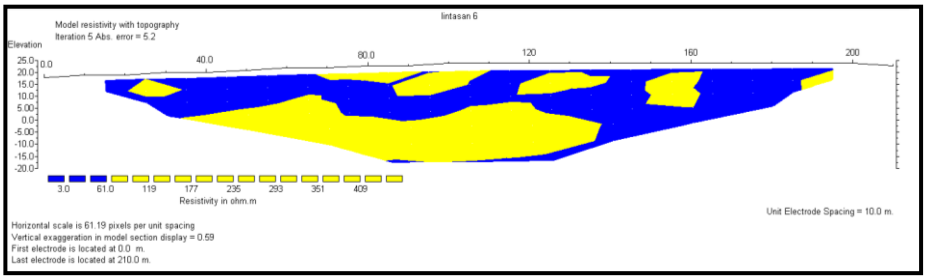

Fig 8. Cross section of liquefaction sediment type resistance of track 4.

Based on the cross-section of track 4, the liquefaction sediments spread evenly. liquefaction sediments tend to thicken towards the west. There are non-liquefaction rocks near the surface that are suspected to be building debris. Calculation of the volume of liquefaction sediment is done by combining the four measurement trajectories. In calculating the volume of liquefaction sediments, X, and Y coordinate data and the value of specific resistance at each depth. X and Y coordinate data were obtained from *Google Earth software* and the data of the specific resistance value was obtained from the inversion results in *Res2Dinv* 5.35 *software*. Then connecting the 4 measurement trajectories. The distribution of specific resistance values is divided into 3 cross-sections of the distribution of specific resistance values of liquefaction sediments based on each depth (Figure 9).

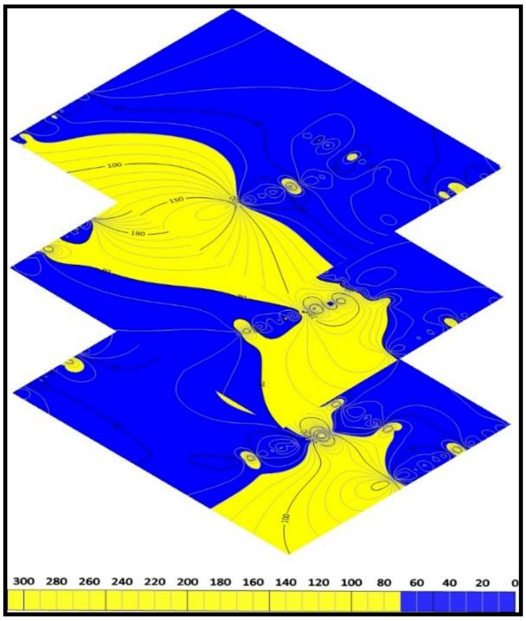

Fig 9. Cross-section of the distribution of specific resistance values at each depth.

After that, calculations were made to obtain the area in each cross section at each depth using *ImageJ software*. Then the calculation to determine the measured volume of liquefaction sediment using the formula in Equation (2.3). To see more clearly the calculation of liquefaction sediment volume is presented in Table 1.

Table 1. Volume of liquefaction sediment per depth

No.	Depth	Wide	Distance	Volume
1	1.75	85275	3.5	250.413
	5.25	57818		
2	5.25	57818	1.75	120.470
	7	79861.1		
3		Total		370.883

Based on the results of the calculation of the volume of liquefaction sediment Table (4.1) uses the cross-sectional method with the guidelines for the *role of gradual change*. At a depth of 1.75 - 5.25 m, the volume of liquefaction sediment is 250,413 m³, at a depth of 5.25 - 7 m, the volume of liquefaction sediment is 120,470 m³. Then the whole of the volume of liquefaction sediment per depth, the total volume of liquefaction sediment is 370,883 m³.

4. CONCLUSIONS

The conclusion of this research is that the lithology in the liquefaction area in Balaroa Village consists of clay, sand, gravel, and building debris. Clay and sand are liquefaction sediments with a specific resistance value of < 67.86 Ωm. While gravel and building debris are non-liquefaction rocks with a specific gravity value > 67.86 Ωm. Liquefaction sediments calculated in Balaroa Village amounted to ± 370,883 m³. the volume of liquefaction sediments thickens in the eastern part, this is due to morphological conditions that tend to be more sloping in the eastern direction.

References

[1] Das Braja M, (1992). *Principle of soil Dynamic PWS*. Boston: KENT Publishing Company.

[2] Hendrajaya, L. & Arif, I. (1990). *Geoelectric Resistivity*. Bandung: Earth Physics Laboratory, Department of Physics, FMIPA ITB.

[3] Kramer, S.L. (1996). *Geotechnical earthquake engineering*, Prentice Hall, Englewood Cliffs, N.J., 653.

[4] Buana, T.W., Hermawan, W., Wiyono, Rahdiana, R.N (2018). *Disaster Mechanisms in Balaroa and Petobo* (*Behind the Charm of Palu*). Bandung: BADAN GEOLOGI Ministry of Energy and Mineral Resources.

[5] Manrulu, R. H., Nurfalaq, A., & Hamid, I. D. (2018). Estimation of groundwater distribution using resistivity geoelectric method of Wenner and Schlumberger configuration at campus 2 of Cokroaminoto University Palopo. *Journal of Flux Physics: Scientific Journal of Physics FMIPA Lambung Mangkurat University*, *15*(1), 6-12.

[6] Nainggolan, R. Y., & Horman, J. R. (2021). Calculation of Limestone Volume Using the Cross Section Method. Intan *Journal of Mining Research*, 4(2): 73-78.

[7] Panissod, C., Michot, D., Benderitter, Y., & Tabbagh, A. (2001). On the effectiveness of 2D electrical inversion results: an agricultural case study. *Geophysical Prospecting*, *49*(5): 570-576.

[8] Prayitno, D. P., and Artati, H. K. (2021). Analysis of Liquefaction Potential Based on Soil Grain Size Distribution and Cone Penetration Test (CPT) Data. *Civil Engineering Communication Media*, 27(2): 242-249.

[9] Sukamto, R. (1973). *Geologic Map of Palu Sheet, Sulawesi, Scale 1:250,000. Bandung: Geological Research and Development Center.*

[10] Telford, W.M. Geldart, L.P, Sheriff R.E and Keys, D.A. (1976). *Applied Geophysics*. USA: Cambridge University Press.

[11] Tohari, A., Wardhana, D. D., Hanif, M., & Koizumi, K. (2021). Understanding of subsurface conditions controlling flow liquefaction occurrence during the 2018 Palu earthquake based on resistivity profiles. *In E3S Web of Conferences* (Vol. 331, p. 03002). EDP Sciences.

[12] Triandys, R., Oktaviana, I. S., & Irdhiani, I. (2022). Study of Liquefaction Potential Around Mushroom Street, Balaroa Village, Palu City. *Inertia: Journal of Civil Engineering*, *14*(1): 41-53.

[13] Wang l.G.Z.Q, Law K.T, 1994, *Sitting in Earthquake Zone*, A.A. Balkema, Rotterdam.