Application of Ground Shear Strain (GSS) for Mapping Liquefaction Potential in Palu, Central Sulawesi, Indonesia

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Abstract- The earthquake occurred on September 28, 2018 in Palu area of Central Sulawesi with a magnitude of 7,5 and made the surface of the soil saturated with water, shaken to become liquefaction. The purpose of this study is to acquire the microzonation parameters and identify locations that are considered the potential for liquefaction, use 54 measurement points in Palu City. The distribution of T_0 values with high criteria (0.6 - 1.718) seconds is dominant in the northern, central, and southern parts of Palu City, indicated by the characteristics of soft soils. The distribution of soil vulnerability values obtained minimum of 0.047 and maximum of 29.188 with high criteria located in the northern and central parts of Palu City, illustrating areas that are more susceptible to earthquake shocks. The highest PGA value in Palu City is 2534 gal which shows that the damage to buildings in Palu City is very high. The result of GSS with a range of minimum is 0,7 x 10^{-4} and maximum of 3 x 10^{-4}. The distribution of high (GSS > 100 x 10^{-4}) indicate the area has a high shifting of the soil and tends not to be able to maintain its position, the soil is damaged and potentially liquefaction. The potential liquefaction area in Palu that needs to be watched out is Baru, Besusu, Bayaoge, Nunu, Siranindi, Kamonji, Silae, Lare, Talise, Kebonena Districts.

Index Terms- Ground Shear Strain, Liquefaction, Peak Ground Aacceleration, Soil Vulnerability

I. INTRODUCTION

An earthquake occurred on September 28, 2018, in Donggala Regency, Central Sulawesi. This earthquake has a magnitude of 7.4 and has a shallow depth of earthquake source that is 11 km (Robby, 2018). Based on the analysis of the BMKG seismotech team, the tectonic earthquake occurred as a result of the Koro Palu Fault activity which was generated by the deformation of the horizontal fault mechanism (strike-slip).

The earthquake not only devastated buildings in Palu City but also triggered another phenomenon, namely liquefaction. The results of the earthquake made the surface of the soil saturated with water, shaken and pushed the sand particles so that there was a liquefaction process. Liquefaction is an occurrence of ground surface movements due to earthquakes (Ridwan, et.al, 2021). Soil with the potential for liquefaction is usually of sanditology, saturated with water and easily submerged.

Potential liquefaction can be indicated through the relation of soil characteristics to the strain level (Ishihara, 1976). According to Ishihara, the characteristics of soil deformation due to earthquakes vary to a certain extent depending on the ability of the soil shear strain. The laboratory analysis result table illustrates the phenomenon that occurs due to the relation between soil characteristics and strain. Strain values below 10^{-4} indicate that the deformation produced is partly elastic and recoverable. The phenomenon appears with this value is vibration or wave propagation. Medium range stretch values, which are between 10^{-4} and 10^{-2}, indicate elastoplastic soil characteristics and produce irrecoverable permanent deformation. Strain values higher than 10^{-2} indicate that the soil is damaged. Phenomena that occur with large strains is soilslides or compaction and liquefaction of soils saturated with water.

This study uses a GSS approach. GSS is one of the quantitative parameters to determine the level of soil strain capability when the soil is crossed by seismic waves (Nakamura, 2000). The calculation result of GSS value is related to the classification of soil dynamics to the strain (Ishihara 1976) can indicate whether the soil has potential of liquefaction.

Mapping the potential liquefaction microzonation in Palu City is needed to provide information about the area that is indicated as potential liquefaction, to the community, especially those living in Palu City. This information is important considering there has been liquefaction which killed many lives. Therefore the purpose of this mapping can be used as a reference in terms of disaster mitigation and further development planning.

Comparison with research conducted by (Nanang, 2017) in Bengkulu City showed that the study resulted in a low GSS value with a range of values of (0,1 - 4.6) x 10^{-4}. This value is influenced by the different characteristics of the constituent area. The GSS value is influenced by the PGA value which the calculations use (Fukushima and Tanaka, 1990) equations which do not enter the dominant period parameters but take into account other requirements.

Comparison with the GSS map made by (Robby W., 2018) the Central Jakarta BMKG seismotech team, addressed the study as having a broader scope area. The GSS map has an interpreted value in the crack category with value of (1 – 50) x 10^{-4}. The method used to obtain the PGA value in the study is the recording station. While this research uses the empirical equation Kanai and the results in the GSS parameters indicated as potential liquefaction.

The purpose of this study is to produce the potential liquefaction microzonation map with other supporting parameters as an effort to mitigate disaster and reference development planning in Palu City. The objectives of this research are to generate parameters for the distribution of T_0, PGA and *Kg* values, generate parameters for the distribution of GSS values in Palu City, and generate potential of liquefaction map based on GGS value.

II. GEOLOGY RESEARCH AREA

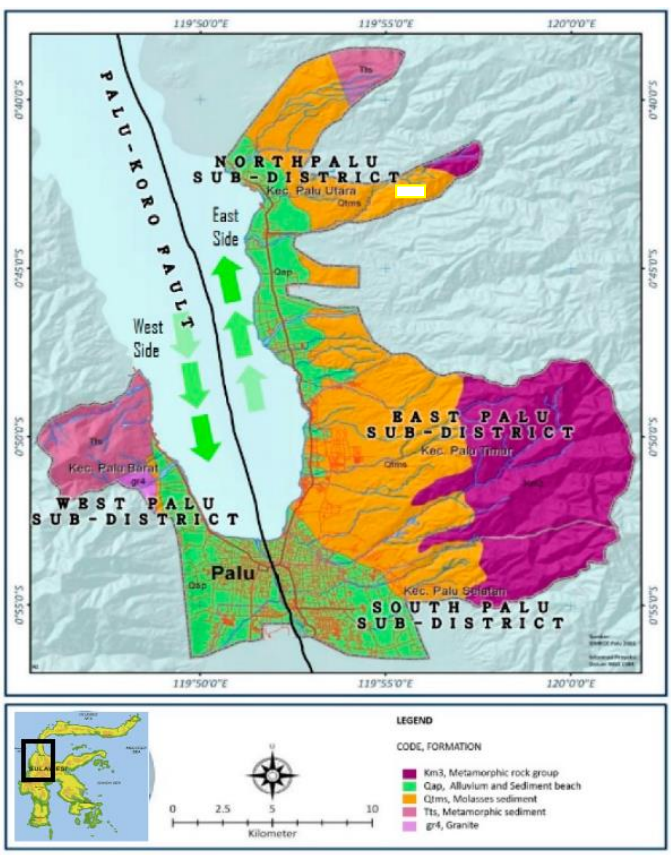

Figure 1. Geological Map of Palu City (Simkot, 2005).

The geomorphology of Palu City alluvial fans were coming from the ridge on the right and left sides of the Palu valley. This alluvial fan flow pattern leads to the Palu Valley. The condition can be interpreted that the sedimentation process is very strong towards the Palu Valley with the possibility of soil movement in areas of high topographic contrast and rocks uncompact (Andikni, 2018).

Based on the 2005 SIMKOT Geological Map of Palu (Figure 1), it shows that Palu City is dominated by Alluvium and the Coastal Deposition Formation. According to (Soekamto 1973), the formation consisted of gravel, sand, mud, and coral limestone. Formed in the environment of rivers, deltas, and shallow seas are the youngest sediment in this area. The deposits are probably all Holocene in age. The area is adjacent to Labea and Tombo of coral reefs form low hills.

The Palu Koro Fault is one of the active structures that dominate in the Central Sulawesi region (Bellier et al., 2001). The Palu Koro Fault movement is a type of left shear fault with a descending component in the north (around Palu). Judging from the morphology, the descending component around Palu shows the appearance of valleys or basins Palu is thought to be an extension that forms a graben structure. The Palu Koro Fault extends southward, starting from Palu Bay to Bone Bay in Central Sulawesi. The existence of this fault can be indicated from the strightness of the fault in the western part of the city of Palu and is increasingly narrowing in the southern part. Observation of corals on a terrace near Tondo in the North of Palu City estimates the average vertical velocity of 4.5 mm/year (Marjiyono, 2013).

III. METHODS

3.1 Microtremor

Microtremor is an environmental vibration with the power generated from two main sources, namely from human activities and natural conditions (Nakamura, 2000). Microtremors can occur due to vibrations caused by human activities such as people walking, car vibrations, factory machine vibrations, wind vibrations, ocean waves or natural vibrations from the ground. The definition of a microtremor is a ground vibration with a shift amplitude of about 0.1-1 μm and a vibration velocity between 0.001 to 0.1 cm/s (Mirzaoglu, et al., 2003).

3.2 Horizontal to Vertical Sprectral Ratio (HVSR) Method

HVSR is a method that compares the horizontal spectrum, the NS and WE components to the vertical spectrum that can be useful in interpreting the soil characteristics of the measurement area with the results of the dominant frequency and amplification parameter. This method can be applied in determining soil vulnerability which can be used in disaster mitigation efforts.

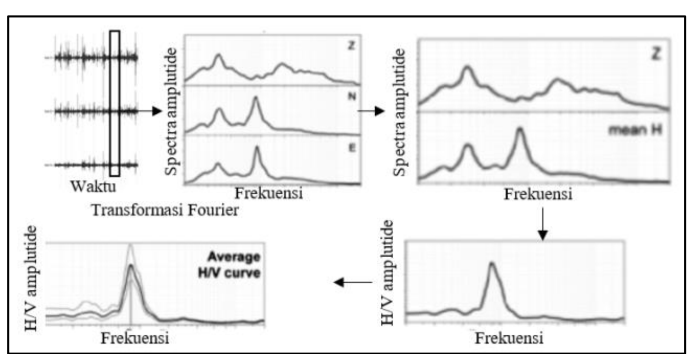

Figure 2. Flowchart H/V ratio processing steps starting from Raw seismogram data to produce H/V curve (Elsayed & Khaled, 2017).

The stages of processing the HVSR method are shown in Figure 2. The HVSR method uses 3 waveform components namely the NS, WE and vertical horizontal components. The three components are then transformed into the Fourier process, which is to change the waveform from the time domain to the frequency domain spectral. Two horizontal components are combined by averaging calculations. The combined horizontal spectral results are calculated using the vertical component using Equation (1) of the HVSR ratio spectrum to produce an H / V curve.

$$r = \frac{\sqrt{H_{EW}{}^2 + H_{NS}{}^2}}{V} \quad (1)$$

r : HVSR spectrum ratio
H_{NS} : north-south horizontal component spectrum
H_{EW} : east-west horizontal component spectrum
V : spectrum of vertical components.

3.3 Dominant Period (T_0)

T_0 parameter is closely related to the dominant frequency (f_0). The value of the T_0 is inversely proportional to the dominant frequency originating from the relation in Equation (2).

$$T_0 = \frac{1}{f_0} \quad (2)$$

T_0 : Dominant Period (seconds)
f_0 : Dominant Frequency (Hertz)

According to (Nakamura et al., 2000), the value of the T_0 can be used to describing the soil characteristics of the measurement area. The assumption that shear waves will be trapped in the deformed soil layer. (Zhao, 2006) shows the relation of soil site classes to the T_0 values made by the National Earthquake Hazard Reduction Program (NEHRP) shown in Table 1.

Table 1. Classification of soil based on T_0 values (Zhao, 2006)

Classification of Soil Sites	T_0 (seconds)	Average of v_s (m/s)	Site Class NEHRP
SC I Rock	< 0,2	> 600	A+B
SC II Hard Soil	0,2 - 0,4	300 – 600	C
SC III Medium Soil	0,4 - 0,6	200 – 300	D
SC IV Soft Soil	> 0,6	< 200	E

3.4 Soil Vulnerability Index (K_g)

Microzonation measurements using the HVSR method in an area can be used as a preliminary study in disaster mitigation efforts and building foundation planning. One of the outputs that can be calculated from the measurement method is the *Kg*. *Kg* is controlled by two factors, namely amplification factor, and f_0. According to (Nakamura et al., 2000) explain the *Kg* describes the level of vulnerability of a soil layer or the level of soil deformation due to an earthquake, with Equation 3.

$$Kg = \frac{A_0{}^2}{f_0} \quad (3)$$

Kg : soil vulnerability index
A_0 : amplification

3.5. Peak Ground Acceleration (PGA)

This research in determining the value of the PGA using the 1966 Kanai method. The grid model is made to estimate the distance of the study area to the point of the earthquake source. The earthquake parameters used are magnitude and distance of the hypocenter, with a source of the United State Geological Survey (USGS) earthquake catalog. Besides that, the dominant period measurement parameters are also used in empirical equations, they can represent the actual field conditions. The acceleration of the soil in a place depends on the propagation of seismic waves and the characteristics of the soil layer (alluvial deposit) in that place (Kanai, 1966). The properties of the soil layer are determined by the T0 of the soil from the soil layer if there is a seismic vibration. Kanai formulates an empirical formula for accelerating ground vibrations which are formulated more concisely in Equation 4.

$$\alpha = \frac{5}{\sqrt{T_0}} 10^{0,61M - \left(1,66 + \frac{3,6}{R}\right) LogR + 0,167^{\frac{-1,83}{R}}} \quad (4)$$

α : ground vibration acceleration measuring point (gal)
M : magnitude moment
R : hyposenter (km)

3.6. Ground Shear Strain (GSS)

GSS values in the soil layer reflect the ability of the soil material to shift or stretch during an earthquake (Nanang S. 2017). Table 2. shows the relation of GSS to the phenomenon of soil dynamics that will occur. From these data, it is known that when GSS value is 1×10^{-2} or above, the ground starts showing liquefaction.
Simply the GSS value is also obtained by Equation 5

$$\gamma = K_g \text{ x } \alpha \text{ x } 10^{-6} \quad (5)$$

γ : Ground Shear Strain

Table 2. Relation of strains to the nature of soil dynamics (Ishihara, 1978)

Size of Strain	10^{-6} 10^{-5}	10^{-4} 10^{-3}	10^{-2} 10^{-1}
Phenomena	Wave Vibration	Crack, Settlement	Soil slide, Soil Compaction, Liquefaction

3.7 Microtremor Single Station Survey

Field data measurements were carried out by the Central Jakarta BMKG Seismotech Field survey team. Measuring points are scattered in several villages in Palu City. The scope of this study is 5 x 7 km. This study uses 54 measurement points and is spread quite randomly with a distance between points ± 500 m. Determination of data measurement points in the field is taken based on places that represent building damage due to earthquakes that vary with a certain distance. The aim is to obtain variations in the value of the dominant period from places that have the impact of earthquake damage (Robby, 2018).
Microtremor data measurements carried out by the Central Jakarta BMKG Seismotek Survey Team used the main instrument to measure natural ground vibrations, namely Broadband Seismometer Trillium Nanometrics.

IV. RESULTS AND DISCUSSION

4.1 Distribution of Dominant Period (T_0) Values

The T_0 parameter is the time taken for seismic waves to propagate beneath the surface. The distribution of T_0 values in Palu City is shown in Figure 3. The maximum T_0 value of the study area is 1,7 seconds, and the minimum value is 0,1 seconds.

The determination of soil characteristics is based on the (Zhao, 2006) classification table 1. Zhao divides the range of T_0 values into 4 based on the characteristics of the soil layers. T_0 value with a range of 0,1 - 0,2 seconds is interpreted by geological conditions with characteristics of rock, T_0 value with a range of 0,2 - 0,4 seconds is interpreted as hard soil, T_0 value with a range of 0,4 - 0,6 seconds is interpreted as medium soil and 0,6 - 1,7 seconds is interpreted as soft soil (Shown in Table 3.). The map of the distribution of T_0 values shows that the north, middle, and south parts of the map have high T_0 values with a range of 0,6 - 1,7 seconds are dominated softer soil than the western and eastern parts of the map. This is related to the geological conditions in Palu City which located in the basin due to the Palu Koro fault where the scope of the study area is in the alluvium formation and coastal sand deposits.

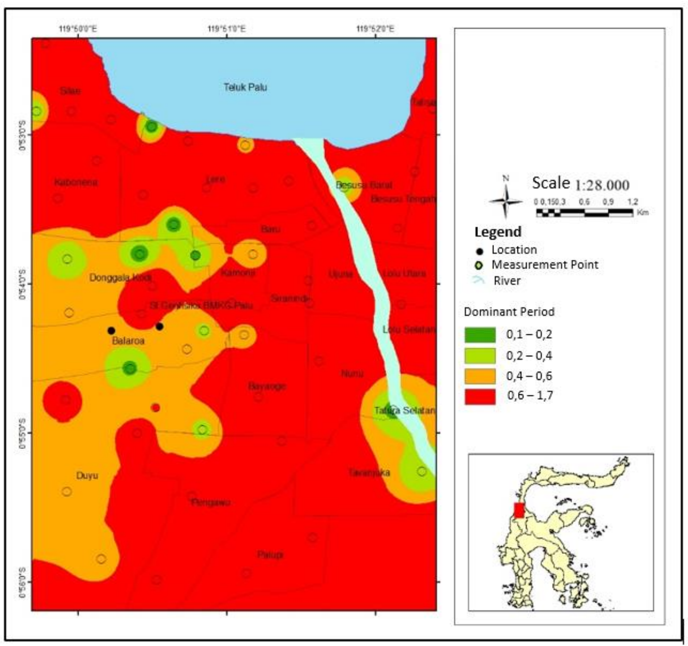

Figure 3. Map of the distribution of T_0 values parameter using 54 measurement points located in Palu City.

The red sections on the map are interpreted to have soft soil characteristics in the form of alluvium and coastal sand deposition. The parameter of the T_0 can be used as supporting data on the potential level of liquefaction. This is because this map can describe the characteristics of the soil layer. The layer of soil with soft or sand characteristics and fine grains is one of the causes of increasing the potential for liquefaction (Bahsan, 2018). The depth of shallow groundwater level in the Palu basin makes the soil with loose sand characteristic so that it can store water easily, so in the event of an earthquake, the water can fill the space between particles so that the interlocking strength between particles is lost and unstable.

Table 3. The division of criteria from the calculation of the T_0 parameters with interpretation and location.

No	Criteria	T_0 (sec)	Soil Characteristics	Location
1	Low	0,1 - 0,2	Rock	-
2	Medium	0,2 - 0,4	Hard Soil	-
3	High	0,4 – 0,6	Medium Soil	Duyu, Balaroa, Tatuna Selatan, Donggala Kodi Districk
4	Very High	0,6 – 1,7	Soft Soil	Silae, Kebonena, Lare, Baru, Siranindi, Bayaoge, Nunu, Pengawu, Palupi, Talise, Besusu Tengah, Lolu Selatan, Besusu Barat, Tavanjuka Districk

4.2. Level of Soil Vulnerability Index (*Kg*)

The value of *Kg* is obtained from the calculation of the amplification value and f_0 parameters. The *Kg* parameter shows how severe the risk or danger of the soil layer due to earthquake shocks. The *Kg* value of the study area starts from the low category ranging from 0,05 to 10, medium 10 to 15, high from 15 to 25, and very high from 25 to 29 shown in Table 4. The map of the distribution of *Kg* values (shown in Figure 4.) being dominated by low values. The distribution of *Kg* values is higher in the northern and central parts of Palu City.

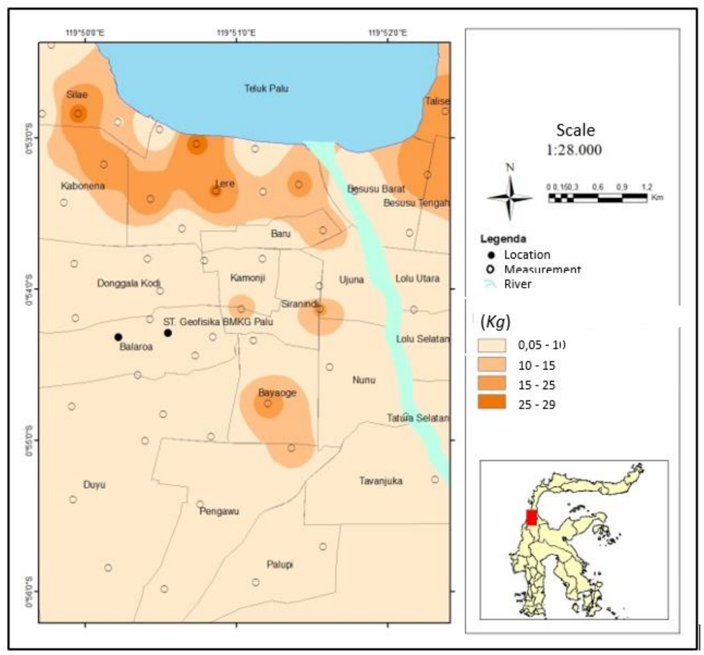

Figure 4. Map of the distribution level of *Kg* using 54 measurement points located in Palu City.

The areas with high *Kg* values can be interpreted as soil vulnerable to earthquake shocks. Besides that in the west, south and east of the city of Palu tend to have a low value then the area has a easier impact compared to the north part. The high value that dominates the map is in the northern part bordering the Palu bay.

Table 4. The division of criteria from the results of the calculation of *Kg* parameters by interpretation and location.

No	Criteria	Kg	Shock Rate	Location
1	Low	0,05 - 10	Easy	Donggala Kodi, Balaroa, Baru, Siranindi, Bayaoge, Nunu, Pengawu, Palupi, Talise, Besusu Barat, Lolu, Tavanjuka, Duyu, Ujuna District
2	Medium	10 - 15	Medium	Lare, Silae, Besusu Tengah District
3	High	15 - 25	Dangerous	Talise, Kebonena District
4	Very High	25 – 29	Very Dangerous	-

The *Kg* value is related to the compactness of its constituent rocks. If the rock layer is less compact then the *Kg* value is high, while the more compact rock character results in a low *Kg* value. Geologically the soil layer of the study area is in the alluvium formation and coastal sand sediments which have soil characteristics in the form of loose sand, then the *Kg* value is generated from the loose sand layer which is characterized by less compact character. The soil character has pores that are open to being traversed by water due to earthquake shocks. This makes the soil saturated with water so that there is a potential for liquefaction.

4.2. Determination of Peak Ground Acceleration (PGA) Value

PGA values were obtained from the Kanai 1966 empirical equation calculation method. The parameters entered were magnitude and hypocenter distance of the earthquake source to the grid point. Seismicity data use the United States Geological Survey (USGS) earthquake catalog. Timing from July 1 2018 to January 1 2019, the aim is to find the largest earthquake event data with magnitude 7.5. The magnitude values obtained were then sorted based on the Palu earthquake and magnitude conversion.

The distribution of PGA values is divided into 3 criteria, namely low (1019 - 1500 Gal), moderate (1500 - 2000 Gal), and high (2000 - 2534 Gal) shown in Table 5. The division is done subjectively because the PGA value obtained by the minimum value is above the last criteria of the MMI IX-XII BMKG Scale (2016) which is more than 564 Gal. The PGA distribution map showing the north and south side of the map has lower values than the west and east parts (Figure 5.). This is due to the mathematical equation, the T_0 value is inversely proportional to the PGA value. However, the hypocenter distance to the grid point also influences the PGA results.

Table 5. The division of criteria from the results of the calculation of PGA parameters by interpretation and location.

No	Criteria	PGA (gal)	Building Demage	Location
1	Low	1019 - 1500	Moderat-Heavy	Silae, Lare, Pengawu, Palupi, Ujuna, Bayaoge, Besusu Tengah, Siranindi, Nunu District
2	Medium	1500 - 2000	Heavy	Kamonji, Balaroa, Duyu, Nunu, Siranindi, Besusu Barat, Baru, Lolu Selatan, Kebonena, Tavanjuka, Lolu District
3	High	2000 - 2534	Very Heavy	Donggala Kodi, Totuna Selatan District

The PGA calculation results are controlled by 2 earthquake events. The first event has a hypocenter distance that is relatively close to the grid point with a magnitude of 5.8 and the second event has a hypocenter distance that is farther than the first event but has a magnitude of 7.5. Both events produce the largest PGA values compared to other events with a significant difference in PGA values.

PGA value is the value of the largest ground vibration. The distribution of the PGA values in research area, the largest PGA value taken was 2534 gal at the City of Palu. This value is considered to be very high for the PGA value compared to other regions due to the geological conditions of the constituents of Palu City. The location of Palu City which is passed by the Palu Koro active fault and sedimentation compiler in the form of loose sand (not compact) and the location of the epicenter which is very close makes Palu City has severe damage due to an earthquake.

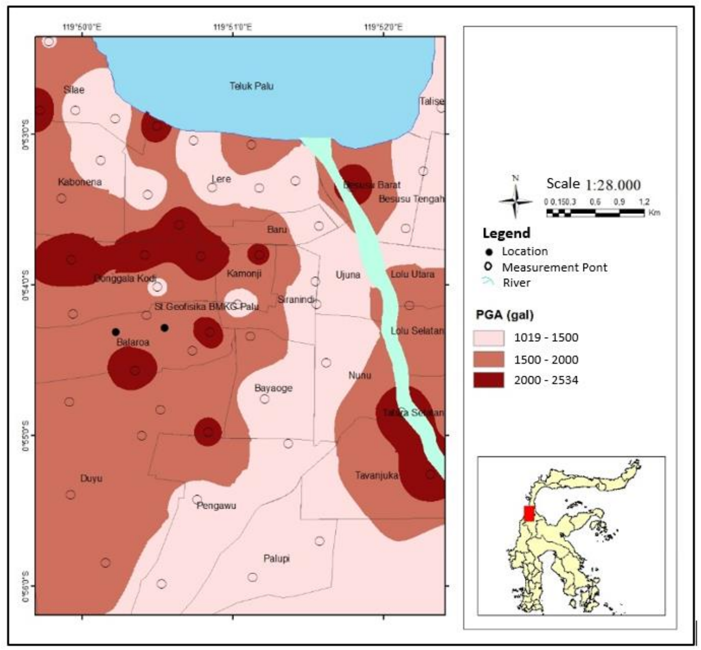

Figure 5. Map of the distribution PGA value parameter using 54 measurement points located in Palu City.

4.3. Ground Shear Strain (GSS) Value Distribution

GSS values are obtained from calculations of the *Kg* and PGA parameters. This value illustrates the ability of the soil layer to shift or stretch when an earthquake occurs. The maximum GSS value in the study area is 300 x 10^{-4} and the minimum value is 0,7 x 10^{-4}. The distribution of GSS values shown in Figure 6.

The results of the GSS value can be related to the classification of strain relations with the nature of soil dynamics (Ishihara 1976). The southeast part of the map ((0,7 – 1) x 10^{-4}) shows vibrational phenomena but is dominated by the west and east parts of the map ((1 – 100) x 10^{-4}) which show cracking phenomena, while the north and middle of the map ((1 – 300) x 10^{-4}) show liquefaction potential (Shown in Table 6.).

The geological process of sediment supply has occurred from the existence of alluvium fans in the west and east of the map. Palu City is in the basin resulting from the Palu Koro fault which has a lower elevation compared to the western and eastern parts of the map which are ridges, so there is a sediment supply at the higher

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elevation layer to the soil with lower elevations leading to the Palu valley. The west and east map's has a layer of soil that tends to be more massive or compact compared to the north and center of the map, interpreted that section is an old alluvium fan deposit. More compact soil layers tend to be more able to maintain a stable state in the event of an earthquake. The soil layer has a lower soil shift value compared to the less compact soil layer and the resulting phenomenon is cracked.

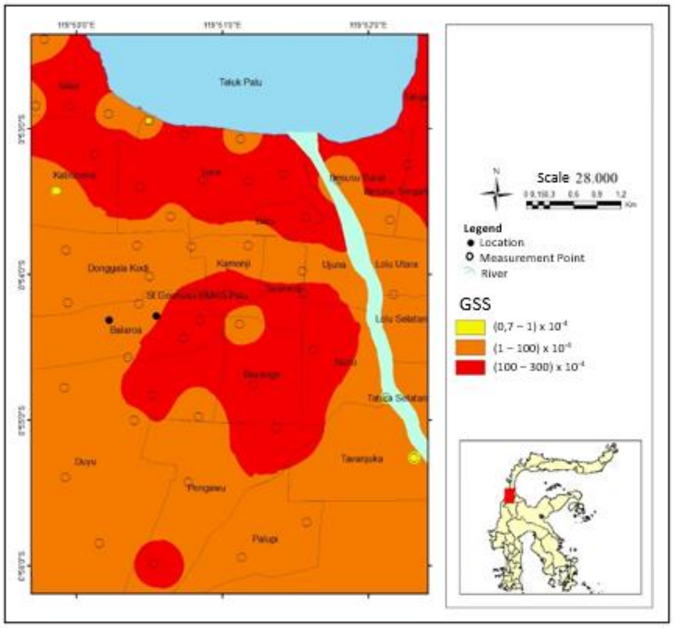

Figure 6. Map of the distribution of GSS values using 54 measurement points located in the city of Palu and its surroundings.

Table 6. Distribution of criteria from the calculation results of GSS parameters by interpretation and location.

No	Criteria	GSS (10^{-4})	Soil Dimamics	Location
1	Low	0,7 – 1	Vibration	-
2	Medium	1 – 100	Crack	Donggala Kodi, Balaroa, Duyu, Tavanjuka, Lolu, Tatuna Selatan, Pengawu, Palupi, Ujuna District
3	High	100 – 300	Liquefaction	Silae, Kebonena, Lare, Baru, Kamonji, Siranindi, Nunu, Bayaoge,Talise, Besusu District

The distribution of GSS values in the middle and north of the map has a higher value than the western and eastern parts of the map. This section has a layer of soil that is less massive than the western and eastern parts of the map, this is due to the geological conditions of the study area which is dominated by the alluvium and coastal sand deposits formation which have loose sand lithology. The beach sand grains are found in the north due to proximity to Palu Bay. So the part bordering with Palu Bay is dominated by higher GSS values. The physical properties of loose soils tend to have high soil shift values, this is due to the soil being unable to maintain a state of silence. So that the soil is very potential for liquefaction.

4.2. Potential Liquefaction Levels

The level of liquefaction potential is obtained from the results of the GSS value with the classification of strain relations with the nature of soil dynamics (Ishihara 1978). Ishihara's classification shows that GSS values ≥ 100 x 10^{-4} can indicate potentially liquefied soil layers. So that the results of the GSS can be weighted to be potentially low liquefaction (GSS < 100 x 10^{-4}), medium ((100 – 200) x 10^{-4}), high ((200 – 300) x 10^{-4}).

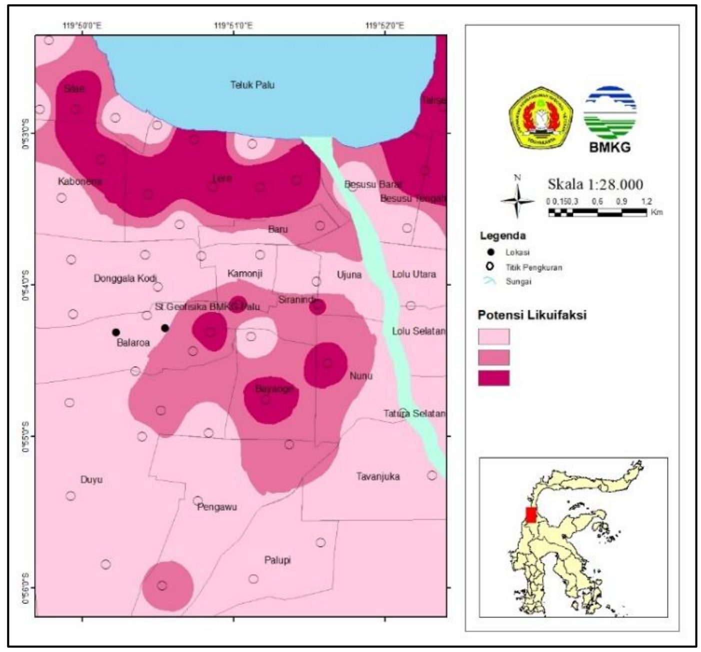

Figure 7. Map of Liquefaction Potential in Palu City, Central Sulawesi, using the GSS approach with the 1978 Ishihara classification

The liquefaction potential map at figure 7 illustrates areas that have the potential for liquefaction. On the liquefaction potential map, there are several areas of concern. There is a very high potential for liquefaction in the northern part of the map. This is also supported by the T_0 map and the index map to the soil light which shows the northern part of the map has a high value. It can be interpreted with the characteristics of soft soils and more danger of shocks will support potential soil liquefaction. The results of mapping liquefaction potential are found areas that need to be watched out for potentially very high liquefaction, including the Baru, Besusu, Bayaoge, Nunu, Siranindi, Kamonji, Silae, Lare, Talise, Kebonena District. The center part of the map is dominated by medium liquefaction potential. While areas with low liquefaction potential include the Donggala Kodi, Balaroa, Lolu, Tavanjuka, Tatuna Selaran, Duyu, Palupi, Pengawu District. However, this does not close the possibility that in areas with low liquefaction potential, liquefaction cannot occur. Because in these areas still have high GSS values. Besides, there are still several factors for liquefaction that should not be ignored.

One of the liquefaction phenomena that has occurred in the city of Palu is in the Balaroa area (depicted on the map in the form of a black point). The liquefaction was caused by an earthquake that struck Palu City with a magnitude of 7.5. Measurement data in this study was carried out after the liquefaction process. The result of the liquefaction potential map shows the area where the liquefaction potential is low. This illustrates that after the liquefaction, there is a change in the value of the measurement results compared to before. Likewise with the state of the soil. The liquefaction process tends to lead to its stability. So that the soil layer in the area has reached a stable point with a lower GSS value.

Table 7. The division of criteria from the results of potential liquefaction based on GSS parameters with their location.

No	Criteria	GSS (10^{-4})	Liquefaction Potential	Location
1	Low	0,7 – 100	Low	Donggala Kodi, Balaroa, Lolu, Tavanjuka, Tatuna Selaran, Duyu, Palupi, Pengawu District
2	Medium	100 – 200	Medium	Baru, Besusu, Bayaoge, Nunu, Siranindi, Kamonji District
3	High	200 – 300	Hogh	Silae, Lare, Talise, Kebonena District

V. CONCLUSION

The distribution of T_0 values with high criteria (0.6 - 1.718 seconds) is dominant in the northern, central, and southern parts of Palu City, indicated by the characteristics of soft soils. The distribution of soil vulnerability values obtained min value of 0.047 and max value of 29.188 with high criteria located in the northern and central parts of Palu City, illustrating areas that are more susceptible to earthquake shocks. The highest PGA value in Palu City is 2534 gal which shows that the damage to buildings in Palu City is very high.

Obtained GSS value with a range of min values in the study area is 0,7 x 10^{-4} and max is 300 x 10^{-4}, the distribution of high values (GSS values > 100 x 10^{-4}) dominates in the north and center at the city of Palu, interpreted that the area has a high value of shifting or stretching of soil and tends not to be able to maintain its position so that it shows the soil is damaged and potentially liquefaction.

The potential liquefaction in the city of Palu that needs to be watched out is in Baru, Besusu, Bayaoge, Nunu, Siranindi, Kamonji Silae, Lare, Talise, Kebonena District.

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