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Seismic Vulnerability Index Analysis In The Sub-District Of Lake Kembar, Solok Regency, As An Effort To Determine The Potential Aslided Area Using HVSR Method

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Abstract: Nagari Kampung Batu Dalam, Danau Kembar District, experienced a landslide caused by high rainfall and steep topography (slope). However, there needs to be more information regarding the classification of landslide potential levels that will occur. So it is essential to carry out this study to determine the soil type, sediment depth, and seismic vulnerability index. Ten microtremor data are scattered in this area. Measurements are carried out using an MAE Sysmatrack and 3D Seismic Surface Sensor, and this is done because these measurements are not difficult to carry out and do not require a large amount of money. However, there is an abundance of information that can be analyzed. Microtremor signal data were processed using Geopsy software with the Horizontal to Vertical Spatial Ratio (HVSR) method and soil profiles which stated the parameters of the shear wave velocity (Vs) and the depth of the sediment layer (H) using the ellipticity curve method. The results obtained show that the f0 value ranges from 0.6-4.37 Hz, the Amplification Factor ranges from 1.4-17.1, the sediment thickness (H) ranges from 24.5-240.8 m, and the seismic susceptibility index ranges from $1.72E^{-04}$ - $3.21E^{-02}$ cm/s^2. Based on the mapping and modeling, it shows that alluvial rocks dominate the locations that have the potential for landslides.

Keywords: Ellipticity Curve, HVSR, Landslide, Microtremor

1. Introduction

A landslide is an event of movement of soil, rock, or debris material as a constituent of the slope that moves down or off the slope due to the influence of gravity or the earth's gravity and is caused by several other factors, such as the condition of the sediment layers, the presence of vibrations and the topographical conditions of an area [1, 2]. One of the events that can give a

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vibration effect is an earthquake, where the effect of the vibration depends on how big the earthquake is and the condition of the material it goes through [3].

Twin Lakes sub-district, Solok district, is one of the areas that has experienced landslides, namely on October 25, 2018, and January 21, 2021, due to high rainfall and the shape of the topography, as is known this area is on the active Sumatran fault line, more precisely located in the northern end of the Tutupan segment with a 4 km wide zone in the area, which is composed of young volcanic deposits (Qyu, Qatg), has a slope level of 8- ≥40% [4] and high rainfall. The condition of the area with steep slopes, the amount of vegetation that grows around the slopes, and the high level of rainfall cause the weathering process to occur quickly. This weathering process can cause the material to lose and slide off easily [5].

This landslide natural disaster cannot be predicted when and where it will occur, so everyone certainly needs to know every change and natural phenomenon that occur in their respective regional environment [6] because an essential part of a disaster mitigation activity is understanding the nature of disasters, because each place has different types of hazards [7]. As is known, According to [8], the Difficult Segment has accumulated energy of 1.19734 x 1023 erg. For this reason, it is necessary to make an effort to determine the direction of the landslide potential.

This can be done based on the seismic vulnerability index (kg) analysis using microtremor measurements. In microwave processing, microtremor generally uses the method popularized by [9], namely the HVSR technique. Research using the HVSR method was conducted to analyze the characteristics of soil dynamics in the city of Mataram, West Nusa Tenggara [10], to determine the area of potential for landslides in the hamlet of Jeruk, Kulon Progo [11] district, to analyze the vulnerability of the soil in Cilacap district [12], identified the Landslide Area of Bagelen District [5], as well as identified the Thickness of the Weathered Layer in the Kalirejo Area, Kulonprogo [13]. These studies provide additional information regarding mapping areas that can potentially occur in landslides in Nagari Kampung Batu in the Danau Twin District. Moreover, there has been no research using the microtremor method in this area, so if this research is added to how big the thickness (depth) of the sediment is, it is likely has the benefit of reducing the risk of disasters that occur and can be used as a reference for mitigation, determining agricultural land or developing areas that are safe from landslides.

2. Materials and Method

The type of research used is descriptive research conducted at ten measurement points in Nagari Kampung Batu Dalam Area. This can be done by measuring the microtremor, which records the natural movement of Rayleigh waves producing a signal in 3 directions, namely vertical (z), horizontal (N-S), and horizontal (E-W). Through the Anti-triggering process, setting the STA and LTA parameters, windowing, Fast Fourier Transform, smoothing, and producing the H/V Curve. as in Figure 1.

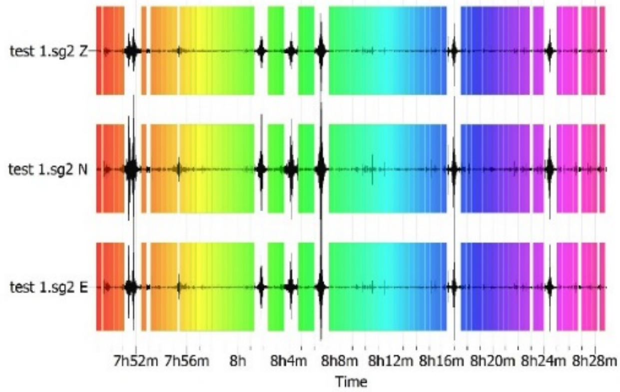


Figure 1. Windowing Signal Microtremor

Based on Figure 1, the HVSR analysis results in microtremor data that has selected with many windows with a window length of 25 s, and the HVSR curve analysis results using Geopsy software is set to Konno and Ohmachi smoothing corrections with 40 bandwidth and using a 5% taper cosine.

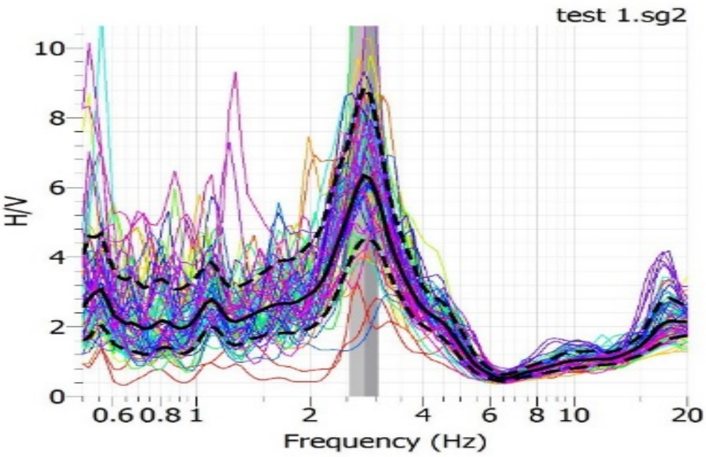


Figure 2. H/V curve At point D1

Figure 2 shows the resulting natural frequency in Hz units and the Amplification factor. The H/V curve contains the dominant frequency's parameter values and the amplification factor's value. Then the seismic vulnerability index (Kg) can be obtained [14]:

$$\mathrm{Kg} = \frac{{A_0}^2}{f_0} \tag{1}$$

By doing the inversion of the dominant frequency, the dominant period value will have obtained, providing information on the type of soil so that a distribution map (contour map) of the natural frequency value, amplification factor, and dominant period can have made. The H/V curve is input into the Dinver software to be processed using the Ellipticity curve method by inputting parameters that follow the geological information at the research site to obtain ground profiles with Vs and Vb data values so that they are mapped into 3D form.

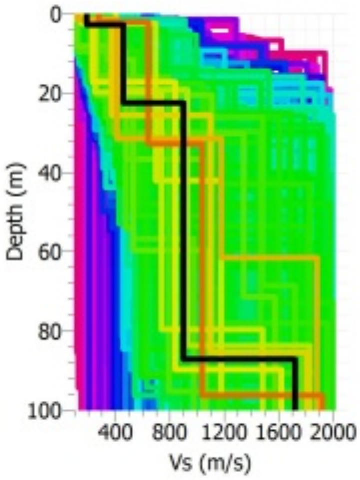


Figure 3. Ground Profile obtained from the Dinver software

Based on Figure 3, the value of the thickness of the sediment layer will have to obtain with the equation [15]:

$$H = \frac{V_S}{4f_0} \qquad (2)$$

After all, parameters have been obtained. It will continue with a mapping using Surfer software to see the effect of each parameter on the location of data collection.

3. Results and Discussion

Geographically, Twin Lakes District is located at coordinates $00^0 57' 48$-$01^0 07' 45$ South Latitude and $100^0 36' 55$-$100^0 44' 55$ East Longitude with an area of 70.10 KM^2. The location for data collection focuses on Kampung Batu Dalam, which is marked with ten green pins, as shown in Figure 4.

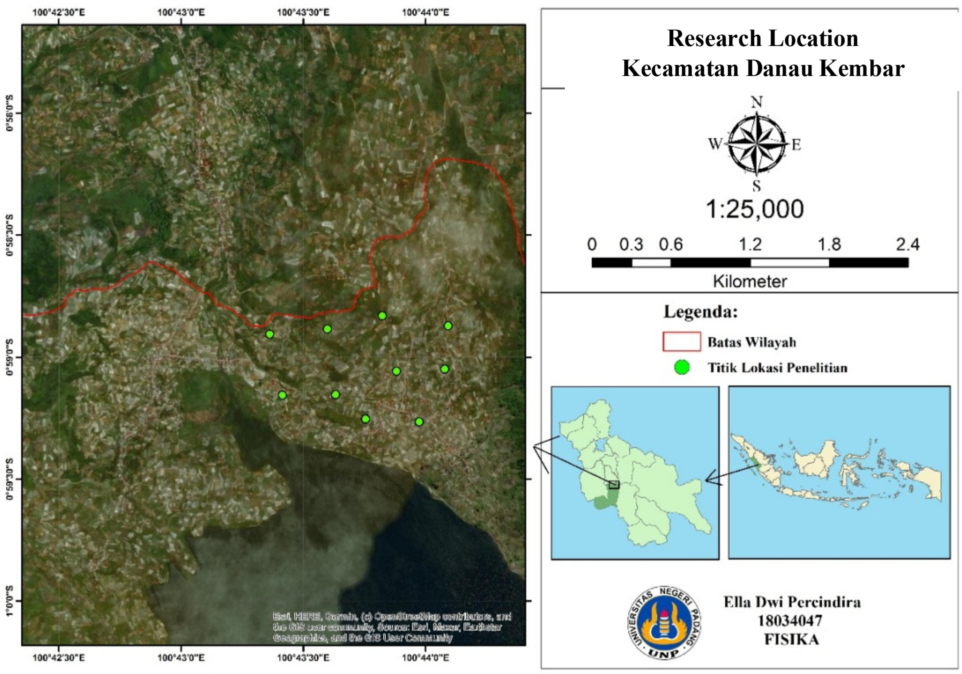


Figure 4. Research location map

According to [16], amplification occurs due to the magnification of seismic waves that experience a striking difference between layers. It means that the medium that is softer than the initial medium through which it will pass will make the seismic waves experience magnification. The amplification value of the soil is related to the impedance contrast of the surface layer and the layer below it. If the impedance contrast of the two layers is high, a high amplification factor occurs, and vice versa, it can be classified based on [17]:

Table 1. Classification of the amplification value of the village of Batu Dalam village

Value of amplification factor	Location	Classification
$A0 < 3$	D5, D7, D6	Low
$3 \leq A0 < 6$	D10, D3, D2	Medium
$6 \leq A0 < 9$	D1, D8, D4	High
$A0 \geq 9$	D9	Very High

Based on Table 1, it can be seen that the amplification values at the research sites are classified from low to high range. The highest peak is at location point D9 and has a soil condition composed of soft sediments. The difference in the value of this amplification factor is caused by several factors, such as differences in topography and geological conditions that affect the distribution of damage caused by earthquakes and trigger other events, such as landslides and wave propagation characteristics on the ground [18].

Table 2. Classification of Dominant Frequency (Hz) and Dominant Period (S)

Dominant Frequency (Hz)	Dominant period (s)	Location	Kanai classification	Description	Character
<2,5	>0,4	D2, D4, D5, D6, D7, D8, D9	Alluvial rock formed from deltaic sedimentation, top, soil, and mud, with a depth of 30 meters.	The thickness of sediment surface is very thick.	Currently
2,5 – 4	0,25 – 0,40	D1	Alluvial rock with sediment thickness >5m. consists of sandy gravel, hard sandy clay, loam. There is a bluff formation.	The thickness of the sediment surface is in the thick category, around 10-30m	Soft
4 – 10	0,15-0,25	D3, D10	Alluvial rock with a thickness of 5m consists of sandy gravel (sand gravel), sandy hard clay (clay), clay (loam)	The thickness of the surface sediment is in the medium category, 5-10m	Very Soft

Based on the Table 2 classification carried out by [8,9], a low f0 value causes high amplification or amplification of earthquake waves, and a low f0 causes a long or high period so that the earthquake waves will be trapped in the soil sediment layer for longer [3]. It is concluded that the areas with points D3 and D10 have high f0 values and low t0 values, indicating that the sediment layer is medium and the bedrock is shallow. Point D1 has thick sediment layers and deep bedrock. While points D2, D4, D5, D6, D7, D8, and D9 have a sediment thickness of >30, the bedrock is classified as very deep.

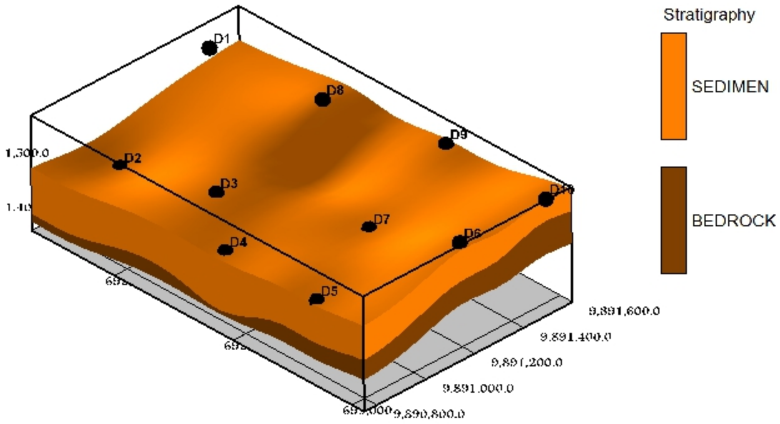
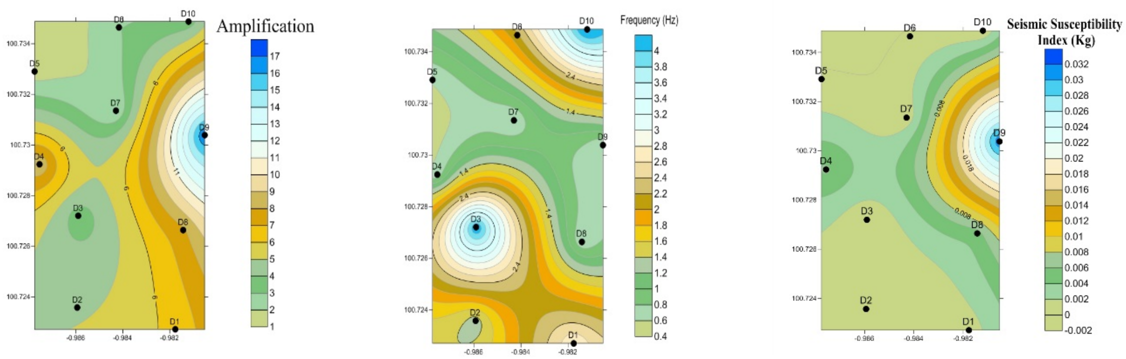


Figure 5. 3D Nagari Kp Sediment Layer. Inner Stone

The thickness of the sediment is related to the shear wave velocity (Vs) and the dominant frequency. The thickness of the sediment is obtained through Equation 2. The H value obtained at Nagari Kampung Batu Dalam ranges from 24.5 m - 240.8 m. The lower the value of Vs, the softer the soil at a location will cause the area to be prone to disasters. This sediment thickness value is then visualized in 3D form, as shown in Figure 5. The highest sediment thickness is at points D5, D7, and D8. Kg is a measurement value to determine the resistance/earth layer level. According to (Warna, et. al., 2011 in [21]), the parameter of the soil vulnerability index (Kg) can reflect local effects. It can have used as an indicator in determining weak points, especially in slope areas. [5] stated that landslides are identical to slope conditions. In other words, landslides will occur in areas with a higher elevation in the direction of landslides in areas with lower elevations.



(a) (b) (c)

Figure 6. Map (a) Amplification Factor (b) Dominant frequency (c) Seismic Vulnerability Index

Figure 6 shows the mapping of the parameter values, which are then analyzed to obtain the earthquake vulnerability index value and map the Kg value. Based on the distribution map, data interpretation and analysis can be carried out to determine whether the research area has a landslide potential. Areas due to earthquakes can occur at any time. This is a form of earthquake disaster mitigation that can be done. A low f0 value causes a high amplification or amplification of earthquake waves. The Dominant period value is inversely proportional to the f0 value, indicating that if the f0 value is low, the T0 value will be high, and vice versa.[10]

In addition, in areas that are prone to landslides, a reasonably high amplification value is also obtained. Based on the classification by [19], the amplification value at D9 is in the very high category. If a large-scale vibration is given, it will experience significant strengthening. In addition to this, the sediment's thickness also influences landslides, so it can be concluded that areas prone to potential ground movement are areas with a thick layer of sediment (> 30 meters) with high slopes and associated with low-very high amplification values. Bedrock has defined as the lower layer of soil whose velocity is higher than the sediment layer above it [22]. Based on this analysis, it is predicted that in the Nagari Kampung Batu Dalam, point D9 has a vast potential to experience landslides, while other points can be categorized. Based on the analysis and discussion, it can be concluded that landslides in the Nagari Kampung Batu Dalam area are classified as significant (D9) and relatively small (D1, D3, and D10). It is because the average sediment thickness is around 30m.

4. Conclusion

Based on the results and discussion, the Kampung Batu Dalam has a seismic susceptibility index value range of $1.11E^{-03}$-$2.20E^{-04}$ with a seismic thickness reaching >30 m, which is 24.5 – 240.8 m, which is composed of alluvial rock seen based on the value of the natural frequency of type 1 and the dominant period. Type 1 has an amplification factor of 1.4-17, classified as low-very high classification depth. If mapped based on the seismic vulnerability index, the area that has the highest landslide probability is at point D9 with a value of $3.21E^{-02}$ and a thickness of 80.9 m, and other location points can also be categorized as landslide-prone areas because they include areas that have the potential to be affected by landslides, this is based on the characteristics of the soil type and the thickness of the sediment layer.

References

[1] D. M. Cruden, "A simple definition of a landslide," *Bull. Int. Assoc. Eng. Geol. - Bull. l'Association Int. Géologie l'Ingénieur*, vol. 43, no. 1, pp. 27–29, 1991, doi: 10.1007/BF02590167.

[2] D. Varnes, "Slope Movement Types and Processes," 1978.

[3] Suhardjono, *Peningkatan Kemampuan Pengamatan Gempa Bumi*. Jakarta, 2007.

[4] D. Widia Kusuma Badan Penelitian dan Pengembangan Provinsi Sumatera Barat Jl Jenderal Sudirman No, "Rencana Pembangunan Jalan Alahan Panjang Pasar Baru Di Kawasan Suaka Margasatwa Tarusan Arau Hilir Dan Analisis Biofisik Das Bayang," *Pros. Semin. Nas. Pelestarian Lingkung.*, no. November, p. 16, 2019.

[5] G. D. A. G. Petiwi, N. B. Wibowo, and D. Darmawan, "Identifikasi Daerah Longsor Kecamatan Bagelen Menggunakan Metode Mikrotremor," Universitas Negeri Yogyakarta, 2018. doi: 10.17509/wafi.v3i2.12740.

[6] S. Mintarjo, *Waspadai Tanah Longsor*. Pakar Raya, 2018.

[7] A. Fadhli, *Mitigasi Bencana*. Gava Media, 2019.

[8] R. Muhammad, "Analisis Energi Potensial Gempabumi di Wilayah Sumatera Barat dan Sekitarnya (3°50' LS – 1°20' LU dan 98°10' BT - 102°10' BT)," Universitas Negeri Padang, 2019.

[9] Y. Nakamura, "Method for dynamic characteristics estimation of subsurface using microtremor on the ground surface," *Q. Rep. RTRI (railw. Tech. Res. Institute)*, vol. 30, no. 1, pp. 25–33, 1989.

[10] U. Azmiyati, K. S. Brotopuspito, and S. Dibyosaputro, "Analisis Karakteristik Dinamika Tanah Berdasarkan Data Mikrotremor di Kota Mataram, Nusa Tenggara Barat," *JUPE J. Pendidik. Mandala*, vol. 3, no. 3, p. 36, 2018, doi: 10.58258/jupe.v3i3.515.

[11] R. Nur and E. Hartantyo, "Penentuan Area Potensi Tanah Longsor Berdasarkan Analisis Mikrotremor Di Dusun Jeruk Dan Sekitarnya Kecamatan Samigaluh Kabupaten Kulon Progo," *Positron*, vol. 11, no. 2, p. 77, Dec. 2021, doi: 10.26418/positron.v11i2.46833.

[12] N. Wachidah, S. F., dan Agsutin, "Analisa Kerentanan Tanah di Kecamatan Adipala Kabupaten Cilacap Mengggunakan Metode Mikrotremor Sebagai Upaya Mitigasi Bencana Gempa Bumi," 2021.

[13] Trianda Obrin, Prastowo Rizqi, and Novitasari Sely, "Identifikasi Ketebalan Lapisan Lapuk di Daerah Kalirejo, Kulonprogo Berdasarkan Pengukuran Mikrotremor dalam Upaya Mitigasi Tanah Longsor," *J. Pros. Nas. Rekayasa Teknol. Ind. dan Inf. XIII Tahun 2018*, vol. 2018, no. Identifikasi Ketebalan Lapisan Lapuk, pp. 246–253, 2018.

[14] M. I. Von Seht and J. Wohlenberg, "Microtremor Measurements Used to Map Thickness of Soft Sediments," *Bull. Seismol. Soc. Am.*, vol. 89, no. 1, pp. 250–259, 1999, doi: 10.1785/bssa0890010250.

[15] K. Kanai, "Improved empirical formula for the characteristics of strong earthquake motions, Proceedings," *Japan Earthq. Eng. Symp. Tokyo,* vol. 39, pp. 1–4, 1966.

[16] Y. Nakamura, "Clear identification of fundamental idea of Nakamura's technique and its applications," *Proc. 12th world Conf.* …, vol. 89(1), p. Paper no. 2656, 2000, [Online]. Available: http://www.sdr.co.jp/papers/n_tech_and_application.pdf

[17] H. B. Seed, I. A. Idriss, and I. Arango, "Evaluation of liquefaction potential using field performance data," *J. Geotech. Eng.*, vol. 111, no. 11, p. 1346, 1985, doi: 10.1061/(ASCE)0733-9410(1985)111:11(1346).

[18] F. Alhasanah, "Pemetaan dan Analisis Daerah Rawan Tanah Longsor Serta Upaya Mitigasinya Menggunakan Sistem Informasi Geografis," Institut Pertanian Bogor, 2006.

[19] Setiawan Januar Herry, "Mikrozonasi Seismisitas Daerah Yogyakarta dan Sekitarnya. Institut Teknologi Bandung, Bandung," Institut Teknologi Bandung, 2009.

[20] K. Kanai, "Seismology in Engineering," *Tokyo Univ. Japan*, vol. 44, no. 11, pp. 1367–1375, 1983.

[21] I. Gazali, "Berdasarkan Inversi Mikrotremor Spectrum Horizontal To Vertical Spectral Ratio (HVSR) Studi Kasus : Tanah Longsor Desa Olak Alen ," 2017.

[22] D. Ambarsari, "Analisis Mikrotremor Dengan Metode HVSR Untuk Mikrozonasi Kabupaten Gunungkidul Yogyakarta," p. 95, 2017, [Online]. Available: https://repository.its.ac.id/72120/