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SPATIAL DETERMINATION OF EARTHQUAKE PRONE ZONING IN CUGENANG SUB-DISTRICT

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ABSTRACT: Indonesia is one of the countries prone to earthquakes due to the importance of geological processes. Plate interactions cause seismic phenomena that have an impact on human life. This research aims to identify the factors that influence earthquakes in Cugenang District and determine earthquake-prone zones located in Cugenang District. The data is processed using a weighting system and Spatial Multi Criteria Analysis (SMCA). This overlay technique uses four parameter maps, namely rock formation maps, slope slope maps, earthquake distribution and scale maps, and geological structure maps. Making maps using geographic information system analysis and remote sensing. The main factor in the damage that occurs is due to fault movement at fine depths and the type of lithology, causing damaging vibrations. The results of the research show that Cugenang District has areas that are very high, high, medium and low prone to earthquakes. High zoning is along the fault movement path, medium category division is in areas far from the epicenter and faults, and low earthquake prone areas are very far from the epicenter and fault alignment. Making a map of earthquake-prone zoning in Cugenang District can be a recommendation for development. The government needs to carry out building code management for buildings that will be built and place buildings in zones that are safe from fault movement.

Keywords: Earthquake; Lithology; Fault; Zoning

1. INTRODUCTION

Indonesia is a country that is on an active tectonic path in the world. The results of three main plates cause the formation of diverse landscapes in Indonesia [1]. The plates that play a role in the formation of morphological diversity are the Eurasian Continental Plate which moves to the southeast at a speed of 0.4 cm / year, the Indo-Australian Ocean Plate which moves at a speed of around 7 cm / year and leads to the north, and the Pacific Ocean Plate which presses westward with a movement speed of 11 cm / year, and the Philippine Sea Plate moves at a speed of 8 cm / year to the northwest [2]. As a result of the interaction of the four plates, a series of active volcanic trails and fault zones are formed, which can be a source of earthquakes and make Indonesia a country prone to geological disasters, especially earthquakes on land and in the ocean.

Data collected from the Catalog of Destructive Earthquakes in Indonesia from 1612 to 2014 shows that there were four destructive earthquakes in 1834, 1844, 1910 and 1912. The year 2022 was the year of the most destructive earthquake. Destructive earthquakes are earthquakes that damage buildings, cause injuries, fatalities and material losses [3].

Based on BMKG reports, on November 21, 2022 until November 22, 2022 there were 140 aftershocks with a magnitude range of 1.2-4.2, in which five of them could be felt by the surrounding community. The earthquakes occurred at shallow depths and caused 268 human casualties and 2,000 houses damaged [4].

The physiography of West Java is very complex. The northern part of West Java consists of alluvial coastal and river deposits that form volcanic alluvium fan. The central part is composed of volcanic rock layers derived from volcanic activity in the Quaternary Period. The southern part is built by older rocks, namely the Oligo - Miocene Period which is composed of volcanic breccia, tuffaceous sandstone, silty sandstone, sandstone, napal, lava, andesite and diorite rock intrusions [5].

This type of earthquake in West Java originates from active faults on land, not from subduction zones [6]. Earthquakes characterized by fault displacement have a higher risk of damage. Even

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with a small magnitude scale. Sometimes this phenomenon occurs at a shallow depth and close to settlements and areas important for human life [7]. Densely populated areas in West Java are scattered in the areas of Cianjur, Bogor, Pelabuhanratu-Sukabumi, Ciamis - Kuningan, Rajamandala-Padalarang, Sumedang- Majalengka, Tasikmalaya and Bandung and parts of the southern mountains in West Java. Earthquakes are often located very close to settlements and are difficult to predict. Therefore, mitigation is needed to minimize the impact [8]. One of them is by trying to identify areas that are potentially prone to earthquakes. This is used as a guideline in designing spatial planning which has been regulated in Law No. 26 of 2007 concerning Spatial Planning. [9] also explained the big problem of the earthquake phenomenon is the resulting losses. Knowing the spatial distribution is very important to estimate the impact of hazards [10]. However, until now no technology has been found that answers in detail and precision to calculate and predict the time and location of earthquakes. Therefore, efforts are made to avoid development in areas where there are faults and design earthquake-resistant buildings.

Proper site design is the key to success in reducing disaster risk. Risk minimization is divided into four stages: mitigation, preparedness, emergency response and recovery. Spatial planning is the initial weapon for long-term mitigation [11]. Unfortunately, in Indonesia there has not been much evaluation of earthquake-based spatial planning, even though there are regulations governing spatial planning issued by the Minister of Public Works M0.21/PRT/M/2007. This regulation is a guide in determining areas prone to volcanic eruptions and earthquakes. The analysis requires supporting data in the form of rock type, geological structure and slope of the area to be studied.

2. METHODS

The research was conducted in Cugenang Sub-district, Cianjur Regency, West Java Province which is located at coordinates 6°48'1.92 "S and 107°5'4.26 "E. Cugenang Sub-district is at the foot of Mount Gede Pangrango, Cianjur. The sub-district consists of 16 villages, including: Benjot, Cibeureum, Cibulakan, Cijedil, Cirumput, Galudra, Gasol, Mangunkerta, Nyalindung, Padaluyu, Sarampad, Sukajaya, Sukamanah, Sukamulya, Talaga, Wangunjaya. Cugenang sub-district is bordered by Pacet and Sukaresmi to the north, Cianjur and Mande to the east, Warungkondang to the south, and Sukabumi Regency to the west. The following is an administrative map of Kecamatan Cugenang (Fig. 1).

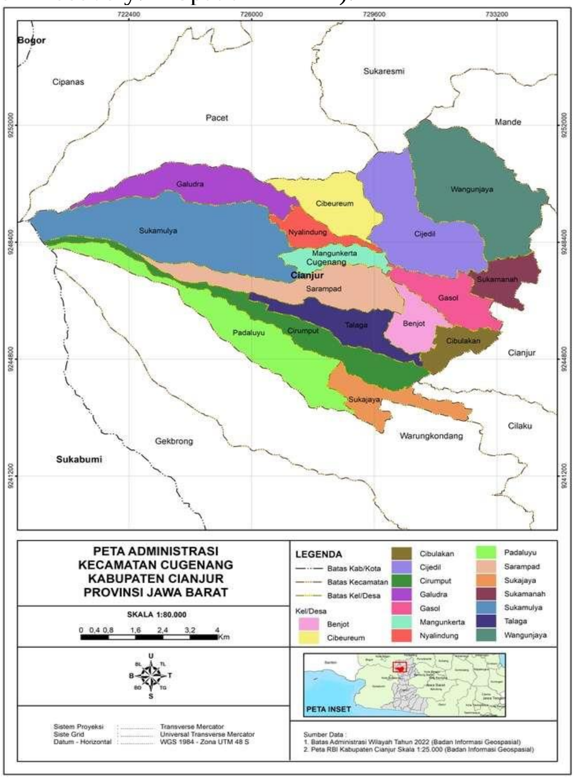

Fig1. Administrative Map of Cugenang Sub-district

The data source of this research is based on the Geospatial Information Agency (BIG) and earthquake distribution points issued by the Meteorology Climatology and Geophysics Agency

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(BMKG). This research method uses the help of geographic information systems and remote sensing. The analysis technique uses score weighting and the method used is to map vulnerability through Spatial Multicriteria Aanalysis (SMCA). This method considers the most dominant parameters and calculates weights based on the strongest indicators that influence the vulnerability of an area [12]. The parameter maps used to determine the zoning of earthquake-prone areas are the geological structure parameter map, the map of earthquake point distribution based on the magnitude scale, the map of lithological characteristics that make up the Cugenang area, and the slope map at this location.

The weighting was designed based on the amount of influence these parameters have on the earthquake hazard. Higher weights were given to parameters that play a role in the earthquake hazard in the area. The scoring calculation for the level of earthquake vulnerability uses a calculation by multiplying the weights and ability scores. The results of the scoring are made into a range of values - class values. This research divides 4 value ranges, namely, low zoning, medium zoning, high zoning, and very high zoning prone to earthquakes. The following weighting matrix and earthquake prone zoning interval classes are used (Table 1 & Table 2)

Table 1. Weighting Matrix for Regional Stability of Earthquake Prone Areas

No.	Geological Information	Kelas Informasi	Capability Value	Weight	Score
1	Geology (Physical and Engineering Properties of Rocks)	Andesite, granite, diorite, metamorphic rock, volcanic breccia, conglomerate, sedimentary breccia, conglomerate.	1	3	3
		Sandstone, coarse tuff, pumice, arkose, greywacke, limestone.	2		6
		Sand, silt, mudstone, clay, fine tuff, shale	3		9
		Clay, mud, organic clay, peat.	4		12
2	Slope Inclination	Flat - Gentle slope (0 - 7%)	1	3	3
		Sloping - Moderately steep (7 - 30%)	2		6
		Steep - Very Steep (30 - 140%)	3		9
		Steep (>140%)	4		12
3	Seismic Activity	MMI / α (g) / Richter		5	
		i – v / <0,05 / <5	1		5
		vi, vii / 0,05 – 0,15 / 5 – 6	2		10
		Viii / 0,15 – 0,30 / 6 – 6,5	3		15
		ix – xii / >0,30 / >6,5	4		20
4	Geological Structure	Far from fault zone	1	4	4
		Near fault zone (100 - 1000 m from fault zone)	2		8
		In fault zone (<100 m from fault zone)	4		16

Source: Minister of Public Works Regulation No.21 Year 2007

Table 2. Scoring to Determine the Zoning of Earthquake Prone Areas

Vulnerability Classification	**Score Range**
Low	15 – 25
Moderate	26 – 35
High	36 – 45
Very High	46 – 60

Source: Minister of Public Works Regulation No.21 (Modified)

The value of capability is given a value of 1 to 4. A value of 1 indicates a low capability for earthquakes, while a value of 4 indicates the highest importance for earthquakes. The greater

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the weight value given, the greater the importance for earthquakes, and conversely, if the weight is low, the importance for earthquakes is small.

3. RESULTS AND DISCUSSION

3.1 Type of Rocks

Based on the geological map sheet [13], the formation units that make up the research location are Breccia and lahars of Mount Gede (Qyg), and Deposits of Old Volcanic Products. Breccia and lahar of Mount Gede (Qyg) are composed by breccia and lahar of Mount Gede. Rocks formed from breccias and lahars of Upper Pleistocene age with lithologies composed of tuffaceous sandstone, tuffaceous shale, tuffaceous

breccia and tuffaceous agglomerate, forming the Cianjur plain. The breccias and lahars of Mount Gede (Qyg) located in Pacet, Cugenang and Cianjur sub-districts have an average thickness of 100 meters. The oldest volcanic deposits (Qot) are composed of breccia and lava. The breccia type contains pyroxene minerals inserted with andesite lava. As revealed by PVMBG, the location of the earthquake damage in Cianjur (Cugenang and Gekbrong) is in the lava and breccia deposits of Mount Gede (Qyg) and the oldest volcanic deposits (Qot). The earthquake damage in Cianjur was classified as severe due to the fact that the buildings were located on rocks that were not solid enough to meet earthquake standards. The distribution of the constituents of the Cugenang area can be seen in Figure.2.

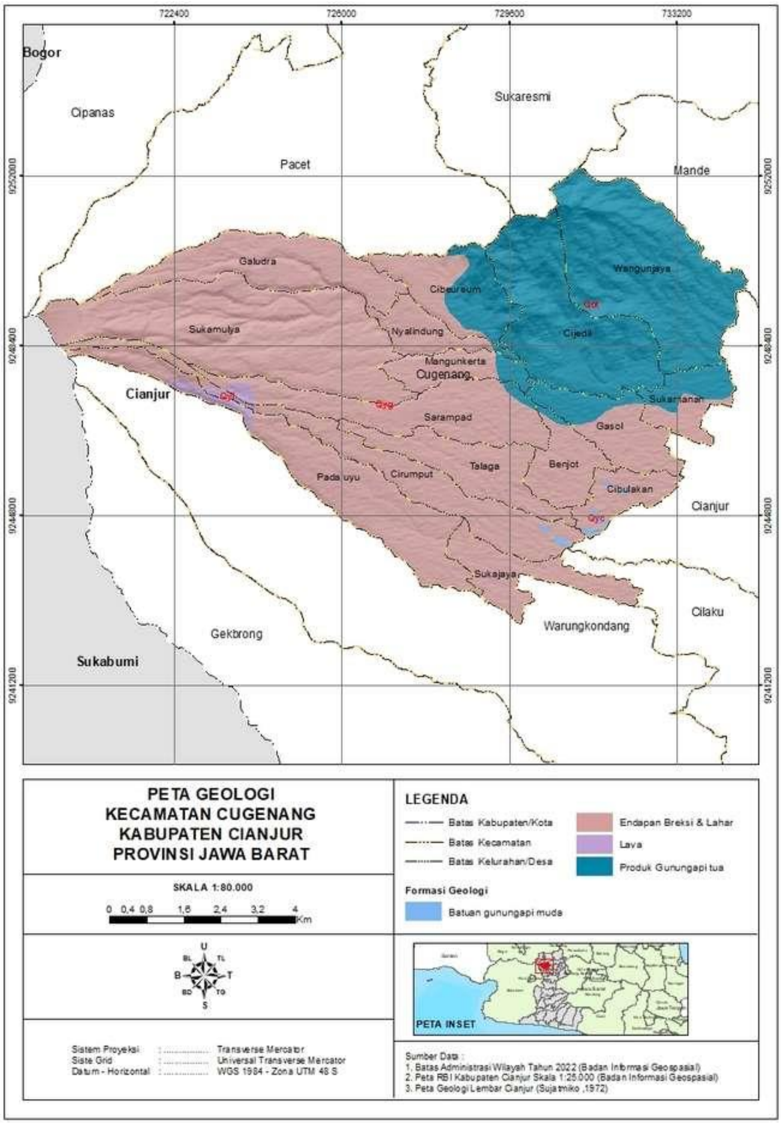

Fig 2. Types of Constituent Rocks in Cugenang Sub-district

3.2 Slope of Inclination

The slope of this area is divided into three types: flat to gentle (0-7%), sloping to moderately steep (7-30%), and steep to very steep (30-140%).

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The dominant slopes are sloping to moderately steep. Around fault alignment zones and earthquake epicenters are also at the same level. This area is very unstable and ground movements can occur at any time. Old ground movements can be reactivated if rainfall and erosion processes are high [14]. The northeast and northwest have steep to very steep slopes. The following is a description of the slope in this area (Figure.3)

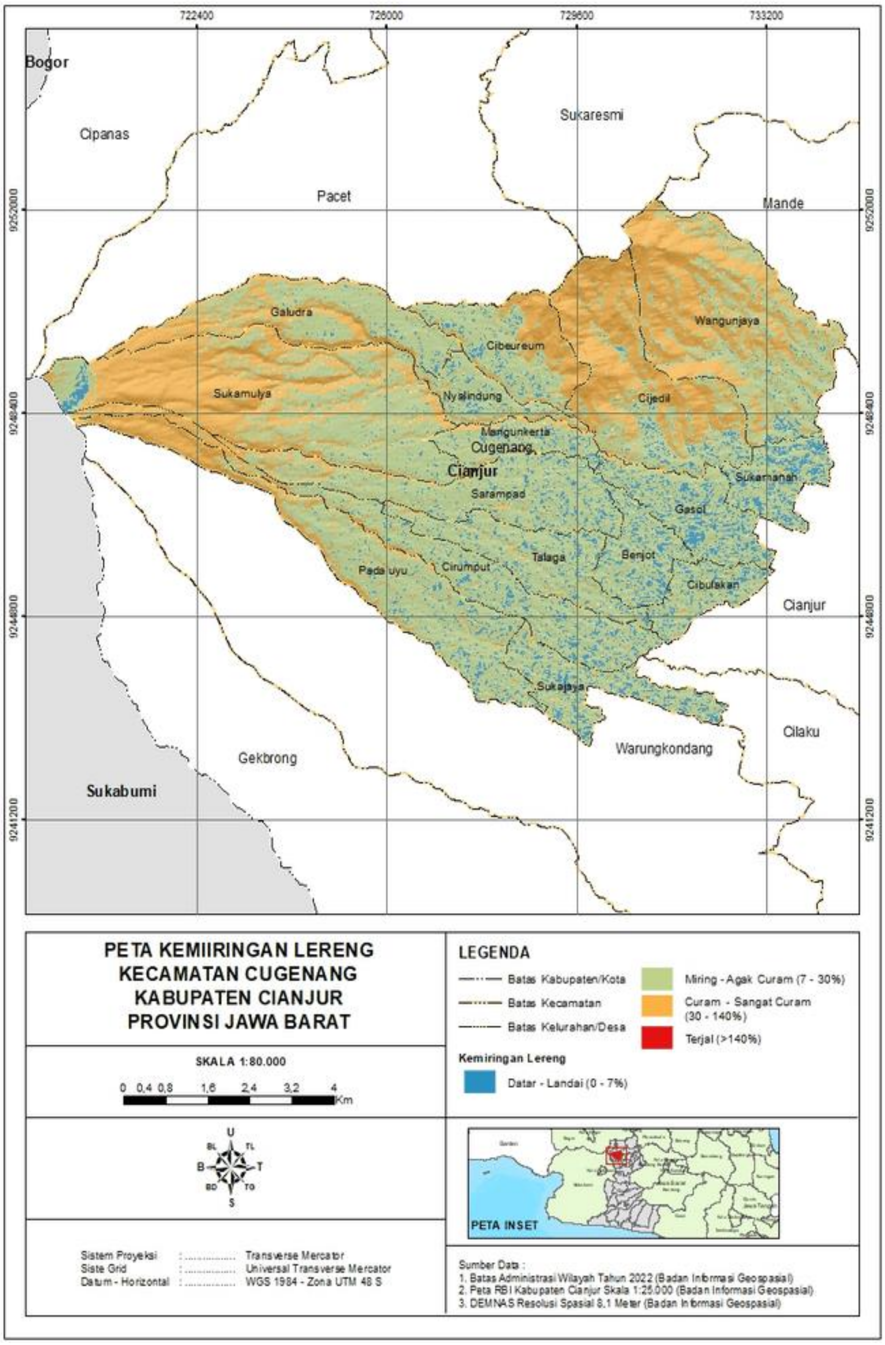

Fig 3. Slope of Cugenang Sub-district Map

3.3 Scale of Seismicity

The first period of the Cianjur earthquake occurred on November 21, 2022 at 13:21 WIB. Up to November 28, 2022, 297 aftershocks with varying strengths were recorded. The magnitude of the largest aftershock was 4.2 M and the smallest was 1.0 M. Based on Modified Mercalli Intensity data issued by BMKG, the intensity of the earthquake reached VII-VIII MMI. This caused damage to buildings. The most severely affected areas were Gasol, Sarampad and Cijedil villages. The following map shows the MMI scale in each region (Fig.4).

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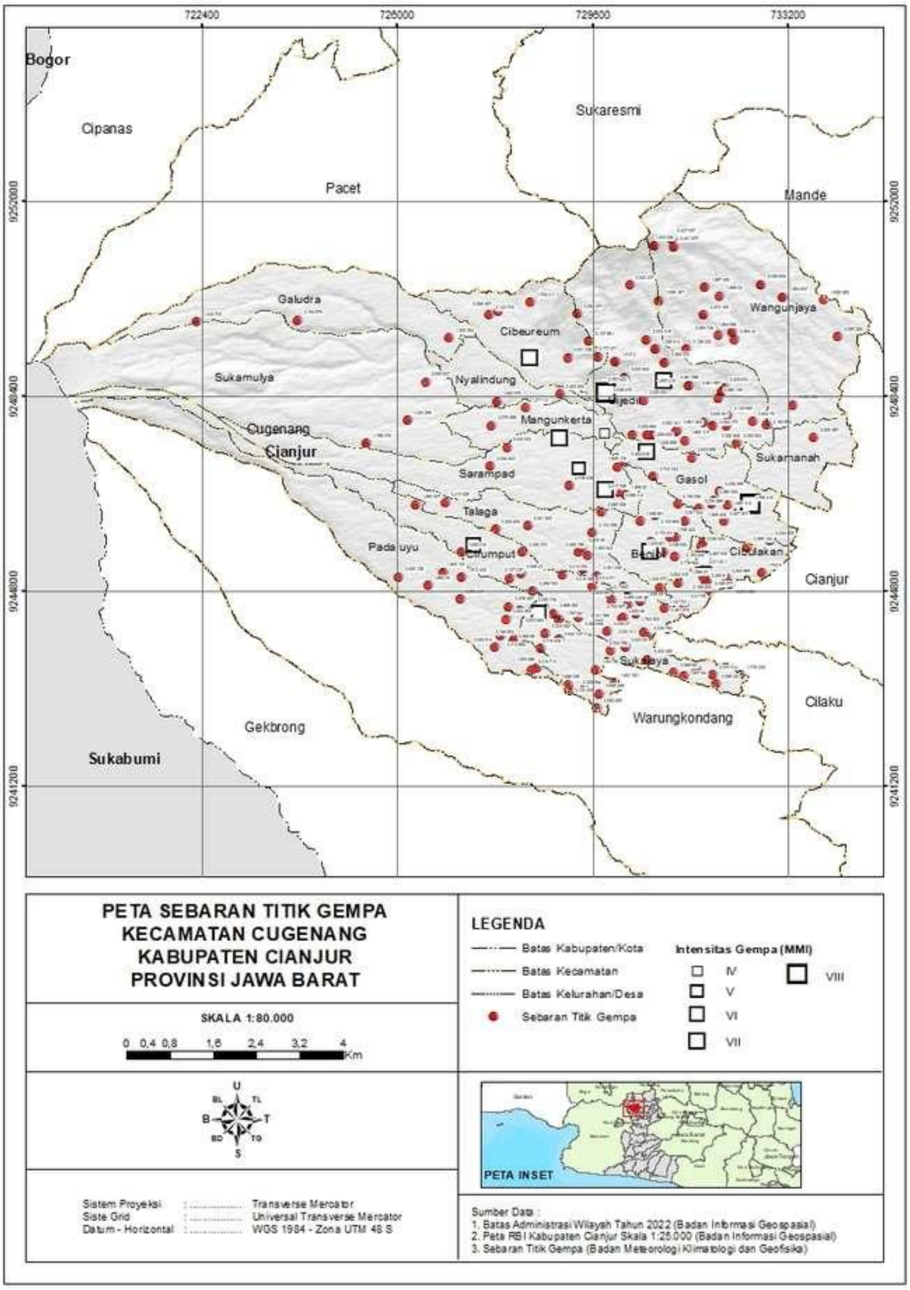

Fig 4. MMI Scale of the Cugenang Sub-district Earthquake

3.4 Geological Structure

What happened after the earthquake hit Cugenang Sub-district remains a mystery. This is because the fault pattern that occurred has a different segmentation from the surrounding faults. The Geological Agency made further observations and discovered that the trigger of the earthquake wave was the movement of a new type of fault, the Cugennag Fault. This fault has an orientation of N 347^{o} E and passes through six villages in Cugenang Sub-district, namely Cibeureum Village, Nyalindung Village, Mangunkerta Village, Sarampad Village, Cibulakan Village, and Benjot Village. Two more villages are in Pacet Sub-district, namely Ciherang Village and Ciputri Village and at the end of the fault is located in Nagrak Village, Cianjur Sub-district. This fault has a slope of 82.8 degrees with a dextral strike-slip movement mechanism. In Figure 5, the distance of the fault zone is divided into less than 100 meters from the fault, 100 - 1000 meters from the fault zone, and the rest is far from the fault zone. Development within the fault zone in the United States and characterized by weakly resistant rocks of Holocene age is 15 meters away from the fault [15]. Japan applies development along faults with a lateral distance of 100 m from the fault [16].

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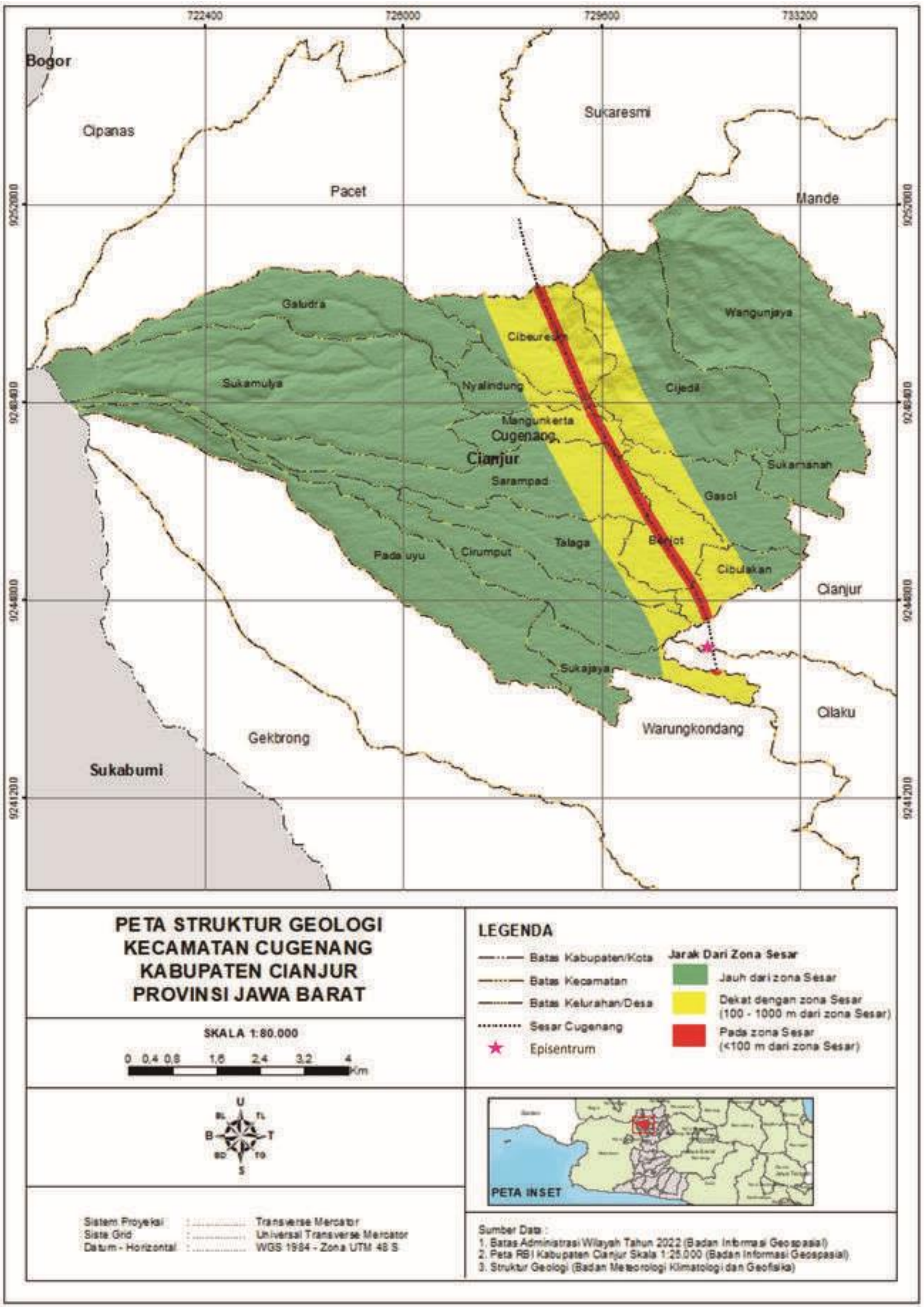

Fig 5. Map of Cugenang Fault Structure in Cugenang District

3.5 Earthquake Prone Zoning

The weighting results of the parameters of constituent lithology, slope, seismicity scale, and geological structure divide the Cugenang Sub-district area into four areas, namely, very high earthquake prone, high earthquake prone, moderate earthquake prone, and low earthquake prone. The area that is very high prone to earthquakes is due to its location near the epicenter of a shallow earthquake, the damage is also triggered by the rock structure of lahar deposits and breccia of Mount Gede (Qyg) which is not yet compact, thus exacerbating the destructive power to the surrounding environment. In addition, the distance to the Cugenang Fault is <100 meters, so it is in the movement zone. High vulnerability analysis is located along the fault zone but the distance from the epicenter is not too close. The medium zone is in the area of more than one kilometer of the Cugenang Fault zone and the low zone is very far from the fault line and the earthquake source point (Figure.6).

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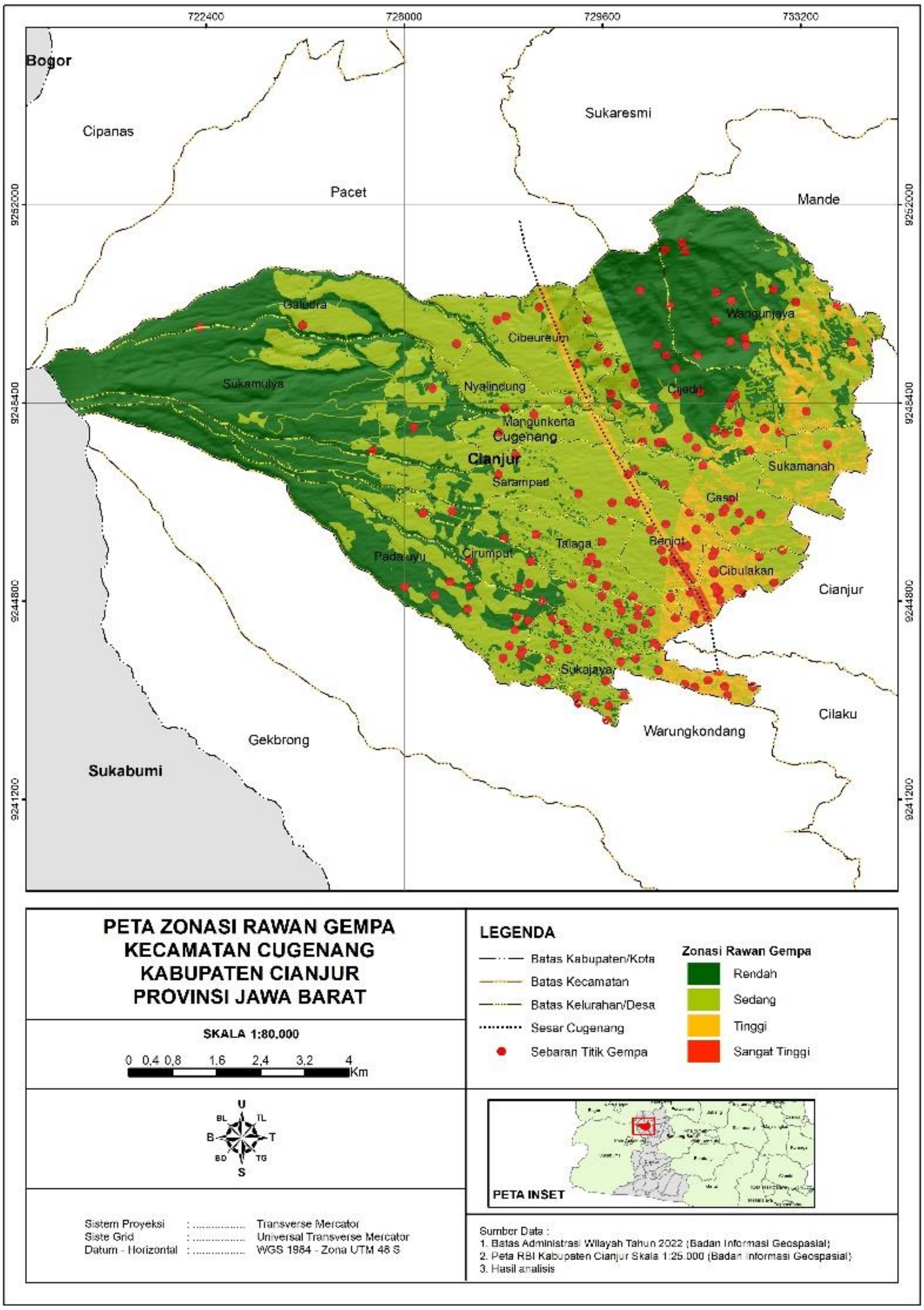

Fig 6. Earthquake prone zoning map of Cugenang sub-district

4. CONCLUSION

The site is composed of incompletely compressed Quaternary Volcanic rocks that cause stronger seismic vibrations and this situation is complemented by steep to very steep slopes that indicate the ease of ground motion. This results in a level of damage characterized by a Modified Mercalli Intensity Scale of VII - VIII resulting in minor damage to earthquake-resistant construction and strong damage to non-earthquake-resistant buildings. The Cugenang Fault structure extends from north to south and along its alignment is an area of high damage. The main factors causing earthquakes in Cugenang Sub-district are the active Cugenang Fault as a newly identified geological structure and the non-resistant constituent rocks as well as the epicenter point which is located in a shallow area, causing stronger vibrations even with a magnitude of 5.6. Cugenang sub-district can be divided into four zones: low, medium, high and very high. The widest vulnerability zoning is medium and along the fault line has a high level of vulnerability, and near the epicenter is at a very high level of vulnerability. The government needs to do real work, namely building building plans based on mitigation spatial patterns early on. The implementation of building codes can reduce losses and casualties [17]. Clear evidence of the disciplined implementation of the building code occurred in Alaska, when the M 7.1 earthquake with a shallow depth of 46.7 km occurred on November 30, 2018, only minor damage occurred [18]. [19] explains that another measure is to build buildings in the safe zone of fault movement, so as to minimize the risks caused.

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