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Identification Of Earthquake-Prone Areas Based On Earthquakes Around Deli Serdang Regency, Indonesia

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Abstract

The purpose of this study is to identify earthquake-prone areas as a study in regional planning in Deli Serdang Regency with the target of this research being to provide benefits in policy making and readiness for earthquake risk in Deli Serdang Regency and this research will contribute to science in identifying areas that have the potential for earthquake disasters. The method in this study is a quantitative method using case study research by collecting earthquake data based on a near-field earthquake with a radius of 15 km from the epicenter with data processing analysis using the Geographic Information System (GIS) program application). The parameters used are geological conditions, physical properties of rocks, slopes, seismicity, fault locations. From the results of the analysis describing earthquake-prone areas for the Deli Serdang Regency with an impacted area, Hamparan Perak sub-district with an area of 95.59 km2, Sunggal sub-district with an area of 16.45 km2, Pancur Batu District with an area of 122.53 km2 or 100%, Gunung Meriah sub-district with an area of 69.69 km2, STM Hulu sub-district with an area of 181.62 km2, Sibolangit sub-district with an area of 177.94 km2, Kutalimbari sub-district with an area of 144.56 km2, Namorambe sub-district with an area of 62.30 km2 or 100 %, Sibirubiru sub-district with an area of 84.85 km2, STM Hilir sub-district with an area of 49.42 km2, Bangun Purba sub-district with an area of 15.21 km2, Patumbak sub-district with an area of 37.24 km2, Deli Tua sub-district 9.36 km2 or 100 %, Labuhan Deli sub-district with an area of 50.86 km2, Pantai Labu sub-district with an area of 46.23 km2, Beringin sub-district with an area of 4.44 km2 and Pagar Merbau sub-district with an area of 4.38 km2

Keywords : earthquake disasters, Geographic Information System, physical properties

1. Introduction

The main effect of an earthquake for an area is the loss that has an impact on social, economic and physical conditions. Based on earthquake data from the USGS, the earthquake that occurred in North Sumatra will have an impact on the surrounding area, especially in Deli Serdang Regency. Judging from the geological map, the Medan sheet shows that the Deli Serdang area is located in a fault zone. Deli Serdang Regency is one of the regencies located on the East coast of North Sumatra. Geographically, it is located at 2057 – 3016' North Latitude and 98033' - 99027' East Longitude with an altitude of 0-500 meters above sea level. The total area is 2,497.72 km2. (Perpres. No. 62 of 2011) states that some areas of Deli Serdang Regency are located in active fault zones, namely parts of Pancur Batu District and parts of Namorambe District in Deli Serdang Regency. The existence of a fault structure seen from the geological structure map of the Medan sheet (Cameron et al. 1982) shows that in the Namorambe and Simpangdurianpitu areas adjacent to the epicenter location, there are indeed several lineament structures suspected of being fault or fault structures. In (Barlian et al. 2021) The existence of a lineament structure seen from the map of fault locations (faults) is found in the Deli Serdang Regency area as many as 44 faults (faults), namely in the districts of Gunung Meriah, STM Hulu, Sibolangit, Pancur Batu, Kutalimbaru, Namorambe, sibirubiru, STM Hilir and Bangun Purba. With the presence of faults in these areas, it can be said that the area has a very low capacity for regional stability in dealing with geological disasters and tends to be unstable. The lineaments for Deli Serdang district consist of NNE-SSW, ENE-WSW, NW-SE, WNW-ESE, NNW-SSE and E-W directions. The following in the Figure 1, shows the location of the suspected fault structure on the geological map of the Medan sheet:

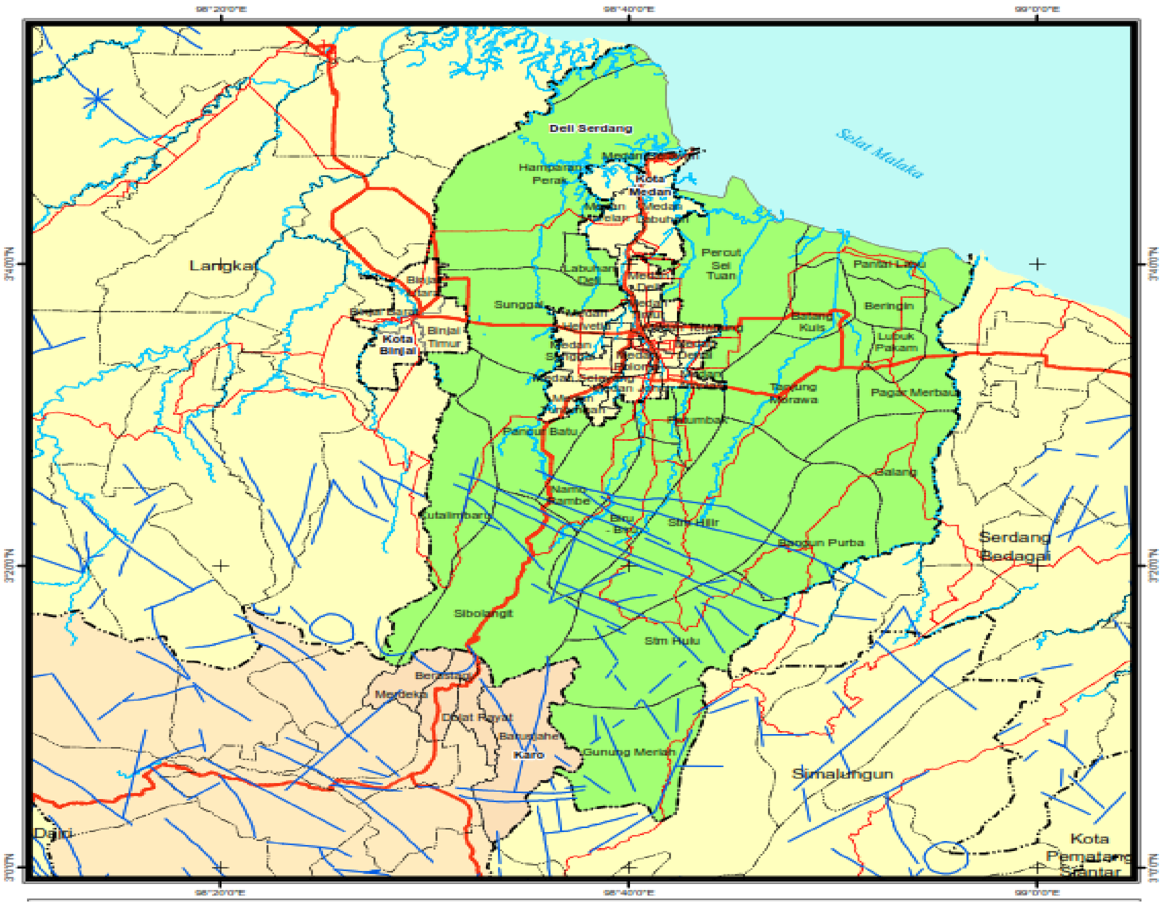


Figure 1. Deli Serdang Regency Administration Map

Based on earthquake data at the BMKG National Earthquake Center during 2018 in the territory of Indonesia, 11,920 earthquakes occurred in various magnitudes and depths. Meanwhile, in 2013 the number of earthquake activities that occurred was only 4234 times. During 2013 to 2018 there has been a drastic increase in the number of earthquake activity in Indonesia. The territory of Indonesia is very active with earthquakes, in one year earthquakes of various magnitudes occur as much as 5,000-6,000 times. Earthquakes with M>5.0 are 250-350 times, destructive earthquakes occur approximately 8-10 times and within 2 years the earthquake has the potential for a tsunami to occur 1 time. (Barlian et al. 2021). The following shows data on earthquake events around Deli Serdang district:

Table 1. Earthquake Occurrence Data around Deli Serdang Regency

Time	Lat.	Long.	depth	mag	Place
2017-01-16	3.3168	98.4696	6.00	5.60	24km N of Kabanjahe, Indonesia
2017-07-11	2.7455	98.9789	146.54	5.40	10km NNE of Parapat, Indonesia
2014-03-15	2.8381	99.0717	171.61	5.40	13km S of Pematang siantar, Indonesia
2017-02-13	3.3452	98.5146	8.12	4.90	26km SW of Deli Tua, Indonesia
2014-12-15	3.7405	97.8673	137.92	4.90	55km SW of Pangkalan Brandan, Indonesia
2017-03-18	3.2783	98.4474	10.00	4.80	20km NNW of Kabanjahe, Indonesia
2013-09-04	2.7935	98.9843	161.43	4.80	10km SE of Sarimatondang, Indonesia

2018-03-02	3.4302	97.8383	129.95	4.70	74km WSW of Binjai, Indonesia
2017-05-16	3.5403	99.1827	185.44	4.70	23km N of Tebingtinggi, Indonesia
2017-02-13	3.3567	98.5166	11.16	4.70	24km SW of Deli Tua, Indonesia
2016-03-21	3.1193	97.9142	84.30	4.70	64km W of Kabanjahe, Indonesia
2018-07-13	2.6375	99.1963	169.25	4.60	29km E of Parapat, Indonesia
2017-01-16	3.2999	98.3861	3.69	4.60	24km NNW of Kabanjahe, Indonesia
2017-02-09	3.3033	98.4167	11.85	4.50	23km NNW of Kabanjahe, Indonesia
2015-12-01	3.0954	98.0064	80.84	4.50	53km W of Kabanjahe, Indonesia
2017-10-31	3.1010	98.5486	10.00	4.40	6km E of Kabanjahe, Indonesia
2017-02-13	3.2861	98.2171	10.00	4.40	36km NW of Kabanjahe, Indonesia
2017-02-09	3.2843	98.5275	42.47	4.40	20km N of Kabanjahe, Indonesia
2015-08-04	2.7631	98.8759	158.46	4.40	10km NNE of Ambarita, Indonesia
2014-11-16	2.6656	98.5303	6.49	4.40	19km WNW of Panguruan, Indonesia
2018-07-18	3.0041	98.0570	111.16	4.30	49km WSW of Kabanjahe, Indonesia
2017-11-12	2.8130	98.9588	159.15	4.30	7km SE of Sarimatondang, Indonesia
2016-10-29	2.8364	99.1763	180.12	4.30	18km SE of Pematangsiantar, Indonesia
2017-01-31	2.9536	98.7408	35.00	4.20	6km NNE of Tigarunggu, Indonesia
2016-06-24	3.5595	97.8935	127.25	4.20	65km W of Binjai, Indonesia
2015-10-13	2.7629	99.0033	6.27	4.00	13km NE of Parapat, Indonesia

Sources: USGS 2017, (Barlian et al. 2021).

The Table 1 above shows the earthquake felt by Deli Serdang Regency in the Kabanjahe, Parapat, Pematang Siantar, Delitua, Pangkalan Brandan, Sarimatondang, Binjai, Tebing Tinggi, Ambarita, Pangururan and Tigarunggu areas. The largest earthquake strength recorded by USGS data was 5.6M with a depth of 6 km.

In this study, the observed area consisted of 22 sub-districts, namely Hamparan Perak sub-district, Sunggal sub-district, Tanjung Morawa sub-district, Percut Sei Tuan sub-district, Pancur batu sub-district, Lubuk Pakam sub-district, Galang sub-district, Gunung Meriah sub-district, STM Hulu sub-district, Sibolangit district, District Kulalimbaru, Namorambe District, Sibirubiru District, STM Hilir District, Bangun Purba District, Patumbak District, Deli Tua District, Labuhan Deli District, Batang Kuis District, Beringin District and Pagar Merbau District.

Judging from the earthquake events in recent years, a level of vigilance is very necessary for the potential for earthquakes and other disasters that can accompany them. This is due to the presence of Indonesia's territory which is located on an active fault line and a subduction zone. The source of the earthquake for the Sumatera region comes from the subduction zone of the Indian-Australian plate, active fault lines and background earthquake sources. (Irsyam et al. 2017). Based on the results of updating the national earthquake map obtained for the Sumatera earthquake source in 2010 consisting of 19 sources and in 2017 55 sources were identified (Irsyam et al. 2017) and currently the Indonesian earthquake revision team is continuing to identify and characterize the source. earthquakes in big cities in Indonesia that have not been properly identified and are a source of background earthquakes. The identified earthquake sources consist of a fault earthquake source and a subduction earthquake source.

According to (Sieh and Natawidjaja 2000), the island of Sumatera is divided into 20 geometrically defined segments of the Sumatera fault system, including the Seulimeum segment, Aceh segment, Batee segment, Tripa segment, Renun segment, Toru segment, Angkola segment, Barumun segment, Sumpur segment, the Sianok segment, the Sumani segment, the Suliti segment, the Siulak segment, the Dikit segment, the Ketaun segment, the Musi segment, the Manna segment, the Kumering segment, the Semangko segment and the Sunda segment. The area of North Sumatera Province is traversed by 3 (three) segments of the Sumatera fault which are the source and path of earthquake propagation on land. The fault segments are the Renun segment, the Toru segment and Angkola segment. The earthquake source map for the Sumatera region can be seen in the following in Figure 2:

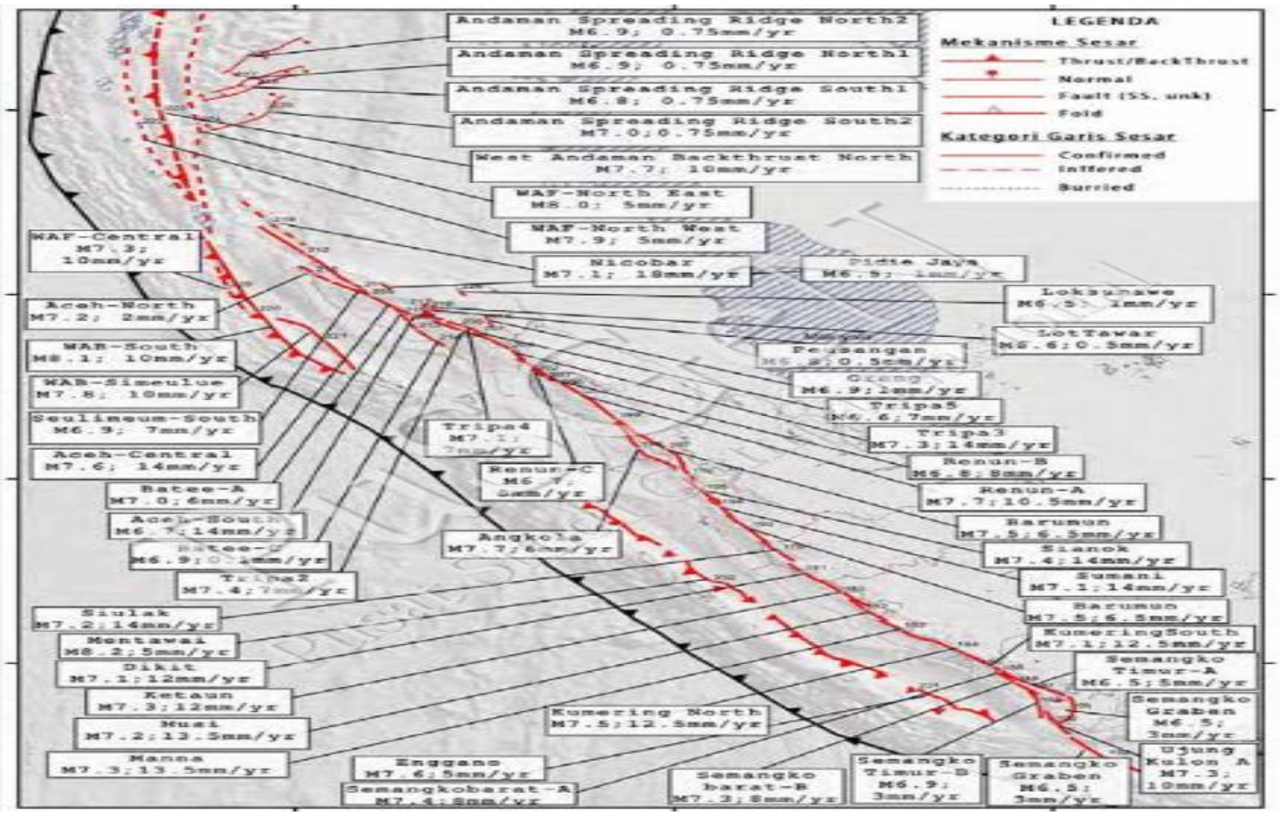


Figure 2. Map of the Sumatera earthquake source in 2017 (Irsyam et al. 2017)

The island of Sumatera is located in an area that has active tectonic conditions caused by the subduction of the Indian Ocean plate from the west into the island of Sumatera in the east which is part of the Eurasian plate. (Naryanto 1997). In the historical record of the last 300 years, there were two large-scale earthquakes with M> 8 in 1833 and 1861 which destroyed several areas in Sumatera caused by shifts between plates ((Newcomb & McCann, 1987); (Prawirodirdjo et al. 2010). The Great Earthquake in 1833 showed that the plate was subducting which resulted in strike-slip faults and unusually large subduction earthquakes (Sieh and Natawidjaja 2000).

2. Literature Review

2.1. The Earthquake

The active tectonics in western Indonesia is dominated by the convergence of the Indo-Australian Plate with the Eurasian Plate. This convergence resulted in the Sumatera trench which extends to the west of Sumatera and south of Java. (Makrup 2013), stated that plates with different types of movement have formed the subduction zone and the transform fault zone (the transform zone), which are now active earthquake source zones. A fault is considered active if it has moved one or more times in the last 10,000 years or the last 5,000 years

All cracks in the earth's surface produce a displacement. Fault is a type of crack where the displacement is large parallel to the surface where the fault occurs. (Nevin 1949). In (Asrurifak 2010), (Noor 2011) said faults or faults in tectonic plates that occur due to their movements, which will contribute to the occurrence of shallow earthquakes. The types of faults consist of normal faults (normal faults), thrust faults and strike-slip faults. (Suppe 2005).

Approaches and concepts in identifying earthquake-prone areas based on near-field earthquakes. The area that will have an impact due to an earthquake is an area that is close to the source of the earthquake, in the study (Heydari and Mousavi 2015) a distance of 10-60 km from the epicenter is a close earthquake. UBC-97 considers a distance of less than 15 km from the epicenter as a short distance. The minimum distance to the fault considered is 10 km. (Estrella, Guindos, and Almazán 2019), (Alhan and ncü-Davas 2016), (Somerville 2003), (Ashrafi et al. 2016) and (Ochoa, Niño, and Vargas 2018). In the study (Adanur et al. 2012) the distance from the fault was less than 10 km. The closer the earthquake source, the greater the risk of damage to infrastructure which can reach eight times that which is located at a distance of 20 km. (Zhong et al. 2020).

3. Methods

The method applied in this research is a quantitative method using case study research by collecting earthquake data that will affect the area of earthquake-prone areas by processing data using the Geographic Information System (GIS) program application. To be useful, information must also be reliable. Information has the quality of being reliable if it is free from error and can be relied on by users as a representation that is appropriate in the circumstances (Simanjuntak et al., 2020 and Yanita et al., 2020). In this study, the parameters used are geological conditions, physical properties of rocks, slopes, seismicity, and fault locations. The physical properties of the rock reflect the condition of the rock's strength in accepting the load and pressure as well as in terms of its compactness, hardness and material. The slope of the slope can provide information about the level of land stability against the possibility of landslides, soil and rock collapse. Seismicity is information that shows the time of occurrence, earthquake coordinates, depth, magnitude and location. The fault zone is an illustration of how large the region's stability is when it experiences an earthquake. The physical properties of rocks are a reflection of the condition of the strength of the rock to accept the load and pressure seen from the strength of the rock, its compactness, its hardness and the material that forms it. The assessment matrix for rock physical properties is presented in the following Table 2:

Table 2. Assessment of geological variables (rock physical properties)

No.	Rock Unit Stratigraphy		Rock Unit	Ability Value
1	Qvbr	Barus Volcano Rock	andesite and pyroclastic lava	High
2	Tob1	Bruksah Formation	sandstone and conglomerate	High
3	QTim	Menden's Microdiorite	Menden's Microdiorite	High
4	Qvba	Sibayak Unit	andesite, dacite and pyroclastic	High
5	Qvbj	Binjai Unit	flow breccia with andesite to decite	High
6	QTvk	Takur-Takur Unit	andesite, dacite and pyroclastic	High
7	Tmb	Baong Formation	mudstone (some glauconite) and sandstone	Medium
8	Mtk	Kuala Formation	shale, sandstone and siltstone	Medium
9	Tmpb1	Member of Notai	reef limestone, glauconite sandstone, siltstone	Medium
10	Qvbs	Short Unit	andesite, dasei, microdiorite, tuff	Medium
11	QTvm	Mentar Unit	Pyroclastic pumice composed of andesite to dacite	Medium

12	Qvt	Tuffa Toba	ryodite tuff, partially welded	Medium
13	Qpme	Field Formation	pebbles; sand; silt and clay	Low
14	Qh	Young Alluvium	gravel, sand and clay	Very low

The slope of the slope can provide an overview of the level of stability against the possibility of landslides or soil and rock collapse, especially during an earthquake disaster. Slope slope information uses the slope classification made by van zuidam (1988). Slope criteria consist of flat, sloping, sloping, slightly steep, steep, very steep and steep. Seismic data obtained from the USGS from 1900 to 2018 with geographic points of take-up coordinates at 7.508º north, -7,463º south, 92.087º west and 108.501º east. Earthquake data obtained consists of latitude and longitude points, earthquake magnitude, depth and location of the incident area. Earthquake data is also combined from the Earthquake Catalog of the Meteorology, Climatology and Geophysics Agency (BMKG). In this study, soil acceleration data in bedrock (PGA) was obtained from Design Spectra Indonesia (Puskim PU) by entering coordinate points based on a grid with a distance of 5 km so that it could display a contour map of soil acceleration. In this study, the concept of identifying earthquake-prone areas is based on near-field earthquakes with a radius of 15 km from the epicenter. Seismicity factor is information that shows the level of earthquake intensity which includes the PGA value. The parameter value of PGA as seismicity variable can be seen in the following Table 3:

Table 3. Assessment of seismic variables

Variable	Assessment Criteria (PGA)	Ability Value
Seismicity	<0,05PGA	High
	0,05-0,15PGA	Medium
	0,15-0,30PGA	Low
	>0,30PGA	Very Low

Source: Ministry of Public Works Regulation No. 21 of 2007

For the study of geological structures, the distance to the fault zone is used as a reference for regional stability. The assessment matrix for the stability of earthquake-prone areas is presented in the following table 4

Table 4. Assessment of geological structure variables

Variable	Assessment criteria	Ability Value
Geological Structure	Far from fault zone >1000m	High
	close to fault zone 100m - 1000m	Medium
	in the fault zone <100m	Very low

Source: Ministry of Public Works Regulation No. 21 of 2007

The location of this research was carried out in Deli Serdang Regency which covers 22 sub-districts with an area of 2497.81 km2, namely: Gunung Meriah District, Sinembah Tanjung Muda Hulu District, Sibolangit District, Kutalimbaru District, Pancur Batu District, Namorambe District, Sibiru Biru District, District Sinembah Tanjung Muda Hilir, Bangun Purba District, Galang District, Tanjung Morawa District, Patumbak District, Deli Tua District, Sunggal District, Hamparan Perak District, Labuhan Deli District, Percut Sei Tuan District, Batang Kuis District, Pantai Labu District, Beringin District, Lubuk Pakam District and Pagar Merbau District, Deli Serdang, Indonesia.

4. Result and Discussion

4.1. Result

Based on Geology, Deli Serdang Regency rock formations consist of Baong Formation (Tmb), 0.07%, 0.30% is Volcanic Rock (Qvbr), 0.74% is Bruksah Formation (Tob1); 0.02% are Kuala Formation (Mtk), 14.98% are Medan Formation (Qpme), 0.25% are Mendem Microdiorites (QTim), 0.02% are Members of yetai (Tmpb1), 0 ,34% is Sibayak Unit (Qvba), 4.06% is Singkut Unit (Qvbs), 15.45% is Binjai Unit (Qvbj), Mentar Unit (QTvm), Takur-Takur Unit (QTvk), Tufa Toba (Qvt), and Young Alivium (Qh). Deli Serdang district rock formations can be seen in the image below:

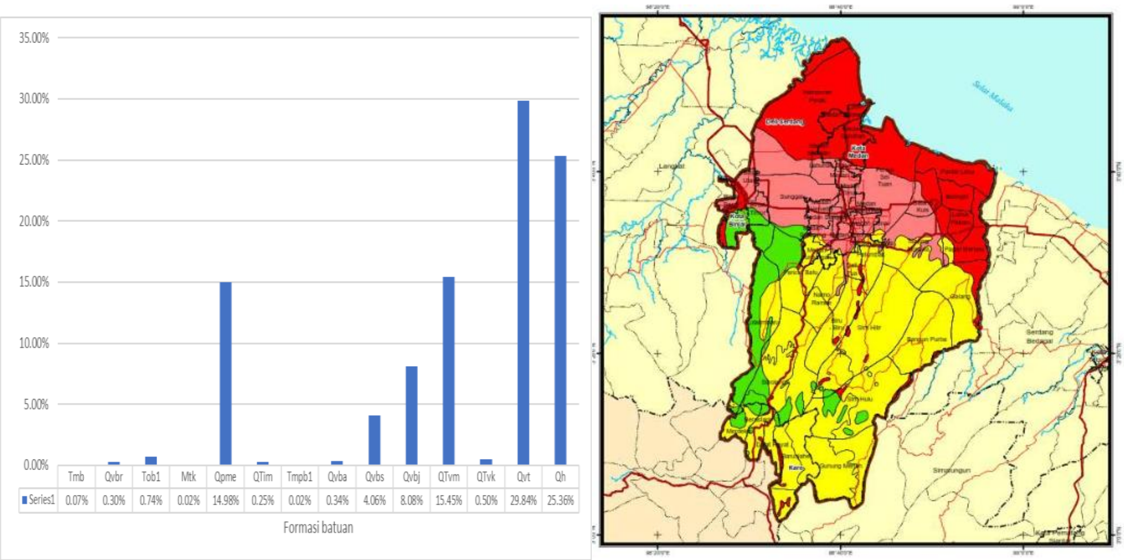
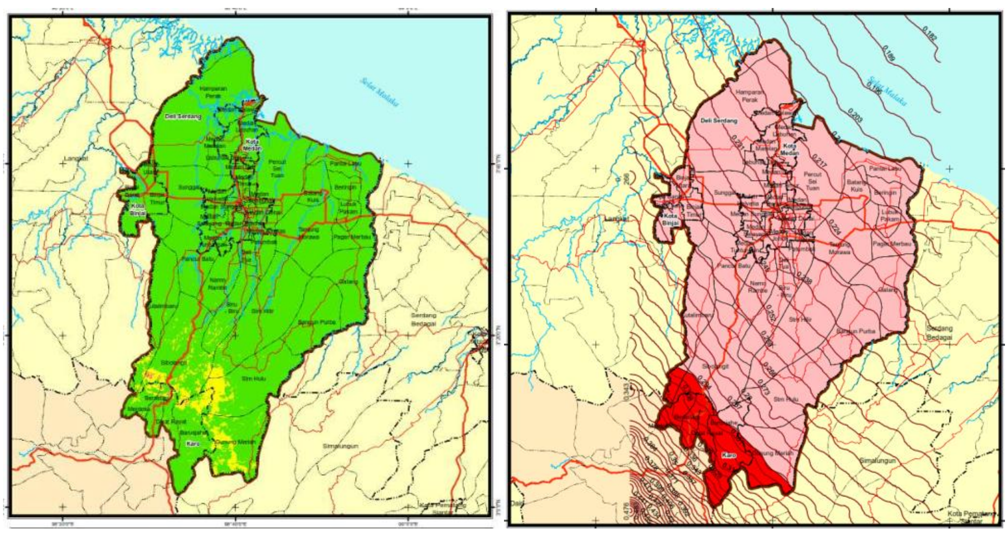


Figure 3. Rock Formation of Deli Serdang Regency

Based on the physical and engineering properties of rocks in dealing with earthquake disasters in the Deli Serdang Regency area, they consist of 10.21% with a high classification, 49.45% with a medium classification, 14.98% with a low classification and 25.36% in a very low classification. The Deli Serdang Regency area is located in a gently sloping area with a steep slope. Areas with steep slopes are located in the Sibolangit and Kutalimbaru areas with an area of only 0.15 km2. In general, the Deli Serdang Regency area has a flat and sloping area with an area of 2,378.71 km2 or 95.23% of the Deli Serdang Regency area.



a. b.

Figure 4.

a. slope map

b. Contour value of ground acceleration (PGA)

Seismic values in the Deli Serdang Regency area ranged from <0.15g-0.30g with a low classification of 97.60% and >0.30g with a very low classification of 2.40%. Areas with a very low classification of earthquake occurrences include parts of Gunung Meriah sub-district which is around 0.91%, some Sibolangit sub-district 0.65% and some Kutalimbaru sub-districts 0.84% of the total area of Deli Serdang Regency.

The most distant sub-district from the fault zone is the Hamparan Perak sub-district with a distance of 38.78 km. Most of the Deliserdang area is included in the very low area classification category due to the large number of inactive faults in the area, including the STM Hulu sub-district with 13 faults. This shows that some areas of Deli Serdang Regency are in the stable zone and some are in the very low zone in dealing with disasters in Figure 5.

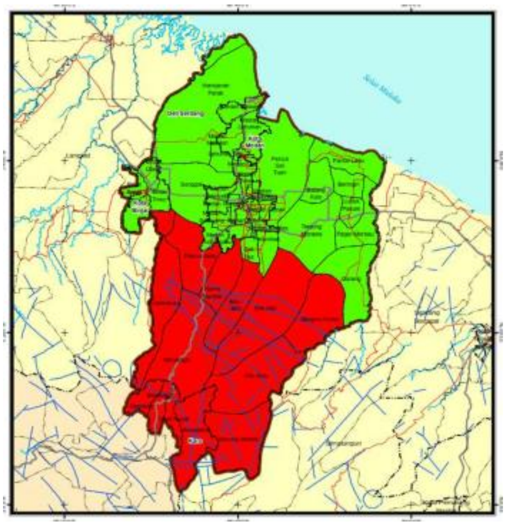


Figure 5. Fault zone area (fault)

The earthquake that was felt around the city of Mebidangro with a radius of 15 km from the epicenter of the earthquake was 21 times with a maximum magnitude of 5.6 and VI on the MMI scale which occurred on January 16, 2017 at a depth of 6 km with a distance of 8.91 km from Sibolangit sub-district and felt in the Pancur Batu sub-district, Sibolangit sub-district, Kutalimbaru sub-district, Sibirubiru sub-district in Deli Serdang district, Berastagi sub-district, Merdeka sub-district and Dolat Rakyat sub-district in Karo district. Data on earthquake events with a radius of 15 km from the epicenter can be displayed in the following Table 6:

Table 6. Earthquake data with a radius of 15 km from the epicenter

Date	Mag	MMI	Depth km	Location	Number of affected areas
1978-03-10T17:11:52	4.20	V	121.00	12.27km from STM Hulu	4.00
1984-02-02T21:13:00	4.40	V	43.90	13.66km from Hamparan Perak	2.00
1986-11-18T06:45:26	4.60	V	185.80	17.93km from Hamparan Perak	2.00
1990-11-27T00:28:28	5.10	VI	144.90	15.96km from Merdeka	3.00

1996-11-25T08:32:49	4.10	V	100.00	1.20km from Kutalimbaru	7.00
1997-07-24T01:44:16	4.00	IV	177.30	17.26km from Gunung Meriah	1.00
1999-10-24T11:42:02	4.40	V	150.70	4.84km from Merdeka	10.00
2000-07-16T15:22:48	4.70	V	146.30	13.23km from Kutalimbaru	2.00
2005-12-20T10:12:26	4.40	V	30.00	3.81km from Pancur Batu	18.00
2006-02-01T11:49:04	4.10	V	30.00	14.29km from Merdeka	3.00
2006-04-20T22:17:53	4.00	IV	30.00	15.03km from Pantai Labu	3.00
2007-05-10T02:25:18	3.70	III	152.60	6.66km from Barusjahe	10.00
2017-01-16T12:42:10	5.60	VI	6.00	8.91km from sibolangit	7.00
2017-01-16T12:46:11	4.60	V	3.69	15.09km from Merdeka	3.00
2017-01-31T15:10:42	4.20	V	35.00	20.14km from Gunung Meriah	1.00
2017-02-09T18:00:07	4.50	V	11.85	12.84km from Merdeka	4.00
2017-02-09T21:50:54	4.40	V	42.47	5.15km from sibolangit	11.00
2017-02-13T17:11:17	4.70	V	11.16	5.41km from sibolangit	8.00
2017-02-13T20:35:57	4.90	V	8.12	5.45km from sibolangit	9.00
2017-03-18T10:51:10	4.80	V	10.00	9.16km from Merdeka	6.00
2017-10-31T00:31:35	4.40	V	10.00	5.15km from Barusjahe	7.00

Source: Researcher Analysis (2019)

Based on earthquake data around the Mebidangro area, it shows that background earthquake sources contribute to earthquake events in the past and in the future. Based on the depth level of the earthquake, it is included in the category of medium earthquake and shallow earthquake and is a near earthquake category. The location of the earthquake point in the Mebidangro area with a radius of 15 km can be seen in the following Figure 6:

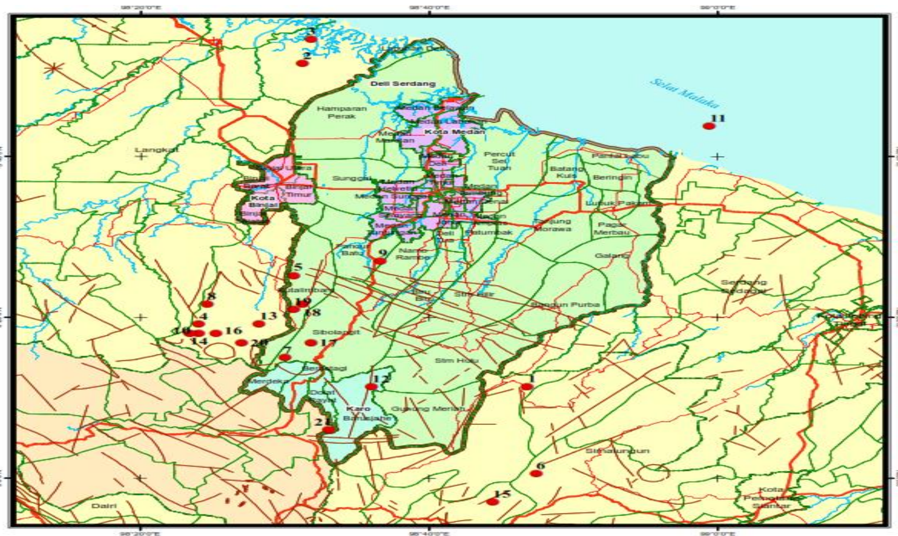


Figure 6. The position of the earthquake with a radius of 15 km from the epicentre

The history of earthquakes around the Deli Serdang district that has occurred is in 1978 with an epicenter distance of 12.27 km from STM Hulu sub-district, in 1984 with an epicenter distance of 13.66 km from Hamparan Perak sub-district, in 1986 with an earthquake center distance of 17. ,93 km from Hamparan Perak sub-district, in 1990 with an epicenter distance of 15.96 km from Merdeka sub-district, in 1996 with an epicenter distance of 1.20 km from Kutalimbaru sub-district, in 1997 with an epicenter distance of 17.26 km from Gunung Meriah sub-district , 1999 with an epicenter distance of 4.82 km from Merdeka sub-district, in 2000 with an epicenter distance of 13.23 km from Kutalimbaru sub-district, in 2005 with an epicenter distance of 3.81 km from Pancur Batu sub-district, in 2006 with a distance of epicenter 14.29 km from Merdeka sub-district and at a distance of 15.03 km from the epicenter of Pantai Labu sub-district, in 2007 with an epicenter of 6.66 km from Barusjahe sub-district, in 2017 with an epicenter of 8.91 km from the sub-district an Sibolangit, at a distance of 15.09 km from the epicenter of Merdeka sub-district, 20.14 km to the distance of the epicenter of Gunung Meriah sub-district, the distance from the epicenter of the earthquake to 12.84 km from Merdeka sub-district, 5.15 km from the epicenter of Sibolangit sub-district, The epicenter was 5.41 km from Sibolangit sub-district, 5.45 km from Sibolangit sub-district, 9.16 km from the Merdeka district and 5.15 km from Barusjahe.

The impact of the earthquake that occurred around Deli Serdang Regency will have an impact on residential areas, public facilities such as government centers, offices, education, places of worship, productive land such as rice fields, forests, irrigation; transportation systems, pipelines, power transmission lines, and water resource networks such as reservoirs. The earthquake was felt in almost all sub-districts, namely: Hamparan Perak sub-district with an area of 95.59 km2, Sunggal sub-district with an area of 16.45 km2, Pancur Batu District with an area of 122.53 km2 or 100%, Gunung Meriah sub-district with an area of 69.69 km2, STM Hulu sub-district with an area of 181.62 km2, Sibolangit sub-district with an area of 177.94 km2, Kutalimbari sub-district with an area of 144.56 km2, Namorambe sub-district with an area of 62.30 km2 or 100%, Sibirubiru sub-district with an area of 84.85 km2, STM Hilir sub-district with an area of 49.42 km2, Bangun Purba sub-district with an area of 15.21 km2, Patumbak sub-district with an area of 37.24 km2, Deli Tua sub-district 9.36 km2 or 100%, Labuhan Deli sub-district with an area of 50, 86 km2, Pantai Labu sub-district with an area of 46.23 km2, Beringin sub-district with an area of 4.44 km2 and Pagar Merbau sub-district with an area of 4.38 km2. The Deli Serdang district affected by the earthquake with a radius of 15 km can be seen in the following Figure 7:

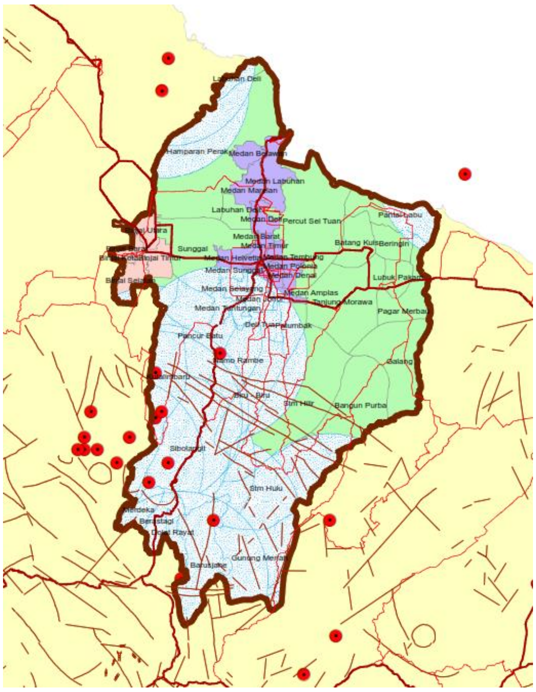


Figure 7. The impact of an earthquake with a radius of 15 km from the epicenter

5. Conclusion

Based on several research results, the following conclusions can be drawn: Earthquake-prone areas for Deli Serdang Regency with an impacted area are Hamparan Perak sub-district with an area of 95.59 km2, Sunggal sub-district with an area of 16.45 km2, Pancur Batu District with an area of 122 km2. ,53 km2 or 100%, Gunung Meriah sub-district with an area of 69.69 km2, STM Hulu sub-district with an area of 181.62 km2, Sibolangit sub-district with an area of 177.94 km2, Kutalimbari sub-district with an area of 144.56 km2, Namorambe sub-district with an area of 62.30 km2 or 100%, Sibirubiru sub-district with an area of 84.85 km2, STM Hilir sub-district with an area of 49.42 km2, Bangun Purba sub-district with an area of 15.21 km2, Patumbak sub-district with an area of 37.24 km2, Deli Tua sub-district 9.36 km2 or 100%, Labuhan Deli sub-district with an area of 50.86 km2, Pantai Labu sub-district with an area of 46.23 km2, Beringin sub-district with an area of 4.44 km2 and Pagar Merbau sub-district with an area of 4.38 km2

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