Assessment of regional spatial plan (RSP) of areas along the active fault of Seulimeum segment in Aceh Province

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Abstract. The Seulimeum Segment is the northernmost branch of the Great Sumatran Fault. This active fault crosses settlements in Aceh Besar Regency and Pidie Regency in Aceh Province. Tectonically, this situation can be a threat along the active fault line. In this study, active fault lines of the Seulimeum Segment were mapped. Based on the active fault lines, residential areas, infrastructure distribution, and Regional Spatial Plan (RSP) were reviewed for eligibility. Some areas, e.g., Tangse, Lamtamot, and Krueng Raya, were the focus of this study. Avoidance zones were categorized based on their distances from the active fault line, which were 20 m from the fault, 100 m from the fault, and 300 m from the fault. According to an active fault line analysis on the RSP map, infrastructure map, and demographics map, the Krueng Raya area would be the most affected by losses due to disasters in the future. Some buildings, hospitals, mosques, government offices, settlements, and industrial areas in Krueng Raya are situated along an active fault line. It is because the RSP of this area has not yet considered the potential for geological disasters in the infrastructure development process. Some recommendations have been proposed to reduce the impact of losses in the future.

1. Introduction
So far, the establishing of the Regional Spatial Plan (RSP) in Aceh Province has not fully considered the geological threat aspects. Previous geological disaster activities have caused a lot of material loss and threatened human lives. This should be the basis for realizing the importance of disaster aspects in infrastructure development in the future. Meanwhile, the government has issued a map of active fault distribution and potential earthquake hazards in Indonesia, including the Aceh region. Along these fault lines, especially in the southern part of Sumatra, there have been quite a lot of seismic activities, while the northern part has not shown significant seismic activity since 170 years ago [1,2]. The north side of the Great Sumatran Fault is divided into two branches that extend to the Andaman Islands, namely, the Aceh Segment that heads to Aceh Island and the Seulimeum Segment that heads to Weh Island, Sabang [2]. Figure 1 shows the seismic activities with Mw ≥ 3 recorded by the United States Geological Survey (USGS) from 1980 to 2020 along the Aceh Segment and Seulimeum Segment [3]. If the energy stored...
in the fault zone is not released, referring to [4], then the Aceh region has the potential to experience an earthquake with \( M_w \geq 7 \). This is a serious threat to the Aceh region in the future. Besides, theoretically, each segment of the GSF ruptures every 100-200 years [1,2]. This seismic gap has the potential to generate earthquakes of around \( \sim 7.4 \) \( M_w \) due to the absence of energy released so far [4].

![Map of Aceh Province and Seulimeum Segment](image)

**Figure 1.** Seulimeum Segment is marked as a research location (red box).

Referring to Figure 1, along the Seulimeum fault, there are several public infrastructures, such as schools, places of worship, hospitals, and residential areas [2,5]. Besides, there are also several historical sites located right on the Seulimeum Segment, such as Lamtamot [6] and Lamreh [7]. Therefore, several studies have been conducted to map faults along the Seulimeum Segment, for example, seismology [8], geophysics [2,9–11], remote sensing [12], and geomorphological observations using DEMNas (BIG, 2018). Based on the information on active faults of the Seulimeum Segment, as a disaster mitigation initiative in Aceh Province, the appropriateness of the Regional Spatial Plan along that segment is an important matter to be reviewed. This research outlines studies and applications to prevent or reduce the risk of disasters and damage from future earthquakes by considering safety, appropriate planning, and finishing processes.

2. **Data and methodology**

In this research, some information regarding the Seulimeum Segment fault based on geophysical, geomorphological, and remote sensing research was used. The data on the fault becomes the base map for adjusting the map of the Regional Spatial Planning of the Aceh regional government. The implementation of the Aceh region as an independent region, taking mandates, and making decisions to regulate and manage the Aceh region has been regulated since 2006 [13]. Then, based on the provisions of Spatial Planning (Law Number 26 of 2007) and based on the provisions of the National Spatial Plan (Government Regulation Number 26 of 2008), each regency or city administrative region, via the regional head, prepares a Regional Spatial Plan. At this stage, the map of the Regional Spatial Plan was obtained from regencies along active fault lines, which are Aceh Besar Regency (Qanun (Local Law) of Aceh Besar Regency Number 4 of 2013) and Pidie Regency (Qanun of Pidie Regency Number 5 of 2014).
However, the spatial planning map was only analyzed partially. The analysis was only conducted on zones through which the fault line passes. In addition, sampling was also conducted to analyze areas representing public activity along active faults. Sampling was expected to be able to describe the overall state of activity along the fault line. This study employed a quota sampling method. Sampling was conducted on three samples with an area of 800 x 4,000 m per sample. Two samples were in Aceh Besar Regency and one sample was in Pidie Regency. These locations were chosen cause to cover all of the Seulimum segments, i.e. Tangse area which characterized as the segment in the tip of the South-West side, while Lamreh is corresponds to the tip of the Northeast side and the Lamtamot as the middle of the Seulimum segment.

3. Result and conclusion
Information about active faults that were obtained from various sources was used as a base map, and then the distance between an object and the fault was classified. Figure 2.a. shows the avoidance zone of Seulimeum Segment, which was divided into 3 zones, namely: 20 m from the fault, 100 m from the fault, and 300 m from the fault. In general, there are several villages in Aceh Besar Regency and Pidie Regency that are in parallel areas with the avoidance zone of Seulimeum Segment. The data showed that there were 77 villages from 2 regencies, which were distributed into 34 villages in 5 sub-districts in Aceh Besar Regency and 43 villages in 4 sub-districts in Pidie Regency. According to statistical data from Statistics Indonesia in 2010 (Figure 2.b), 21,183 people were in locations that intersected with active faults. A total of 13,713 people were in Aceh Besar and 7,470 people were in Pidie. The 2010 data were chosen because the population survey in Indonesia is conducted every 10 years (Law Number 6 and Law Number 7 of 1960). Of course, the population in those areas has probably increased by now. Based on the projection results, population growth in Aceh in 2020 will reach 0.19%.

![Figure 2](image-url). (a) Distribution of areas that are adjacent to the active fault line of the Seulimeum Segment, (b) population in villages that intersect with the main fault of the Seulimeum Segment (modification based on Statistics Indonesia (BPS), 2010).

Besides, statistical data showed that Lamtamot was the village that was close to the fault and had the largest population, which was ~ 2,022 people, while as many as ~1,022 people lived in Lamteuba Dro Village, Lambada Village, Meunasah Keudee Village, Meunasah Mon Village, Lhok Keutapang Village, Alue Calong Village, and Beungga Village. In the locations that have been mentioned, a good mitigation initiative must be implemented because greater losses will be potential for densely populated...
areas. Based on experience, even relatively small-magnitude earthquakes caused very large losses, for example, the Central Aceh earthquake in 2013 with Mw 6.1 [5], the Pidie Jaya earthquake with Mw 6.5 in 2016 [4,8], and two earthquakes near the Seulimeum Segment in 1936 with Mw 7.1 - 7.3 [14] and in 1964 with Mw 6.5 [2]. This was because the epicenters of the earthquakes were located close to the residential area.

To study the potential area of the surface structure, focusing areas in several places that were in direct contact with the Seulimeum Segment, such as Lamreh in Krueng Raya, and Lamtamot in Seulimeum, Aceh Besar Regency, and Tangse in Pidie Regency, were analyzed. Figure 3a shows development activities, infrastructure, and settlements in the area of Lamreh, Aceh Besar. Public activities, in the form of settlements, were in the middle on the east side, heading towards the middle to the end of the northwestern part, while the rest were landscapes, such as shrubs, agricultural land, and rivers. Figure 3b is the distance of the Seulimeum Segment fault area to public activities and public infrastructure in Aceh Besar, which are specifically located at (a) Lamreh, Krueng Raya, and (b) Lamtamot, Seulimeum, Aceh Besar. The map shows that several places intersect with the fault, namely rice fields, ponds, and agricultural land. Important areas that are in contact with active faults are settlements, buildings, and places of worship. Several other places, from health care facilities, hospitals, buildings, houses of worship, government offices, to residential and industrial areas, are still in the avoidance zone. The area of Lamtamot, Seulimeum (Figure 3b), is still in the avoidance zone, although this area is generally located in forest and shrubland and is used as rice fields and agricultural land in general. Based on the maps, infrastructure development is right on the fault trail of the Seulimeum Segment. The infrastructure consists of residential houses, places of worship, health care facilities, administrative offices, and markets, which are located in the avoidance zone that is relatively close to the Seulimeum Segment.

As a Lamtamot area, the Tangse in Pidie Regency is also in geomorphology of the forest, agricultural land, and several rivers. Figure 4 shows that the centralization of development is in the northwest direction and concentrated in the southeast. Several important places, namely, houses of worship, health care facilities, government offices, and residential areas, intersect with active faults. Figure 4b shows that some public infrastructures, such as hospitals and settlements, are on the Seulimeum Segment line.
(marked by the white line in the figure). Referring to [15], the Acehnese people tend to evacuate themselves to places of worship when a disaster occurs, especially a tsunami or an earthquake disaster. However, the analysis of the distance of Seulimeum Segment with several infrastructures indicated that most of the places of worship, health care facilities, and puskesmas (community health centers) were right on the fault line or were close to the avoidance zone, even though these places are the first places to await for evacuation when a disaster occurs. As shown in Figure 4.c, the position of the mosque in Tangse Village is close to the Seulimum fault.

Therefore, several recommendations are formulated as an effort to reduce the risk of infrastructures that are built close to the Seulimeum Segment, for example, recommendations for establishing evacuation routes and building assembly points. The assembly point at Lamreh, Krueng Raya, is recommended to be in the east along the coastline and relatively close to places of worship. Meanwhile, in the Tangse area, it is recommended that the evacuation route and assembly point be built on the northeast and southeast, it caused to a safe distance from the fault (as shown by the blue dotted line in Figure 4). In addition, other recommendations are to limit infrastructure development in areas that intersect the fault or adjacent to the fault line, conduct settlement relocation, relocate buildings, prohibit reconstruction, prohibit tenancy, and prohibit the construction of new buildings that are excluded based on recommendations from comprehensive geological studies.

Based on the analysis data, the feasibility study of the Regional Spatial Plan, residential areas, and infrastructure distribution conclude that the potential for geological disasters has not been considered
both in the preparation of the Regional Spatial Plan and the development process in the area along the Seulimeum Segment. The recommendation that is proposed based on this research is to review the Regional Spatial Plans of areas that intersect with active faults. This is crucial to avoid disaster risks and formulate future disaster mitigation plans. In addition, a policy regarding structures and buildings that have been erected along active faults needs to be made. The policy is expected to be able to limit development and relocation and be able to provide knowledge to the public about the major risks to be faced in the future.

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