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Location Mapping and Tsunami Disaster Evacuation Pathway Using Dijkstra Algorithm in Kota Sigli District, Pidie District

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Abstract

Sigli City Sub District is one of the Sub Districts affected by the 2004 tsunami. At that time, the community did not understand the danger of the tsunami and did not understand how to save themselves. The purpose of this study was to identify and to map out effective tsunami evacuation locations and routes in Sigli City Sub District using Dijkstra algorithm. Primary data (tsunami inundation) for this study were obtained from interviews with community representatives involving 32 people in 16 villages. Administrative map, topographic map, population density map, contour map and land use map (secondary data) were obtained from relevant institutions. The results of the study indicate that horizontal evacuation can be done through available paved road living the coastal area towads 4 recommended locations based on the physical feasibility of the land. For vertical evacuation, 24 buildings available in 7 villages can be recommended, on the condition that their structural feasibility and access standard are met.

Keywords: Evacuation Location; Evacuation Route; Dijkstra Algorithm

1. Introduction

The major disaster that ever hit Indonesia was the earthquake and tsunami that occurred on December 26, 2004 in Aceh. The earthquake measuring 9.3 on the Richter scale occurred at a depth of 30 Km, which killed 127,720 people, 93,285 people were lost and 635,384 people had to be displaced (Aceh-Nias Reconstruction Rehabilitation Agency, 2009).

The tsunami that hit Aceh was one of the biggest natural disasters in the world that occurred around 45 minutes after the earthquake was shaken, then the tsunami waves swept the coast along 800 kilometers (LIPI-UNESCO / ISDR, 2006). The number of casualties and chaos during the evacuation, is evidence of the inability of the community to deal with the tsunami disaster at that time (Leitch, 2007).

Sigli City District is one of the areas affected by the tsunami in 2004 (Steuer et.al, 2008). This event has destroyed public facilities, community settlements, claimed as many as 1,359 lives and disturbed the psychological condition of the community (Detik News, 2004).

At that time, the community did not understand the dangers of the tsunami and did not carry out proper evacuation resulting in many losses and casualties (Montz et.al, 2017). Panic during evacuation can cause mass buildup on roads caused by the community.

This shows that the community in Sub-district Sigli clearly needs an understanding of the location of evacuation and good evacuation routes, so as to reduce the impact of a tsunami disaster, the objectives of this study are: (1) Identifying effective locations and evacuation routes in the event of a tsunami in the City of Kota Sigli, Pidie District; and (2) Mapping the location and effective tsunami evacuation route in Kota Sigli Subdistrict, Pidie Regency using the Dijkstra algorithm.

Tsunamis are shallow water waves that can cross the entire ocean without losing large energy. The Tsunami phenomenon experiences strong wave shoaling, which together with a funnel and an internal resonance effect can increase the tsunami wave height by less than one meter in the deep sea to several meters on the coastline.

2. Area Descriptions, Methods And Material Studied

The study was conducted using ArcGIS Desktop software with Network Analysis Tool and Dijkstra's algorithm method to obtain vertical evacuation maps, while obtaining horizontal evacuation maps was done manually using ArcGIS (Maguire, 2008; Ormsby, et.al., 2004). To facilitate this research is done by collecting the necessary maps such as administrative maps, road network maps, topographics maps, population density maps, contour maps and land use maps (Harley, 2009). For tsunami immersion obtained by interviewing 32 people.

3. Results and Discussion

Time Arrives Tsunami for Kota Sigli District

Currently the City of Sigli District has not yet obtained the results of a study of tsunami evacuation time, so the evacuation time used is the average time of arrival of the tsunami, 30 minutes, if the local earthquake source is around Indonesia (Public Relations Cabinet Secretariat of the Republic of Indonesia, 2014). With 30 minutes, it is expected that the community in Sigli City can use it to carry out the evacuation process before the tsunami waves reach the shoreline. 2004 Tsunami Inundation Height in the City District of Sigli. In the table below is the 2004 tsunami inundation height data. This data is used to determine the effective evacuation location in order to avoid a pool of tsunamis, following table 1 and figure 1 which shows the tsunami inundation height.

Table 1. Interview Data for 2004 Tsunami Inundation Height

No	Sub-district	Tsunami Inundation Height
1	Benteng	2,54
		2,52
2	Pasi Peukan Baro	2,52
		2,50
3	Kuala Pidie	2,50
		2,48
4	Blang Paseh	2,49
		2,40
5	Pasi Rawa	2,40

		0,90
6	Blok Bengkel	1,90
		0,80
7	Pante Teungoh	1,10
		1,05
8	Kramat Luar	0,80
		0,65
9	Peukan Baro	0,48
		0,28
10	Kramat Dalam	0,35
		0,32
11	Lampoh Krueng	0,1
		0
12	Blok Sawah	0
		0
13	Blang Asan	0
		0
14	Gampong Asan	0
		0
15	Meunasah Peukan	0
		0
16	Tanjong Krueng	0
		0

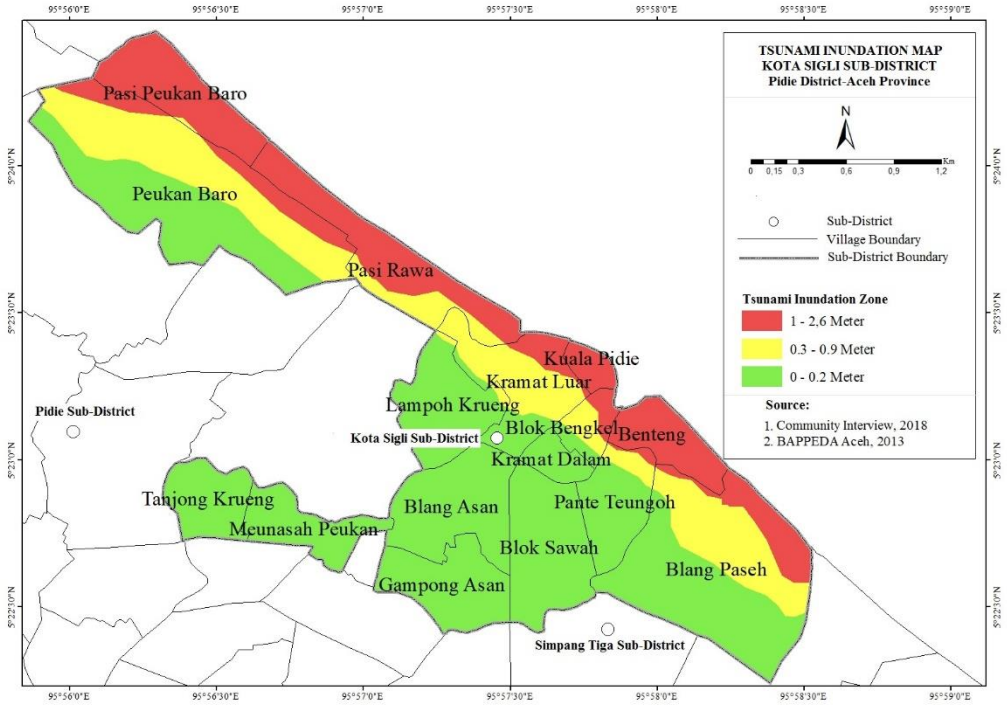

Figure 1. Tsunami Inundation Map of the City of Sigli Districth

Based on Table 1 and Figure 1 above, the 2004 tsunami inundation data in the highest Sigli City was 2.54 meters in Benteng Village and Pasi Peukan Baro Village was 2.52 meters high, Kuala Pidie Village 2.50 meters, Blang Paseh Village 2.40 meters and Pasi Rawa Village 2.40 meters. For Lampoh Krueng village, Sawah Block, Blang Asan, Meunasah Peukan and Tanjong Krueng the tsunami was not submerged at all. The tsunami inundation map in this study is also useful for providing information to the public to find out how high the 2004 tsunami pool was in certain villages. This can alert the public to stay away from the beach if in the future they get a tsunami threat in the City of Sigli District.

For the tsunami evacuation action in the Sigli City Subdistrict, the first two horizontal evacuations were carried out, namely evacuation carried out by running away from the beach to a safe location. While vertical evacuation is the rescue to the nearest tall buildings to save themselves.

Horizontal Evacuation Location

For horizontal evacuation actions in Sigli City use highways that can be used by the community when a tsunami occurs to run away from the beach. The entire chosen road leads to away from the beach as a horizontal evacuation route. For evacuation routes that are too far away to a safe location, a rescue building (Escape Building) will be recommended. Rescue buildings will spread in all villages, so that people can use them to reach a safe point in a short time before the tsunami waves reach the shoreline.

There are 4 recommendation locations in the following villages, such as Peukan Baro Village, Tanjong Krueng Village,Gampong Asan Village and Pante Teungoh Village. In this study also recommends new pathways as an evacuation route to reach the rescue building quickly and shortest. This needs to be sought, in order to minimize the fall in the number of victims in the event of a tsunami in the future. The following is Figure 2, which shows a map of the horizontal evacuation path along with recommendations for the rescue building in Kota Sigli District.

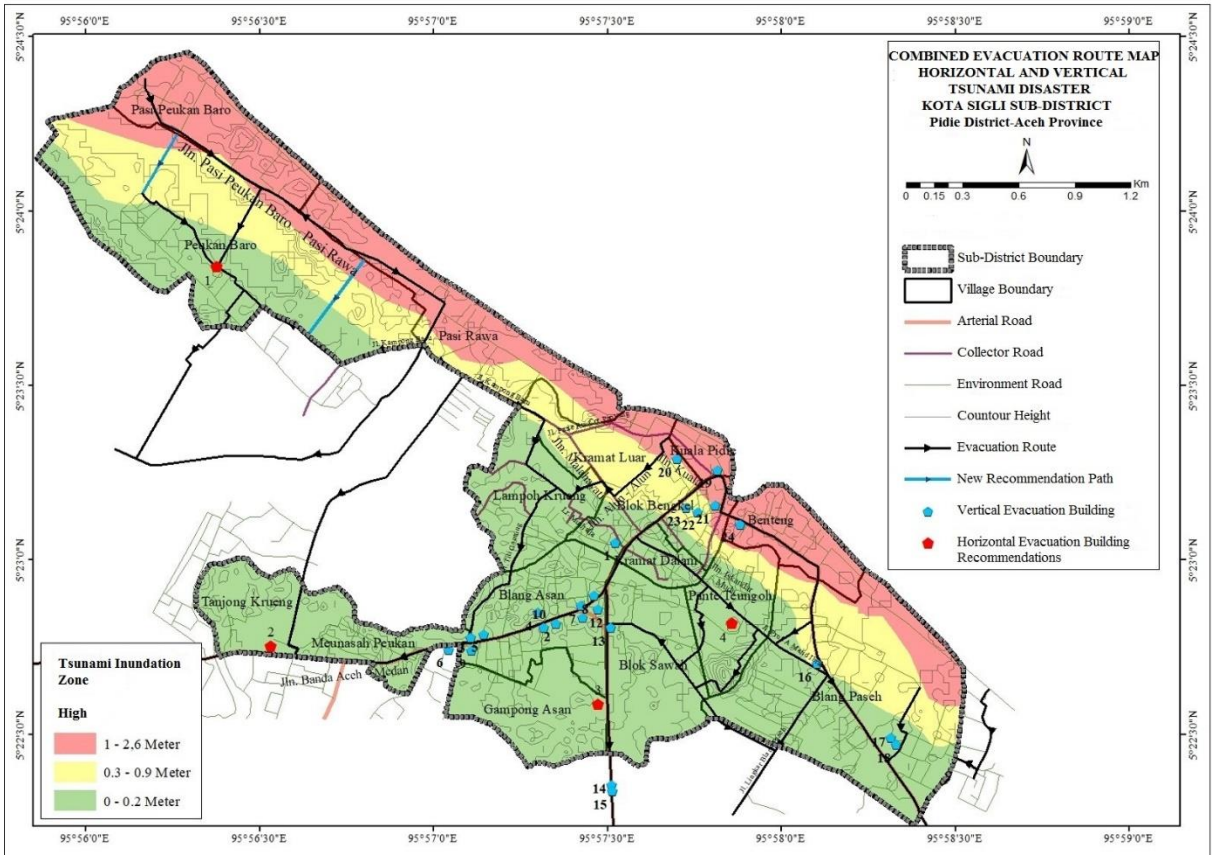

Figure 2. Map of Horizontal Evacuation Recommendations

Based on Figure 2, for Pasi Peukan Baro Village, Peukan Baro and Pasi Rawa can take Pasi Peukan Baro-Pasi Rawa Road as an evacuation route. The direction of evacuation can be carried out to the village of Peukan Baro heading outside the Sub-district Kota Sigli and heading to the District of Pidie. In these three villages, two new evacuation routes were also recommended to make it easier for people to run away from the beach.

For Kramat Luar and Lampoh Krueng Villages, you can use Jalan Kampong Baru and Pasi Rawa-Cot Panyang as evacuation routes to nearby villages such as Blang Asan Village and Gampong Asan as a safe gathering place. For Kuala Pidie village, you can use Jalan Alun-alun as an evacuation route to Blang Asan Village or Gampong Asan. From the villages of Blang Asan and Gampong Asan you can use the Banda Aceh and Medan-Banda Aceh Road as an evacuation route to a safe location. For Blok Bengkel Village, Kramat Dalam and Blok Sawah, you can use Jalan Medan-Banda Aceh as an evacuation route to the nearest village or to another sub-district to run to save yourself. As for Benteng village, you can use Peritis Road to go to Jalan Medan.

Banda Aceh as an evacuation route to a safe place. For Pante Teungoh and Blang Paseh villages you can use Jalan Prof. A. Majid Ibrahim headed Jalan Medan-Banda Aceh as an evacuation route. From Blang Paseh Village, you can also use the Blang Paseh Ring Road to a place that is safer towards other sub-districts. For Blang Asan Village, Gampong Asan, Meunasah Peukan and Tanjong Krueng can use Banda Aceh Road as an evacuation route.

Vertical Evacuation Location

Vertical evacuation in Sigli City was carried out because there was still no special rescue building available that could be used as an evacuation site. Buildings that have been chosen, mostly government

buildings, several school buildings, hotels, mosques and 1 tsunami museum that has 2 floors and a spacious room. The building can be used as an evacuation place with the requirements as an evacuation building fulfilled.

Based on the results of the survey that has been conducted, the vertical evacuation buildings in the District of Sigli City amount to 24 buildings spread across 7 villages. The following is Table 2 which shows buildings that can be used for evacuation and vertical evacuation maps in the Sigli City District, as shown in Figure 3 below.

Table 2. Vertical Evacuation Buildings

No	Village Name	Building Name
1	Kuala Pidie	Museum Tsunami Sigli
2	Kramat Luar	GOR Sigli & Meunasah Nurul Iman
3	Blok Bengkel	SMP N 1 Sigli, Office of the Ministry of Religion, & TK Kartika Jaya
4	Benteng	Kantor PNA
5	Blang Asan	Kantor PLN, Prosecutor's Office, Meeting hall, Court office, Mess Pemda, SD Sigli, Bank Aceh, Grand Blang Asan, Cempaka Hotel, & KP2TSP Office
6	Blok Sawah	Al-Falah Mosque, Riza Hotel, Citra Husada Hospital, & Lestari Hotel
7	Blang Paseh	Istiqamah Mosque, Islamic Sharia Office, & Dayah Education Service

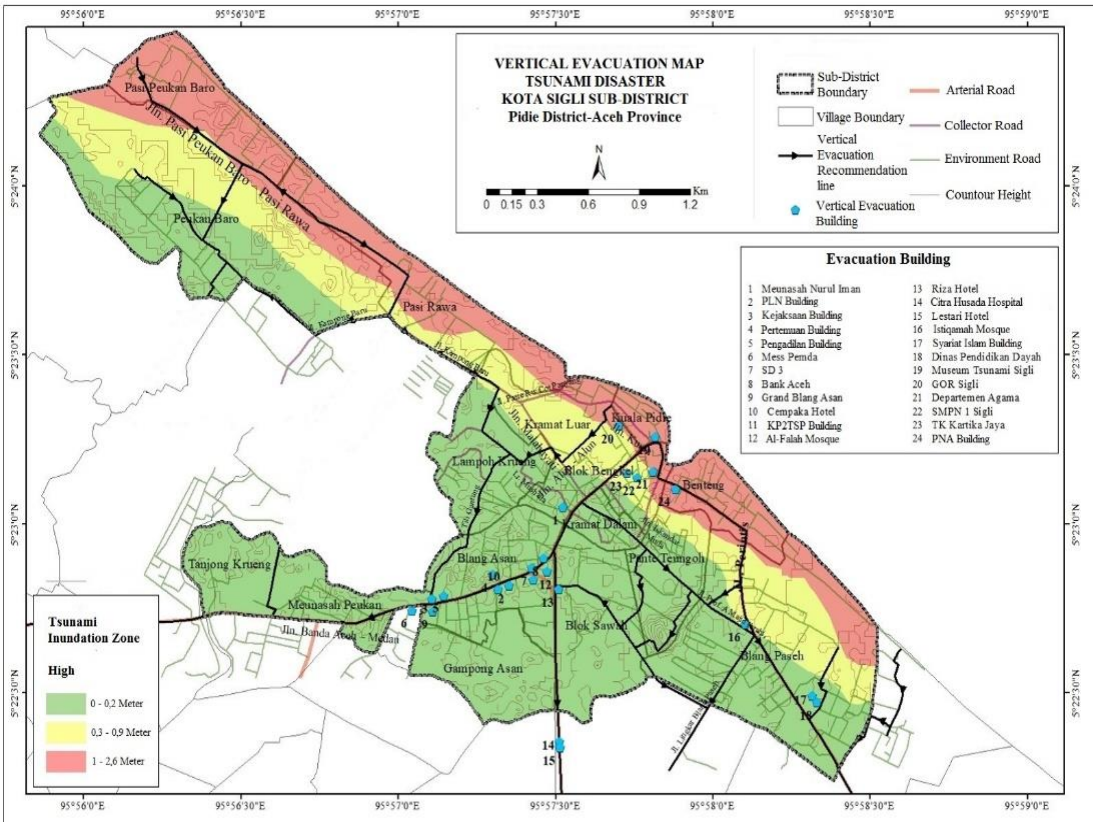

Figure 3. Map of Vertical Evacuation Recommendations

Figure 3 above is an evacuation location map and an explanation of the vertical evacuation building in Kota Sigli District which fulfills the requirements for evacuation as many as 24 buildings as listed in Table 2 and Figure 3. Each building has good conditions to be used as an evacuation place for the community to save yourself when a tsunami occurs. The travel time for the community to reach the location of the evacuation building will vary greatly, influenced by the route traveled, place of origin and destination as well as the age factor of the community itself. The length of the evacuation process to get to the evacuation location also greatly affects the road width and road conditions, the wider the road, the more effective the evacuation process will be.

Vertical evacuation buildings must consider such conditions, the building has 2 floors, can be reached in a fast time, the building is earthquake resistant, located far from the beach. The most important thing is that the building can accommodate the number of people in the village and its surroundings, along with an explanation.

1. Pasi Peukan Baro Village

Located very close to the shoreline, this village does not have a vertical evacuation building so the evacuation will be carried out to the nearest village that is considered safe, such as the Sigli City GOR building, Meunasah Nurul Iman, SD 3 Sigli, Department of Religion and TK Kartika Jaya with travel time around 7-18 minutes by running.

2. Pasi Rawa Village

This village is also the village that was worst during the 2004 tsunami and does not have a vertical evacuation building, so evacuation can be done to the nearest village that is considered safe which has evacuation buildings such as Meunasah Nurul Iman, GOR Sigli City, 1 Sigli Middle School, Department of Religion and TK Kartika Jaya with a travel time of 15-18 minutes by running.

3. Peukan Baro Village

For this village also does not have a vertical evacuation building, but has a slightly high topography with a height of 4-6 meters above sea level, so evacuation can be carried out. However, vertical evacuation can also be done to nearby buildings, such as Sigli City GOR, Meunasah Nurul Iman, SD 3 Sigli, SMPN 1 Sigli, Department of Religion and TK Kartika Jaya but it takes an average of 25 minutes.

4. Kuala Pidie Village

This village is very close to the shoreline, evacuation can be done to vertical evacuation buildings such as the tsunami meusium building which has a large room to accommodate the community, besides that evacuation can also be done to GOR Kota Sigli buildings, Department of Religion, Sigli SMPN 1 and TK Kartika Jaya . The five buildings can be reached within 5 minutes by running.

5. Kramat Luar Village

The village has vertical evacuation buildings such as the Sigli City GOR, TK Kartika Jaya SMPN 1 Sigli Department of Religion and Meunasah Nurul Iman with a travel time of approximately 2 minutes by running. Evacuation can also be done to the nearest village which has a high topography of 6-12 meters above sea level.

6. Lampoh Krueng Village

This village does not have buildings for vertical evacuation, but vertical evacuation can also be done to the Meunasah Nurul Iman building, Mess of Pidie Regional Government, Prosecutor's Office, Grand Blang Asan and the Court Office with a travel time of approximately 7 minutes by running.

7. Blok Bengkel Village

This village is only partially affected by the 2004 tsunami and has an evacuation building that can be used, such as the building of 1 Sigli Middle School, Department of Religion and TK Kartika Jaya with a travel time of approximately 1 minute by running.

8. Benteng Village

This village was mostly hit by the 2004 tsunami because it was very close to the shoreline. The population in this village is 1453 people but only has 1 closest evacuation building, namely the PNA Office, it is very clear that the building cannot accommodate such a large population, the solution is to evacuate to the nearest village.

9. Kramat Dalam Village

This village was safe when the 2004 tsunami and did not have vertical buildings that could be used for the evacuation process. The population in this village is 916 people, if in the event of a tsunami, this village can accommodate its population and can even be used to save people from other villages.

10. Blang Asan Village

The village was not affected by the 2004 tsunami and was considered safe by the community as a place to escape when the 2004 tsunami. The village also has many buildings that can be used for evacuation, such as the National Electricity Company (PLN), Prosecutor's Office, Court Office, Meeting House , Mess of Pidie Regional Government, SD 3 Sigli, Grand Blang Asan, Cempaka Hotel and Investment Office and One Stop Integrated Service (KP2TSP) which can be reached in approximately 2 minutes by running.

11. Gampong Asan Village

This village is also one of the villages that accommodated many people during the 2004 tsunami and did not have a vertical evacuation building but had topography with a height of 6-12 meters above sea level.

12. Block Sawah Village

Al-Falah Mosque located in Blok Sawah Village is a mosque that was used as a gathering point for most Sigli City residents at the time of the 2004 tsunami. Other buildings that can be used as vertical evacuation such as the Riza Hotel building, Lestari Hotel and Mufid Hospital and Citra Hospital Husada can be taken within 1-3 minutes by running.

13. Blang Paseh Village

The village was only partially hit by the 2004 tsunami and the Istiqamah Mosque building was a mosque that was used by the community to evacuate the 2004 tsunami, besides Blang Paseh village also had several buildings that could be used for vertical evacuation, such as the Islamic Sharia Office and the Dayah Education Service. traveled within 5-11 minutes by running.

14. Pante Teungoh Village

This village is only a small part of the 2004 tsunami and only shops can be used as vertical evacuation buildings. In this village a rescue building will be recommended so that people can use it when a tsunami occurs.

15. Meunasah Peukan Village

This village is very far from the shoreline and is not at all submerged by the waves of the 2004 tsunami. However, there is a Court Office building, Mess of Pidie Regional Government, Prosecutor's Office and Grand Blang Asan that can be used as evacuation buildings within 1 minute by running.

16. Tanjong Krueng Village

This village is also far from the shoreline and is not completely submerged by the 2004 tsunami. In this village it is recommended to build rescue buildings because this village can be used as one of the horizontal evacuation locations because the path can be directed from the shoreline.

Tsunami Evacuation Line

Determination of the tsunami disaster evacuation route in Kota Sigli Subdistrict was carried out to make it easier for people to evacuate to safe areas. As a solution for providing evacuation routes, village roads that are used by residents as daily transportation infrastructure can be used as evacuation routes. Each evacuation route has a short time not exceeding 30 minutes. The established route is sure to have no obstacles when the horizontal and vertical evacuation process, the evacuation route also has a fairly wide road. Every road that is in Sub-district Sigli has a wide range of roads, here is an explanation:

1. Arterial Road

Urban roads in Sub-district Kota Sigli which have 8 meters with 2 lanes.

2. Road Collector

Road that connects 1 village with another village with a width of 4 meters and not 2 lanes.

3. Road Environment

The path that is located in each village is 2 meters wide.

From each width of the road in the District of Sigli City, it can be used for users to walk during the evacuation process. A wide road makes it easier to access and has a large capacity to use when evacuating, meaning that the wider the road, the more people will be saved. For horizontal evacuation routes in the Sigli City Subdistrict everything is chosen to lead away from the beach. Some of the lanes are out of Kota Sigli Subdistrict, this is done so that the community quickly gets to a safe location and is not reached by tsunami water. The following is a map of the tsunami evacuation route for Sub-district Kota Sigli.

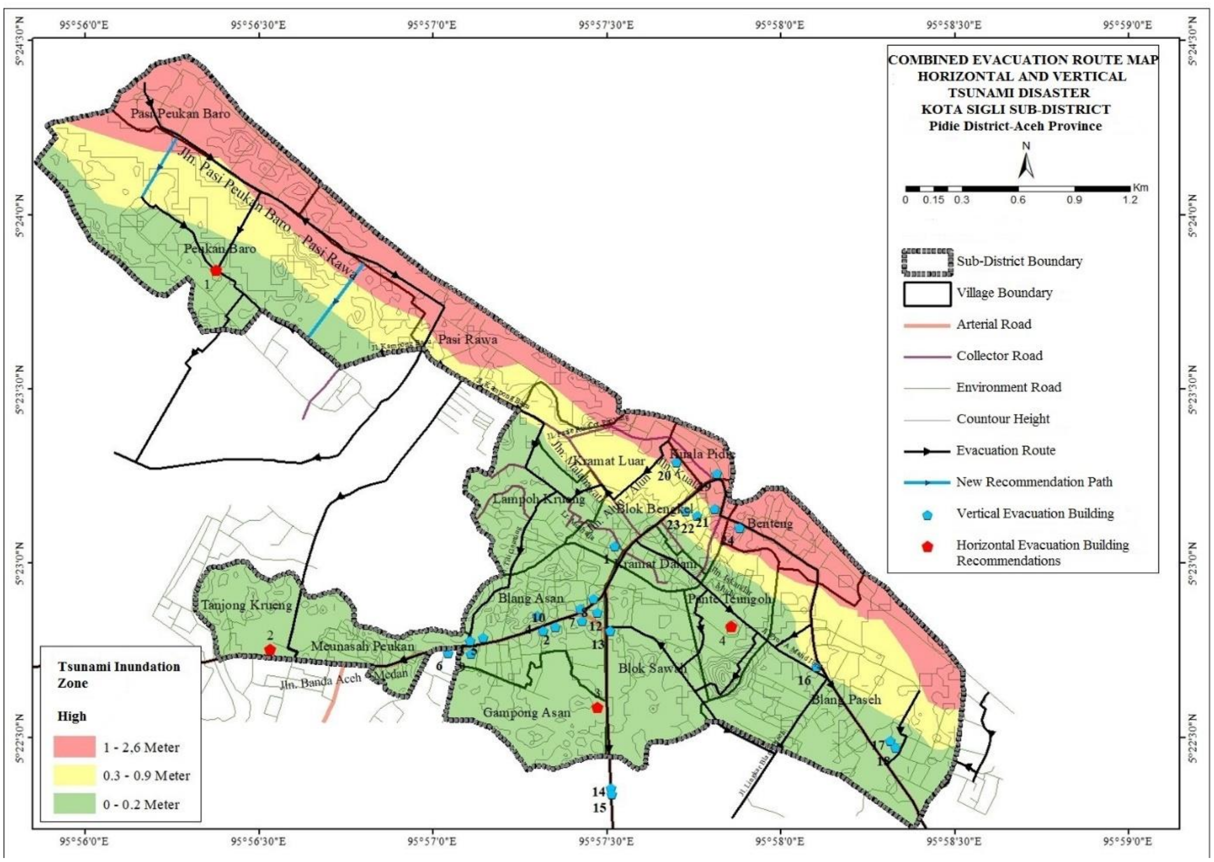

Figure 4. Map of Evacuation Path Recommendations

The following is an explanation of each tsunami evacuation route from the village to vertical buildings and horizontal evacuation routes:

1. Tanjong Krueng Village

For the people of Tanjong Krueng Village, evacuation routes can be accessed on Jalan Medan-Banda Aceh so that they can reach the closest vertical evacuation buildings, such as the Prosecutor's Office, Pidie Regional Government Mess, Court Office and Grand Blang Asan by spending 7 minutes running.

2. Peukan Baroe Village

Peukan Baroe Village community is located in Kampung Baroe Street which can be accessed as an evacuation route to reach vertical evacuation buildings, such as Sigli City GOR, Meunasah Nurul Iman, SD 3 Sigli, 1 Sigli Middle School, Department of Religion and TK Kartika Jaya by spending an average of 25 -27 minutes by running.

3. Blang Asan Village

The Blang Asan Village community has the main Medan-Banda Aceh Road which can be used as an evacuation route to the nearest vertical evacuation building, such as the Meeting Building, Cempaka Hotel, PLN Office, SD 3 Sigli, Bank Aceh, Riza Hotel and KP2TSP Office by spending around 3 minutes by running.

4. Lampoh Krueng Village

The Lampoh Krueng Village community can use Pasi Rawa Road, and Titi Gantung Road as an evacuation route to reach the main Medan-Banda Aceh road to get to the nearest vertical evacuation building, such as Meunasah Nurul Iman, Mess Local Government, Prosecutor's Office, Grand Blang Asan and Kantor. The court spent about 8 minutes running.

5. Blang Paseh Village

The Blang Paseh Village community can access the Sigli-Kembang Tanjong Road and Perintis Road as an evacuation route to reach the nearest vertical evacuation building location, such as the Istiqamah Mosque, the Dayah Education Service and the Islamic Shari'a Office by spending around 4 minutes running.

6. Blok Bengkel Village

Blok Bengkel Village Community can use Jalan Malahayati as an evacuation route to reach the closest vertical evacuation buildings, such as Meunasah Nurul Iman, SD 3 Sigli, Bank Aceh and Meunasah Nurul Iman by spending 15 minutes to get to the location by running.

7. Pasi Peukan Baro Village

The Pasi Peukan baro Village community can use Pasi Rawa Road as an evacuation route to reach vertical evacuation buildings such as Meunasah Nurul Iman, SD 3 Sigli, and Bank Aceh and Riza Hotels by spending around 15-20 minutes to get to the location by running. For this village, there are recommendation paths to provide road access during the evacuation process.

8. Kramat Dalam Village

Kramat Dalam Village Community is located on Jalan Iskandar Muda which can be used as an evacuation route to go to the main Medan-Banda Aceh road to reach the nearest vertical evacuation building, such as Meunasah Nurul Iman, SD 3 Sigli, Riza Hotel, Bank Aceh and KP2TSP Office - approximately 2 minutes by running.

9. Pasi Rawa Village

The Pasi Rawa Village community has a Pasi Rawa Road which can be used as an evacuation route to the closest vertical evacuation buildings, such as Meunasah Nurul Iman, SD 3 Sigli, Bank Aceh and Riza Hotel by spending 15-18 minutes running.

10. Meunasah Peukan Village

The Meunasah Peukan Village community can use Jalan Medan-Banda Aceh to access the evacuation route to get to the nearest vertical evacuation building, such as the Court Office, Mess of Pidie Regional Government, Prosecutor's Office, and Grand Blang Asan by spending 1 minute running.

11. Gampong Asan Village

The Gampong Asan Village community has the main Medan-Banda Aceh Road that can be used as an evacuation route to the nearest vertical evacuation building, such as the meeting building, Cempaka Hotel and the PLN Office which can be reached in 1 minute by running.

12. Block Sawah Village

The Blok Sawah Village Community has the main Medan-Banda Aceh Road which can be used as an evacuation access point to the nearest vertical evacuation building, such as Riza Hotel, Al-Falah Mosque and KP2TSP Office by spending only 1 minute by running.

13. Kuala Pidie Village

Kuala Pidie community can use vertical evacuation buildings such as Meunasah Nurul Iman, SD 3 Sigli, Bank Aceh and Al-Falah Mosque by accessing Jalan Kuala as an evacuation route by spending only 5 minutes by running.

14. Kramat Luar Village

Kramat Luar Village community can use Pasi Rawa Road and Iskandar Muda Street as an evacuation route to reach vertical evacuation buildings, such as Meunasah Nurul Iman, Bank Aceh, SD 3 Sigli, Al-Falah Mosque by spending 2-5 minutes running.

15. Benteng Village

The Benteng Village community can use the Meunasah Nurul Iman building, Al-Falah Mosque, Bank Aceh, SD 3 Sigli and Riza Hotels by spending around 7 minutes running.

16. Pante Teungoh Village

The Pante Teungoh village community can use Jalan Malahayati as an evacuation route to reach the nearest evacuation building, such as the Istiqamah Mosque, the Islamic Sharia Office and the Dayah Education Office by spending about 5-10 minutes to get to the location by running.

Conclusions

Tsunami Evacuation Location

The horizontal evacuation route in the Sigli City sub-district was chosen to lead away from the beach, but there were several routes that came out of Kota Sigli Subdistrict, with the aim to quickly get to a safe location. On horizontal evacuation, new roads are recommended as evacuation routes and 4 points are also recommended for building rescue buildings. Rescue buildings are chosen in routes that are too long to be taken by the community and do not have vertical evacuation buildings around them.

The selection of vertical evacuation sites is done because in Sigli City does not yet have a special evacuation building that can be used by the community to save themselves. There are 24 recommendations for vertical evacuation buildings spread across 7 villages that can be used by the community. The travel time to reach the evacuation building will be very different, but no more than 30 minutes by running.

Tsunami Evacuation Line

All horizontal evacuation routes that have been chosen stay away from the beach. the lane has a wide road width which facilitates the evacuation process. There are several evacuation routes that come

out of Kota Sigli Subdistrict, because the lane must be completely away from the coast so that safe evacuation locations can be selected to other sub-districts. For vertical evacuation, there are 24 buildings that can be used by the community when evacuating.

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