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Tsunami Vertical Evacuation Building Analysis (Shelter) Based on Number and Location: Case Study of Koto Tangah District- Padang City

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ABSTRACT

Koto Tangah Sub-district is a sub-district where part of its area is located on the coast, making it prone to tsunami disasters. Despite the fact that the large number of exposures in the tsunami red zone predicted to happen in this District, there are only three tsunami shelters in the red zone of Koto Tangah District. The purpose of this study was to determine the distribution of official shelters in Koto Tangah District, the distribution of planned shelters, and the coverage of shelter service areas. The research method used is a quantitative descriptive method. In this study, what is discussed is the number and location of shelters, as well as the location of the planned tsunami shelters. Also, this present study sought to finding out the coverage area that can be served by the shelter with the help of GIS applications. The results of the data analysis are as follows: (1) There are nine villages (kel.) that are in the tsunami red zone of the Koto Tangah District and are not served by official shelters, namely: Kel. Padang Sarai, Kel. Batipuh Panjang, Kel. Lubuk Buaya, Kel. Pasia Nan Tigo, Kel. Batang Kabung Ganting, Kel. Koto Pulai, Kel. Koto Panjang Ikua Koto, Ex. Dadok Stumping Black, and parts of Ex. Parupuk Tabing. (2) The analyzed planned shelters and horizontal points examined that all of the Koto Tangah red zone areas can be served by shelters, and the planned shelters can be reached in the span of 34.5 minutes with a distance of 1554.57 m, meaning that people who are in the tsunami red zone can evacuate safely before the tsunami hits the city. (3) local government needs to add another 6 planned shelters in Kel. Padang Sarai, Kel. Lubuk Buaya, Kel. Pasie Nan Tigo, Kel. Batang Kabung Ganting, and Kel. Parupuk Tabing, with each shelter's planned height of 8.5 meters.

Keywords: *Shelter; Location; Tsunami; Evacuate; Inundation*

INTRODUCTION

The growth of a city can be observed in its infrastructure development. In addition to infrastructure development, the growth of a city can also be seen from the expanding urban areas, the emergence of growth centers and the increasing number of people living and doing activities in urban areas. Based on data from the Central Statistics Agency (BPS), 56.7% of Indonesia's population reside in urban areas in 2020. This percentage is projected to increase to 66.6% in 2035. However. The current condition of urban development in Indonesia is not supported by supporting the environment, devices and strict regulations, resulting in cities growing and developing uncontrollably. The high growth rate of urban population has an impact on changes and developments in the physical and non-physical aspects of cities, transportation needs, entertainment, and other aspects [1].

There will be a greater number of social and economic activities in the area if there are more urban residents. This will affect the demand for housing, settlements, offices, trade, industry, and other facilities.The high rate of population growth and increasing population density in urban areas can make urban areas busier.This can also make it more difficult for people to reach safe areas when a disaster happens, especially a tsunami.

Padang, a city in West Sumatra on Sumatra's west coast, has a high risk of experiencing tsunami damage.West Sumatra has been hit by a number of earthquakes that have caused a lot of damage and deaths. Seven major earthquakes have struck West Sumatra, including the Singkarak earthquake (1926 and 1943) with a magnitude of 7.2 on the Richter scale, Pasaman with a magnitude of 5.5 SR (1977), Solok with a magnitude of (Andreas et al., 2020). The tsunami had a significant impact on Padang City since so many people lived in and moved to the coastal area [3].

According to BPS data for 2020, there will be significant differences in the population of Padang City's coastline zones. Koto Tangah District has 197,797 population, while North Padang District has 55,171, West Padang District has 42,957, and East Padang District with 77,755 inhabitants. According to the Padang City tsunami evacuation route map, there are six areas with the greatest potential for tsunami disaster exposure. Given the large number of residents living in coastal areas, it will be difficult to evacuate these residents in a short time to a safe zone. With inadequate transportation facilities, crowded vehicles, and panicked people, it will be difficult and time-consuming to reach a higher location [3]. Thus, one of the efforts to reduce the impact of the tsunami is the construction of TES (temporary evacuation shelters) and shelter infrastructure.

A shelter is a place where people can temporarily go to escape the consequences of a natural disaster. Padang, located on the west coast of Sumatra, has a significant potential of being impacted by a tsunami, hence the government has been working to construct and offer both permanent and temporary evacuation sites. One of the temporary evacuation sites built by the authorities of Padang City is a vertical evacuation site or shelter in the disaster's red zone [4].

According to the National Disaster Management Agency's 2013 Tsunami Temporary Evacuation Site (TES) Planning Technical Guidelines, the maximum distance from a tsunami with a 15-minute arrival time is 804.5 meters. The location of the shelter is also determined by other factors, including the condition of the road infrastructure, the evacuation capacity, and the number of people who must be evacuated. Initial observations were conducted at the office of the Regional Disaster Management Agency on December 1, 2022, and the results were discussed with Mr. Rezko Yunanda, S.T., the director of the Disaster Analyst division. He explained that Padang presently has only three official shelters, which are located in Ulak Karang, Bungo Pasang, and Parupuk Tabing. These three official shelters are administered by BPBD Kota Padang at the present time.

There are a total of 58 buildings in Padang that could function as potential shelters. Based on the reserach findings byMr. Rezko Yunanda, S.T.', only 23 buildings in the city of Padang met the criteria for buildings that could serve as potential shelters. He also clarified that, of the eight subdistricts in Padang City, the Koto Tangah District, with an area of 4,015.12 hectares, posed the greatest tsunami risk. In comparison to other subdistricts, the Koto Tangah subdistrict has the maximum number of people potentially exposed to the tsunami, namely 101,215 people. Based on the large number of potential tsunami disaster exposures in the city of Padang, it is necessary to conduct further research regarding the needs of TES buildings [5].

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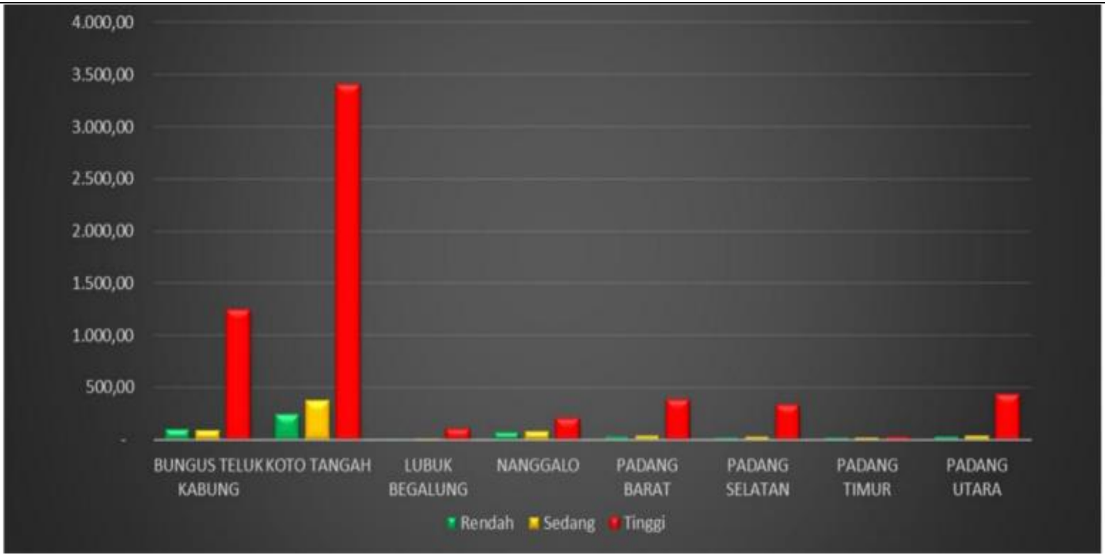

Figure 1. Potential Area of Tsunami Hazard in Padang City
Source: [6]

METHOD

The research method used is a quantitative descriptive ~~research method~~. Quantitative descriptive research is research that aims to explain an event, symptom, and incident in a factual, systematic and accurate manner. This study discusses the sub-districts that have a high level of vulnerability due to the tsunami disaster in Koto Tangah District, calculates the number of shelters and shelter locations based on the number of residents who are in tsunami-prone locations, and determines the coverage area that can be served by the shelter using the help of GIS applications.

This study was conducted over the course of three months, from December 2022 to March 2023. Prior to December 2022, a literature review and observation were conducted at Padang City Regional Disaster Management Agency Office. This study was conducted in the tsunami red zone in Koto, District Tangah.

The population is all of the significant data, which consists of items or individuals at a particular time and location.

While the sample is representative of the number and features of a population, it is collected using specific procedures. This study's population encompasses all territories under the authority of the Koto Tangah District. In the meantime, the sample comes from a region that is extremely vulnerable owing to the tsunami calamity.

According to statistics from the 2014–2018 Padang City Disaster Risk Research Document, the total area at risk from tsunamis in Padang City is 4,292.28 ha, which places it in the high risk category. With a total size of 2,346 ha, the Koto Tangah subdistrict is the subdistrict with the greatest exposure to the tsunami. at the specified scope and time. The tools used in this study use hardware (*hardware*) and software (*Software*).

Hardware

The following hardware instruments were utilized in the study:
Laptop computers are utilized for data processing and the completion of final projects.
Smartphones are used for document retrieval (camera) and building coordinate retrieval.

Software

The following are examples of research-related software tools:
Sas Planet is used to acquire data regarding satellite imagery.
ArcGIS is utilized for data analysis and processing in order to generate tsunami vulnerability maps and shelter locations.
Google Maps (street) is utilized to match and visualize field conditions.
The GPS Map Camera is used to capture images with location and coordinate information.
This study utilizes both primary and secondary data. The explanation of primary and secondary research data is provided below.

Primary Data

Primary data comes from direct measurements made in the field or from data that has been calculated. Direct field observation served as the method for gathering primary data in this study. The primary data from this study are:

- Vertical evacuation building location
- Land use
- Evacuation signs to the shelter

Secondary Data

Secondary data is information that comes from the processing of primary data or from research and data collection. Secondary data needed to help analyze the data in this study include:

- Population Data for Koto Tangah District
- Koto Tangah District village data is included in the tsunami red zone.
- Shelter data is available in Koto Tangah District.
- Administrative Map of Koto Tangah District
- Map of the Koto Tangah District Road Network
- Map of the Koto-Tangah Tsunami Landing
- Population Distribution Map of Koto Tangah District
- Related Journals.

The initial stage in the implementation of this research is introduction. At this stage, the researcher collects data in the form of various relevant references that can be used as a reference in conducting research. In addition, at this stage, the researchers also made initial observations by visiting the Padang City Regional Disaster Management Agency office.

Initial observations at Padang City Regional Disaster Management Agency office were the main way that this study got its information.Interviews with the Head of Disaster Analyst, Mr. Rezko Yunanda, S.T., were among the things that were done there.

In this study, one way to get secondary data is to download some information from the internet through several websites.The data downloaded in shape format (*.shp) is a map of the road network, an administrative map, and a map of where buildings are located in the Koto Tangah District.The download was also done to get information about the number of people living in the Koto Tangah District and how close together they live.Data collection was also carried out in several journals related to this research so that the required data would be more complete.

Data analysis was carried out in several stages, the first of which was to determine the range of shelter services. The range of shelter services can be found using the AET (actual evacuation time). The actual evacuation time can be found by calculating the following formula:

RsT = ETA – ToNW

ToNW = IDT + INT

Table 1. Data Processing of Actual Time of Tsunami Evacuation

Time Calculation	Mark	Information
AND	36 minutes	Padang City tsunami arrival time in worst case scenario, Borero 2007
IDT	3 minutes	InaTEWS Tsunami Warning Service Guidelines, 2012
INT	5 minutes	Estimated optimal duration of detecting a tsunami, InaTEWS 2012
RT	0 – unknown	Depends on the influence of social and psychological complexity on human reaction time (Post, et al. 2009)
RT	5 minutes	Warning interval estimation, Post et al. 2009)

After obtaining the actual tsunami evacuation time, the optimal evacuation distance from the evacuation point to the evacuees is calculated, assuming a refugee speed of 0.751 m/s (The Japan Institute for Fire Safety and Disaster Preparedness, 1987; Amin, 2006; Ashar et al., 2014; Aprilanda et al., 2021). To calculate the distance, the following equation can be used:

S = V x T

Information:
S = Distance of the evacuation site to the evacuees
IN = Evacuation Speed
T = Time Multiplier Factor

Service area modeling shelter using method network *analysis* that is service *area* and location-allocation. After acquiring the service area shelter then do the calculation of the height of shelter plan based on inundation data. The formula for the height of the TES facility from ground level based on FEMA P646, 2008 is as follows:

T = Ti + Freeboard
T = Ti + (3 +30% Ti)

Information:
T = TES height from ground level (in meters)
Ti = Tsunami wave inundation height (in meters)

RESULTS AND DISCUSSION

Total Population in Koto Tangah District

Based on data from the Central Statistics Agency for 2020, the total population in the Koto Tangah District is 197,797 people. The age group in Koto Tangah District in 2020 at the age of 0-14 years is 36,905 people, the age group 15-64 is 153,316 people, and the age group over 65 years is 7,576 people. Population data in Koto Tangah District based on urban village can be seen in the following table:

Table 2. Total Population of Koto Tangah District by Village

No	Ward	Amount
1	Dadok Stump Black	21.387
2	That Pacah	11.597

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No	Ward	Amount
3	Lubuk Minturun River Lareh	10.832
4	Bungo Install	15.561
5	Tabing crackers	18.979
6	Changing sackcloth stems	12.627
7	Buaya Crocodile	21.926
8	Sarai field	22.793
9	Koto Panjang Ikua Koto	13.361
10	Pasia Nan Tigo	11.568
11	Koto Pulai	2.693
12	Gadang Hall	18.846
13	Long Batipuh	15.628
Total		197.797

Capacity of Shelters in the Koto Tangah District

Capacity Shelter can be determined based on the area of the shelter by calculating the area of the shelter building and calculating the number of floors. According to the ITB Disaster Mitigation Research Center in 2013, the capacity of a shelter is measured by dividing the area of the shelter by two, as each person requires 0.5 m2 of standing room for evacuation. As for the room size required for comfort, 1 square meter per person is necessary. According to research undertaken on the official construction of a shelter in the Koto Tangah District, the following information was obtained:

Table 3. Capacity*Shelter* in the District of Koto Tangah

No	***Shelter***	**Floor**	**Area (m2)**	**Capacity (Soul)**		**Height (m)**
				1 m2 (2 people)	**1 m2 (1 people)**	
1	*Shelter* Darussalam Mosque Tsunami	2	481,43	963	482	18
		3	403,18	807	403	
		4	481,43	963	481	
		5 (Roof)	432	864	432	
		Total	**1798,06**	**3.597**	**1.799**	
2	*Shelter* Nurul Haq Mosque	3	598,201	1197	598	20
		4	598,201	1197	598	
		5 (Roof)	636,746	1274	637	
		Total	**1833,14**	**3.668**	**1.833**	
3	*Shelter* Parupuk Tabing (PU Office Workshop)	2	165	330	165	16
		3	165	330	165	
		4 (Roof)	198,47	397	198	
		Total	**528,47**	**1.057**	**528**	
Total			**4159,68**	**8.322**	**4.160**	

Service Range Distance *Shelter*

Based on Table 1, the RsT value is obtained:

$$\mathbf{RST = ETA - ToNW - RT}$$

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RsT = 36 min – (3 min + 5 min) – 5 min (Padang)

= **23 Minutes** (Actual Evacuation Time / Actual evacuation process)

Within the real evacuation time of 23 minutes, the people who left had to get to a safe place away from the risk of a tsunami. In areas with critical evacuation times, such as research locations, emergency evacuation places in the form of shelter are needed. Therefore, refugees are expected to reach shelter within the specified time.

Evacuation mileage calculation

$S = V \times t$

$S = 0.751$ m/s x 1380 seconds

$S = 1036.38$ m

The estimated distance between the location of the refugees and their new location is 1,036,8 meters. Depending on how quickly people move, it is expected that an evacuation will take two minutes, four minutes, six minutes, eight minutes, ten minutes, or twenty-three minutes.

S_1 = 0.751 m/s x 120 seconds = 90.12 m

S_2 = 0.751 m/s x 240 seconds = 180.24 m

S_3 = 0.751 m/s x 360 seconds = 270.36 m

S_4 = 0.751 m/s x 480 seconds = 360.48 m

S_5 = 0.751 m/s x 600 seconds = 450.6 m

S_6 = 0.751 m/s x 1380 seconds = 1036.38 m

Then the distance between the initial point of evacuation of refugees, to the building shelter or service coverage radius shelter is 1036.38 m. To get details of time variations, 3 types of time scenarios were created, namely; normal time (1x), 1.5x, and 2x.

Service Range Distance *Shelter*, *Shelter* Plans, and Horizontal Evacuation Points

Service range modeling shelter carried out using the help of the ArcGIS application using the method network *analysis* that is service *area* and location-allocation. The application can work according to the data that has been entered into the application. Then do the analysis and proceed with implementing so as to get *output* namely the zones that can be served by the potential shelter according to the specified distance. For more details, see the map below:

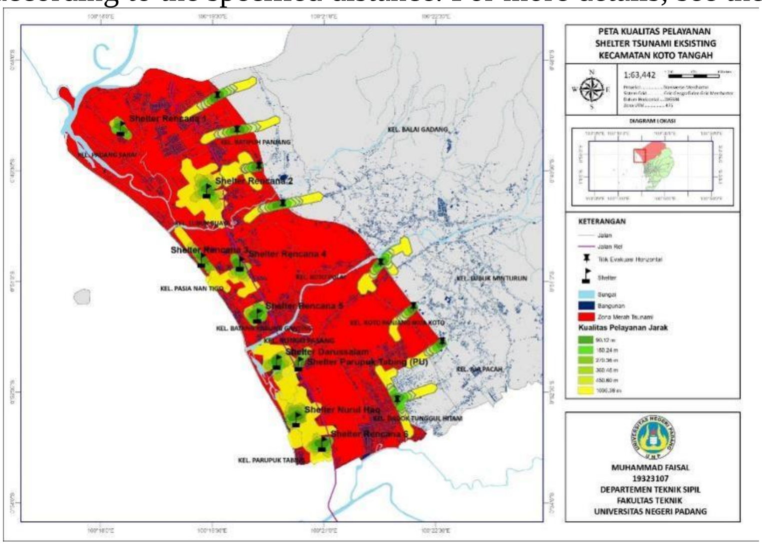

Figure 2. Service Quality Map *Shelter* Existing, Horizontal Evacuation Points, and *Shelter* Plan (*Service Area* 1036,38 m)

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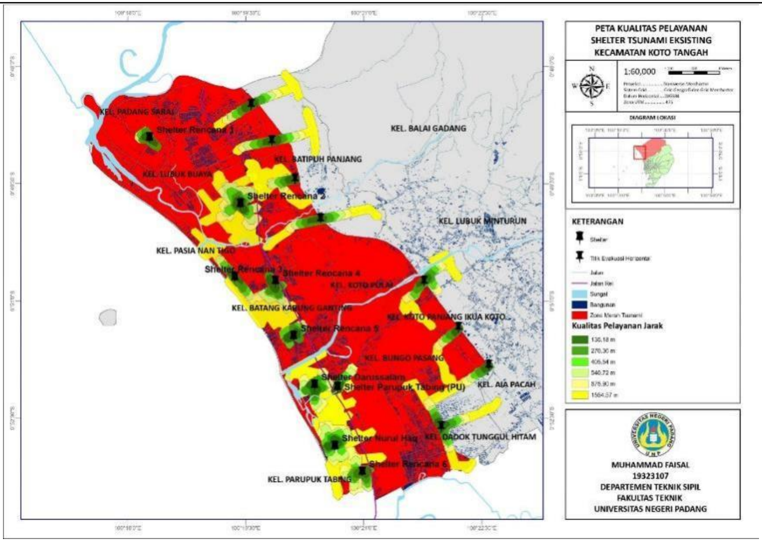

Figure 3. Service Quality Map *Shelter* Existing, Horizontal Evacuation Points, and *Shelter* Plan (*Service Area* 1554,57 m)

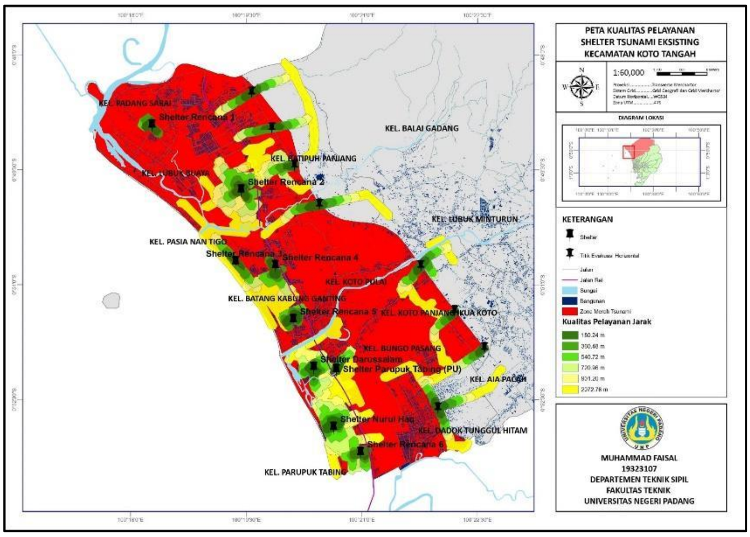

Figure 4. Service Quality Map *Shelter* Existing, Horizontal Evacuation Points, and *Shelter* Plan (*Service Area* 2072,76 m)

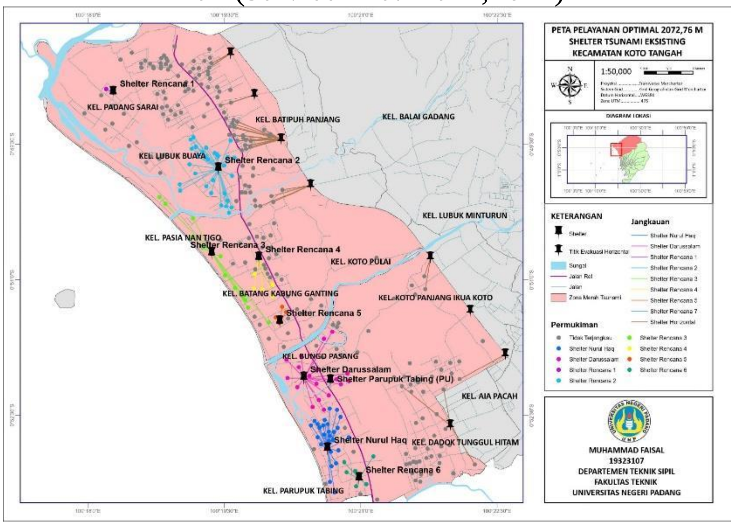

Figure 5. Optimal Service Quality Map *Shelter* Tsunami (*Location-Allocation* 2072,76 m)

Number and Location *Shelter* Plan

Shelter tsunami which must be added based on the results of the analysis using the method surface *area* and using TES planning guidelines is 6 shelter plans. The plan also determines the height of the building shelter. Altitude planning from shelter This tsunami can be determined using the height formula inundation as follows:

$$T = Ti + Freeboard$$
$$T = Ti + (3 + 30\%\ Ti)$$

Because of the location*shelter* plan is in an area that has a height inundation > 3 meters, if the planned inundation height is 4 meters. Then get the height for shelter plan 1 is as follows:

$$T = 4 + (3 + (30\% \times 4))$$
$$T = 4 + 4.2$$
$$T = 8.2 \text{ meter}$$

So, the minimum building height is from shelter plan is 8.5 meters.

CONCLUSION

On the basis of the outcomes of the data analysis, discussion, and study objectives, the following can be concluded:

1. There are sub-districts that cannot be served by shelter official in the District of Koto Tangah, namely; Ex. Padang Sarai, Kel. Batipuh Panjang, Kel. Lubuk Buaya, Kel. Pasia Nan Tigo, Kel. Batang Kabung Ganting, Kel. Koto Pulai, Kel. Koto Panjang Ikua Koto, Ex. Dadok stumps Black, and parts of Ex. Parupuk Tabing.
2. Due to the fact that officials can only accommodate 0.24085 percent of the population of the Parupuk Tabing and Bungo Pasang Subdistricts, the level of service at the building shelter has officially slipped into the category of "poor."
3. To achieve the best distribution of tsunami-resistance buildings, it is required to add a shelter in a hamlet that lacks one, particularly for those in the tsunami red zone in the Koto Tangah District.
4. In accordance with the inundation findings depicted on the shelter design, the minimum height of the shelter in each building shelter plan is 8.50 meters.

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