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Analysis Placement of Tsunami Vertical Evacuation Shelters Based on Number and Location (Case Study: Painan City)

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ABSTRACT

Painan City is a city whose part of the area is located on the coast, so it is prone to tsunami disasters. This disaster is unpredictable and can occur at any time. Based on interview data with BPBD South Pesisir Regency, Painan City has 10 shelters ranging from; official shelters, buildings that are multifunctional as shelters, and natural shelters. The purpose of this study is to determine the range of services of the tsunami shelter in Painan City today. The research method used is a quantitative descriptive method. In this study, what was discussed was the evaluation of the number and location of existing shelters, as well as determining the location of planned or additional tsunami shelters, as well as to determine the coverage of areas that can be served by these shelters with the help of GIS applications. Based on the results of the analysis, it was found that the entire tsunami danger zone area of Painan City could be served by existing shelters, in a span of 26 minutes with a distance of 1,171.56 meters. This means that people in the tsunami danger zone can evacuate safely before the tsunami disaster comes.

Keywords: *Shelter; Tsunami; ArcGIS; Evacuation; Inudation.*

INTRODUCTION

A resident is a group of people who live in a particular area. Although the area where residents live is permanent, the number of residents continues to grow every year due to births and deaths. Indonesia, as a developing country, experiences an increase in population by 1.13% annually [1]. The density and growth of cities is basically influenced by the dense and growing population. Along with the increasing density and population growth in urban areas, as well as increasing needs in various fields, it has led to an increase in the use of Geographic Information Systems by urban residents.

Indonesia's position is at the confluence of three main plates, namely the Australian, Eurasian, and Pacific plates. With these conditions, Indonesia is one of the countries that is very vulnerable to natural disasters, especially earthquakes and tsunamis with varying intensity and strength [2]. West Sumatra is located in the western central part of Sumatra Island, and is an area prone to collisions between earth plates as well as active fault activity that causes earthquakes [3]. Based on historical records, there were large earthquakes that occurred in 1797 with a magnitude of 8.3 on the Richter scale, and in 1833 with a magnitude of 8.9 on the Richter scale, accompanied by tsunamis that hit West Sumatra and Bengkulu. Experts predict that large earthquakes may reoccur in subduction zones at intervals of about 200 years [4].

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South Pesisir Regency is one of the areas in West Sumatra that is directly adjacent to the Indonesian Ocean. The region is prone to earthquakes because it lies between three main earthquake sources, namely the Mentawai Megathrust line in the subduction zone, the Mentawai Fault, and the Sumatra Fault. Earthquakes often occur in South Coastal Districts with fairly close time intervals [5]. Earthquakes that occur in the sea can trigger a tsunami.

Painan City is the capital of South Pesisir Regency located on the west coast of Sumatra Island. This makes Painan City a high-risk area for tsunami. Painan is a nagari and small town that is the center of government of South Pesisir Regency, West Sumatra, Indonesia. This city is located in District IV Jurai and can be reached via the West Sumatra Cross Highway.

Based on population figures from BPS data in 2022, there is a significant difference in the number of residents in the coastal area of District IV Jurai. Nagari Painan has a population of 6,010 people, Nagari Painan Selatan Painan has a population of 4,863 inhabitants, Nagari Painan Selatan Painan has a population of 5,716 inhabitants. It can be seen in the table below.

Table 1. Number of Population Per Nagari in District IV Jurai in 2022

No	Nagari	Gender		Amount
		Male	Female	
1	Salido	3.946	3.889	7.835
2	Painan	2.987	2.984	5.971
3	Lumpo	538	566	1.104
4	Tambang	1.038	972	2.010
5	Bungo Pasang Salido	2.477	2.514	4.991
6	Sago Salido	3.181	3.189	6.370
7	Painan Selatan Painan	2.391	2.352	4.743
8	Painan Timur Painan	2.929	2.957	5.886
9	Bukik Kaciak Lumpo	635	649	1.284
10	Sungai Sariak Lumpo	375	404	779
11	Sungai Gayo Lumpo	489	512	1.001
12	Gunung Bungkuak Lumpo	434	427	861
13	Ampang Tareh Lumpo	604	599	1.203
14	Ampuan Lumpo	548	580	1.128
15	Balai Sinayan Lumpo	344	391	735
16	Taratak Tangah Lumpo	621	600	1.221
17	Batu Kunik Lumpo	408	422	830
18	Limau Gadang Lumpo	636	570	1.206
19	Koto Rawang	776	731	1.507
20	Salido Sari Bulan	959	936	1.895
Kecamatan IV Jurai		26.316	26.244	52.560

(Source:[6])

One of the factors causing tsunamis is earthquakes that occur at sea, so that the South Coastal Regency area becomes vulnerable to the threat of tsunamis. To reduce the risk of heavy casualties, it is important to have tsunami evacuation routes and shelters, especially for coastal

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residents or those living in danger zones.

Shelter is a building structure built as part of structural mitigation efforts to deal with tsunami disasters [7]. Structural mitigation is an effort to prevent or reduce disaster risk carried out through physical infrastructure development [8]. Vertical evacuation systems are important to reduce risk due to limited evacuation time. Determination of evacuation location using GIS technology; which manages geographic data for vulnerability analysis, evacuation planning, post-disaster damage evaluation, and shelter location modeling. GIS helps protect lives and infrastructure and facilitates proper disaster management.

According to [9], the number of shelters in the form of buildings and hills in Painan City is 10, including: Bukit Langkisau, Bukit PDAM Painan, Bukit Kabun Taranak, Rawang Painan Shelter, Jalan Pagaruyuang Shelter, South Coast Police, Damkar Painan, South Coast Education Office, South Coast Library and Archives Office, and Nagari Bank.

The community is expected to evacuate in order to reduce exposure to disasters, one of which is the tsunami disaster[10]. The method that can be done in this tsunami evacuation is vertical evacuation. Vertical Evacuation is an effort to save yourself by moving to a higher place in the form of a hill or building that has more than one floor. One example of vertical Evacuation is to a Temporary Evacuation Site (TES) [11].

METHOD

The type of research used in this final assignment is a quantitative descriptive research method. Quantitative descriptive research is research that aims to explain events, symptoms and incidents factually, systematically and accurately. This final assignment discusses the coverage of the service area of the existing shelters in Painan City using the Network Analyst and Multiple Ring Buffer methods with the help of the ArcGIS 10.8 application. Data analysis was carried out in several stages, the first stage was to find the distance of shelter service coverage using RsT or Actual evacuation time. The RsT calculation [12] is carried out using the following formula:

$$RsT = ETA - ToNW - RT \quad (1)$$

Which is,

$$ToNW = IDT + INT \quad (2)$$

Table 2. Data Processing of Actual Tsunami Evacuation Time

Time Calculation	Mark	Information
ETA	26 minutes	The worst potential tsunami time for Painan [13]
IDT	3 minutes	Tsunami Warning Service Guidelines [14]
INT	5 menutes	Estimated optimal duration for detecting a tsunami [14]
RT	0 – not known	Depends on the influence of social and psychological complexity on human reaction time [12]
RT	5 minutes	Estimated warning interval [12]

It was found that the RsT value was 13 minutes, then the optimal evacuation distance was calculated from the evacuation point to the evacuees with the slowest evacuee speed, namely 0.751 m/sec [15]. Calculations are carried out using a simple formula, namely:

$$S = V \times T \quad (3)$$

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Information:

S	=	Distance from evacuation point to evacuees	(m)
V	=	Evacuation Speed	(m/s)
T	=	Time Multiplier Factor	(s)

Modeling the shelter service coverage area is using the Network Analyst and Multiple Ring Buffer methods. The results of the analysis are in the form of a map of the service coverage of shelters in Painan City. The analysis process is presented in the research flow (Figure 1). Service areas are based on predefined distances, so both underserved, and underserved areas can be seen in this analysis.

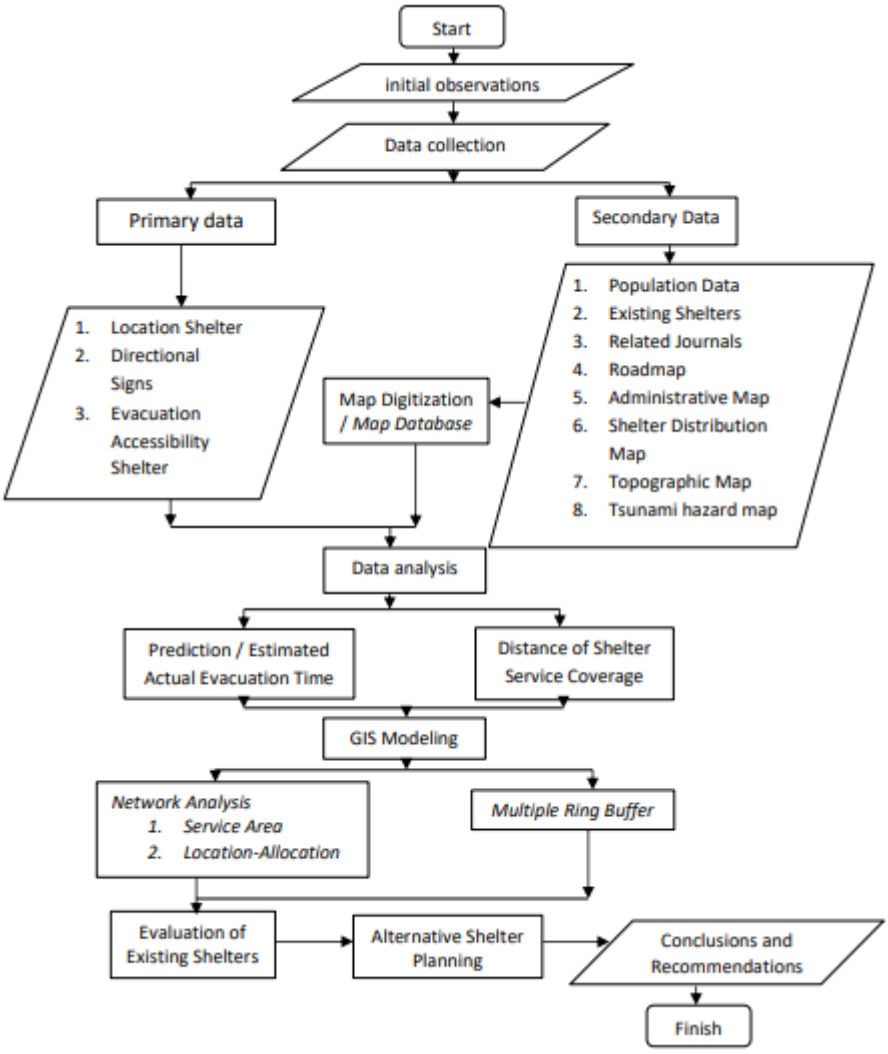

Figure 1. Flow chart

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RESULTS AND DISCUSSION

Residents of Painan City

Painan City has 3 Kenagarian and all three have the potential to be affected by the tsunami because they are along the coast and the red zone (ramp) of the tsunami. The following countries that are included in the red zone or affected by the tsunami include: Painan District, South Painan Painan District and East Painan Painan District. The total population in these 3 Kenagarian is 16,600 people. The capacity of the shelter in Painan City is seen from the area

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per floor of the shelter building. The capacity of the shelter is equal to 2 times the shelter area, because each person needs space for evacuation of 0.5 m2. The capacity of shelter capacity in Painan City based on shelter area can be seen in table 3.

Table 3. Shelter Capacity in Painan City

No	Name *Shelter*	Floor	Shelter Area Size (m2)	Capacity (Soul)		Hight (m)
				1 m^2 (2 person)	1 m^2 (1 person)	
1	Bukit Langkisau	-	1.656.410	3.312.820	1.656.410	207 mdpl
2	Bukit PDAM Painan	-	204.835	409.670	204.835	75 mdpl
3	Bukit Kebun Taranak	-	1.117.624	2.235.248	1.117.624	115 mdpl
4	*Shelter* Rawang Painan	-	4.840	9.680	4.840	27 mdpl
5	*Shelter* Jalan Pagaruyuang	2	55	110	55	15
		3	90	180	90	
		4	90	180	90	
		Total	235	470	235	
6	Polres Pesisir Selatan	2	1.198	2.396	1.198	7,5
		3 (roof)	1.198	2.396	1.198	
		Total	2.396	4.792	2.396	
7	Kantor Pemadam Kebakaran	2	175	350	175	7,5
		3 (roof)	175	350	175	
		Total	350	700	350	
8	Dinas Pendidikan Pesisir Selatan	2	1.305	2.610	1.305	7,5
		3	1.305	2.610	1.305	
		Total	2.610	5.220	2.610	
9	Dinas Perpustakaan dan Arsip Pesisir Selatan	2	890	1.780	890	11
		3	890	1.780	890	
		Total	1.780	3.560	1.780	
10	Bank Nagari	2	875	1.750	875	14
		3	875	1.750	875	
		4 (roof)	875	1.750	875	
		Total	2.625	5.250	2.625	
Total			2.993.705	5.987.410	2.993.705	

Shelter Service Range

The actual evacuation time was 13 minutes or 780 seconds, meaning that evacuees must be in tsunami-safe areas within that time frame. From the time value, the equation to (3) is used as follows:

S = 0.751 m/s x 780 seconds
S = 585,78 m

The distance of 585.78 meters is the distance between the starting point of the refugee location to the tsunami shelter. Due to the different locations of residential areas, scenarios were carried out in several time groups. Starting from 2 minutes, 4 minutes, 6 minutes, 8 minutes, 10

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minutes, 13 minutes, and multiplied by 1.5 and 2 in each time group scenario. So it can be seen in table 4:

Table 4. Range Distance in some Scenarios

No	Name	Time (T)	Velocity (V)	Range Distance (S)
1	S1	2 minutes / 120 seconds	0,751 m/seconds	90,12 m
2	S2	4 minutes / 240 seconds	0,751 m/seconds	180,24 m
3	S3	6 minutes / 360 seconds	0,751 m/seconds	270,36 m
4	S4	8 minutes / 480 seconds	0,751 m/seconds	360,48 m
5	S5	10 minutes / 600 seconds	0,751 m/seconds	450,6 m
6	S6	13 minutes / 780 seconds	0,751 m/seconds	585,78 m
7	S1*	3 minutes / 180 seconds	0,751 m/seconds	135,18 m
8	S2*	6 minutes / 360 seconds	0,751 m/seconds	270,36 m
9	S3*	9 minutes / 540 seconds	0,751 m/seconds	405,54 m
10	S4*	12 minutes / 720 seconds	0,751 m/seconds	540,72 m
11	S5*	15 minutes / 900 seconds	0,751 m/seconds	675,9 m
12	S6*	19,5 minutes / 1170 seconds	0,751 m/seconds	878,67 m
13	S1**	4 minutes / 240 seconds	0,751 m/seconds	180,24 m
14	S2**	8 minutes / 480 seconds	0,751 m/seconds	360, 48 m
15	S3**	12 minutes / 720 seconds	0,751 m/seconds	540,72 m
16	S4**	16 minutes / 960 seconds	0,751 m/seconds	720,96 m
17	S5**	20 minutes / 1200 seconds	0,751 m/seconds	901,2 m
18	S6**	26 minutes / 1560 seconds	0,751 m/seconds	1171,56 m

(Source : Analysis Results)
Information:
* = Initial time multiplied by 1.5
** = Initial time multiplied by 2

Shelter Service Modeling

Shelter Service Modeling Modeling of the range of official shelter services is carried out using the ArcGIS 10.8 application using proximity analysis methods, namely Multiple Ring Buffer and Network Analyst. This application can run by inputting coordinate data from the shelter and service distance. The results of this analysis are zones that can be served by shelters and zones that cannot be served by shelters. For more details can be seen in the following table:

Table 5. Coordinates of Existing Shelters in Painan City

No	Name *Shelter*	South latitude	East longitude
1	Bukit Langkisau	1°20'55,86"S	100°34'1,17"E
2	Bukit PDAM Painan	1°20'22,62"S	100°35'1,07"E
3	Bukit Kebun Taranak	1°21'13,41"S	100°34'45,30"E
4	*Shelter* Rawang Painan	1°20'31,46"S	100°35'11,33"E
5	*Shelter* Jalan Pagaruyuang	1°20'27,93"S	100°34'50,49"E
6	Polres Pesisir Selatan	1°20'54,62"S	100°34'44,46"E
7	Kantor Pemadam Kebakaran Painan	1°20'59,29"S	100°34'44,62"E
8	Dinas Pendidikan Pesisir Selatan	1°20'58,52"S	100°34'46,37"E
9	Dinas Perpustakaan dan Arsip Pesisir Selatan	1°20'53,61"S	100°34'50,70"E
10	Bank Nagari	1°20'52,22"S	100°34'29,26"E

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Based on the table of coordinates of the existing shelter, the distance of service coverage can be seen on the map below:

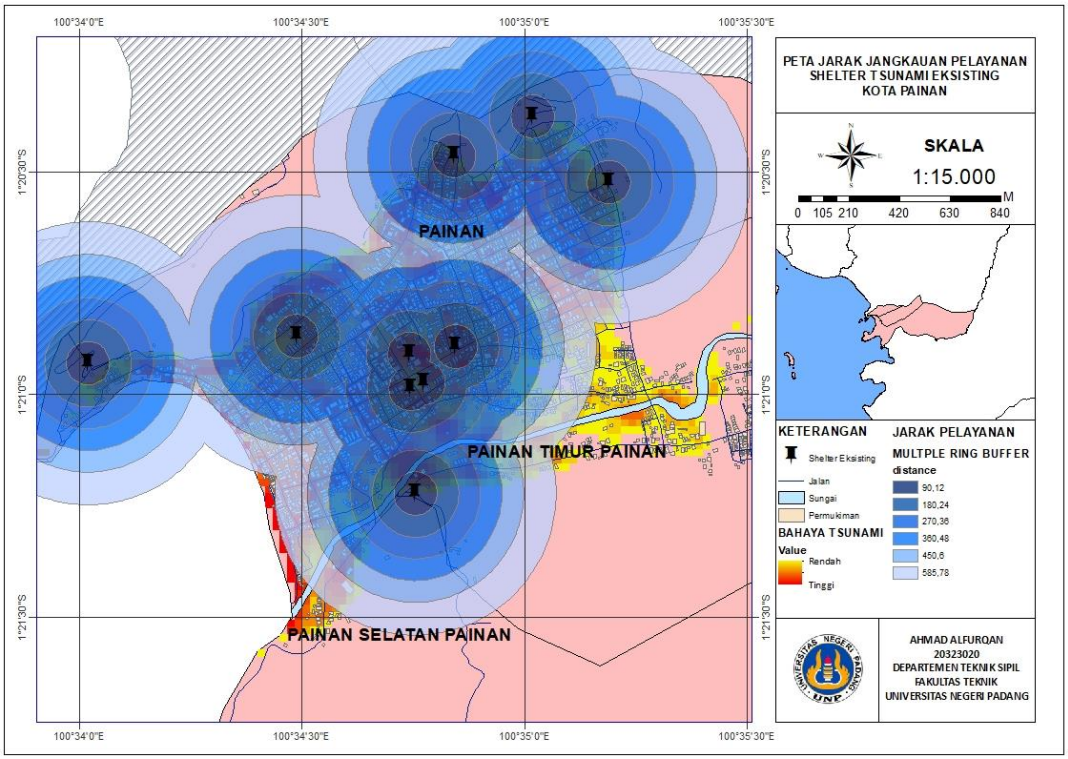

Figure 2. Selter Service Coverage Distance in Painan City (Distance 585.78 m)

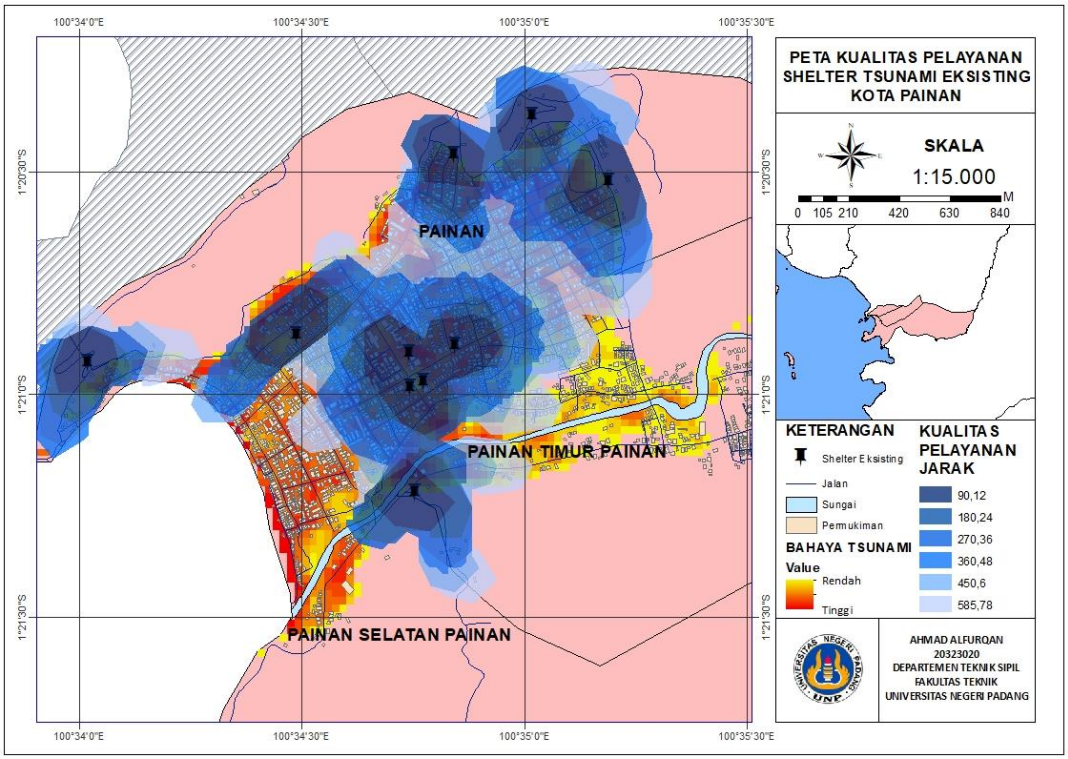

Figure 3. Service Quality Map of Existing Tsunami Shelter in Painan City (Distance 585.78 m)

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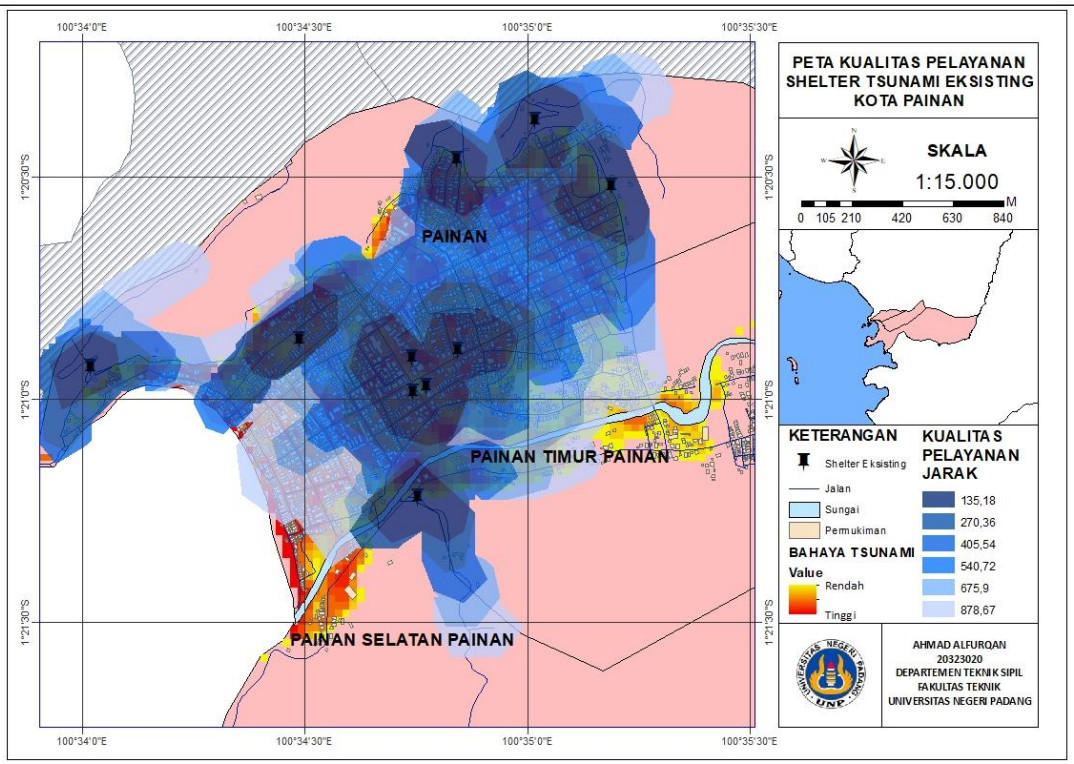

Figure 4. Service Quality Map of Existing Tsunami Shelter in Painan City (Distance 878.67 m)

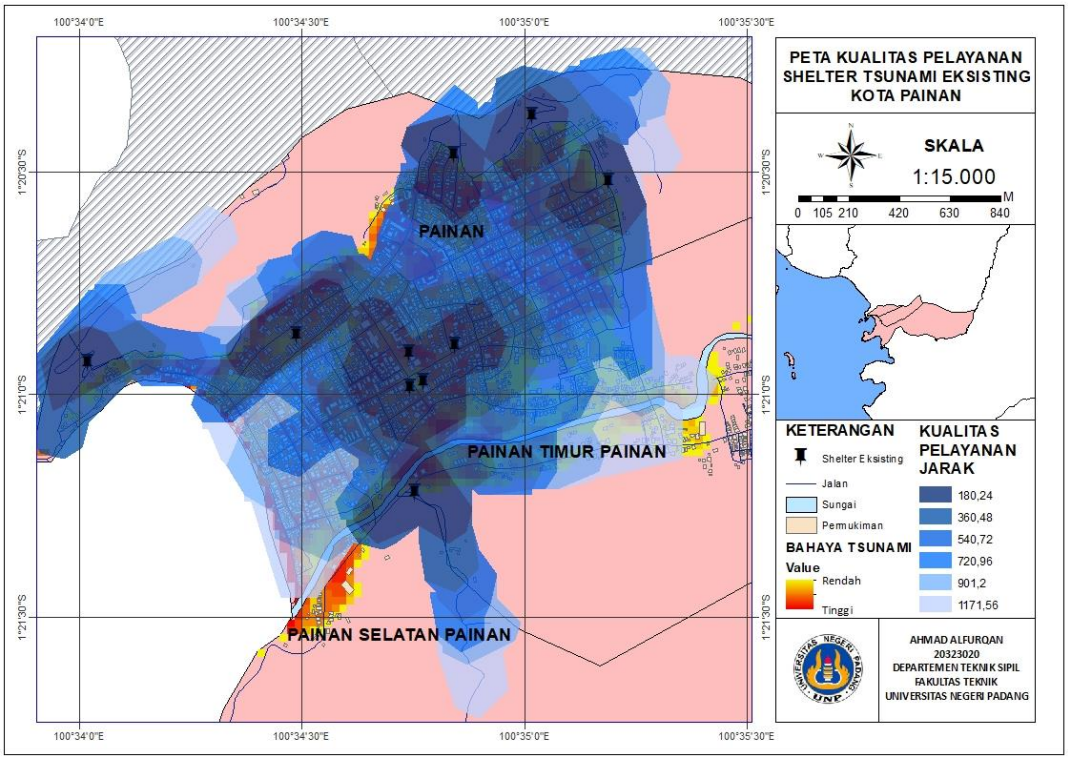

Figure 5. Service Quality Map of Existing Tsunami Shelter in Painan City (Distance 1171.56 m)

CONCLUSION

Based on the results of data analysis, discussion and purpose of the study, namely to determine the distance of shelter service coverage in Painan City with the Multiple Ring Buffer and Network Analyst methods, the following conclusions can be drawn:

1. Based on the results of multiple ring buffer analysis, shelters in Painan City can cover all areas in Painan City with a service distance of 585.78 m, with a time of 13 minutes, while using the Network Analyst method, shelters in Painan City can cover all areas in Painan City with a service distance of 1171.56 m with a service distance of 26 minutes.
2. The quality of service from the shelter capacity is included in good quality because the shelter is able to accommodate all people in Painan City with a capacity of 2,993,705 people for an evacuation room of 1 m2 and 5,987,410 people for an evacuation room of 0.5 m2.

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