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TSUNAMI HAZARD MAPPING AND LOSS ESTIMATION IN YOGYAKARTA INTERNATIONAL AIRPORT AREA

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ABSTRACT

Yogyakarta International Airport and Temon District in Regency Progo are located on the southern coast of Java island with the potential for tsunami disaster. The BNPB (National Agency for Disaster Relief) data along the southern coast of Java is a high priority region with high tsunami risk. This study aims to predict and analyze tsunami disasters with a height of 15 meters and 20 meters. To show the element of risk exposed using the overlay technique with a tabulated system using GIS software (Autocad and Global Mapper) to map the affected map. With a total area of study of 5,872 hectares in the 15-meter-wide scenario of the area reaching 2,836 hectares in 12 villages, the 206-hectare 206-acre scenario covers 14 villages. For the physical aspect, the 15-meter scenario is located at 6517 dilapidated buildings and the 20-meter scenario is at 9697 buildings. For the social aspect, there are 281,345 people for the 15-meter scenario and 295,554 for the 20-meter scenario. For TES Evacuation (TEA Evacuation Station) and TEA (Final Evacuation Station), for TES a total of 19 points that are TES based at Aerotropolis and TEA are on a hillside 4 kilometers from the coastline.

Keywords:
Tsunami, Evacuation, YIA Airport, Temon District

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1. Introduction

Indonesian territory is on active tectonic plates so it is more prone to earthquake disasters. Earthquakes that occur on the seabed caused vertical movements to produce a flow of seawater energy that moves towards the beach in the form of large waves which we know as tsunamis. Coastal areas are prone to Tsunami disaster if the area is adjacent to an active tectonic plate and bordered by the ocean. Based on data from the National Disaster Management Agency (BNPB) the southern part of Java's coastal region is a priority area with a high tsunami risk. Kulon Progo is one of the districts in the Province of the Special Region of Yogyakarta that borders the Indian Ocean.

The airport as the main access in the distribution of logistics when a disaster occurs from the airline and with the presence of airports in an area will have a large impact on economic growth so that the area around the airport will become more congested. The airport area has a faster development compared to other regions. The importance of the airport is not only as a facility for transportation via air but also as an element to channel logistics when disasters occur in the region.

In 2020 an international airport was operating in Temon sub-district. Temon District is one of the districts in Kulon Progo Regency. The distance from the airport terminal to the coastline is around 900 meters. YIA Airport (Yogyakarta International Airport) has the potential to accommodate 20 million passengers a year with an area of 210,000 meters making it one of the largest airports in Indonesia. YIA Airport will serve international flights and domestic airports replacing Adisucipto airports. With a potential of 20 million passengers a year, a day could reach 54,800 people making the area to be wary of for safety factors against disasters. In the simulation conducted by the Indonesian Disaster Experts Association (IABI), the mapping of the Kulon Progo regency and the YIA Airport area (Yogyakarta International Airport) were included in the zone which was vulnerable to the Tsunami disaster. In this simulation, a vulnerability map with a tsunami wave run-off of 5 meters, 10 meters, 15 meters, and 20 meters were produced.

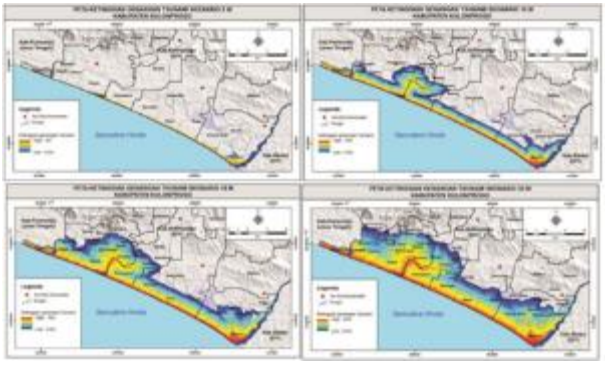

Figure 1. Tsunami Wave Simulation Map Height of 5 m, 10m, 15m and 20m

Source: The Second Annual Scientific Meeting of The Indonesian Disaster Expert Association (IABI)

In the history of tsunamis that have occurred in Indonesia from table 1, the highest tsunami waves are located in Aceh on the island of Sumatra in 2004 which has a height of 50 meters and the second largest is on the island of Flores, East Nusa Tenggara with a height of 26 meters in 1992 In this study using a simulation map of tsunami wave run-off height of 15 meters and 20 meters from the results of a seminar conducted by IABI (Indonesian Disaster Experts Association) for overlay maps because according to the history of tsunamis that have occurred in Indonesia in table 1, precisely in the coastal area of Java island is in Banyuwangi in 1994 with a height of 13.9 meters and in Pangandaran in 2006 with a height of 10 meters.

Table 1. History of Tsunami in Indonesia

No.	Year	Location	Wave Height
1.	1968	Sulawesi	8 – 10
2.	1969	Sulawesi	10
3.	1992	Laut Flores	26.2
4.	1994	Jawa	13.9
5.	1996	Irian Jaya	7.68
6.	2004	Aceh	50.9
7.	2006	Jawa	10

In this study, the problem questions are 1). Knowing the conditions exist in the area of YIA Airport (Yogyakarta International Airport) against tsunamis with a height of 15 meters and 20 meters. 2). Knowing the impacts in the YIA Airport area (Yogyakarta International Airport) based on physical impacts, social impacts, and economic impacts. 3). to find out the evacuation point during a tsunami disaster with a height of 20 meters. The condition of the airport location which is less than 1 kilometer from the coastline of the Java sea which is directly connected to the Indian Ocean making it vulnerable to tsunami disasters.

The purpose of this study is to predict and analyze the impact of tsunamis at YIA Airport (Yogyakarta International Airport) so that disaster mitigation measures can be taken to reduce the resulting impacts. So that the future benefits of this research are to find out how much the impact of the tsunami disaster can be used as a reference for evacuation which is one element of disaster mitigation. Evacuation is carried out to reduce the impact of the number of fatalities in the YIA Airport Area (Yogyakarta International Airport). When after an earthquake occurs when a tsunami hits, people must immediately evacuate to safe places such as TES (Temporary Evacuation Site) and TEA (Final Evacuation Site). The point of the evacuation plan takes into account the speed at which people walk, the time of arrival of the tsunami and the length of the evacuation route so that it can be easily accessed by the community during a tsunami disaster.

1.1. The Originality of The Research

Before this study, other studies discussed tsunami disaster mitigation in the YIA airport area, namely from the Technology Assessment and Application Agency (BPPT) and from Angkasa Pura 1. According to Widjo Kongko, one of the earthquake experts from the Agency for the Assessment and Application of Technology (BPPT), YIA airport has the potential to face a tsunami with a height of 10 to 15 meters on the shoreline and the airport has the potential to be hit by a tsunami. Also, PT. Angkasa Pura 1, as the project manager, put forward a plan to plant and maintain coastal trees to withstand coastal abrasion and the tsunami indicated the area was prone to tsunami disasters. There have been many studies discussing tsunami mitigation at YIA airport and this research discusses the specific impacts that occur at YIA airport and the temon district which is one unit of discussion.

2. Literature Review

2.1. Tsunami Disaster

According to Law No. 24 of 2007, explaining about Disasters is a series of events that threaten the lives and livelihoods of people caused by nature or non-nature as well as human actions, causing casualties and damage in the area around the YIA Airport (Yogyakarta International Airport).

Tsunami wave height reaching the coastline will cause damage. Tsunami waves will continue to hit at high speed that hit land and pass through areas that have different heights below. The height of the contour of the place can be a factor to determine the potential inundation area of tsunami waves. The existence of a puddle is an indication of information that there has been a possibility of damage in the area due to tsunami waves (Zaitunah, et al, 2012).

The distance of the impact of the tsunami's reach to the mainland is determined by the steep and sloping shape of the coast. the coastline which has a steep contour of the tsunami does not greatly affect the reach of the mainland because it is blocked by the coastal cliffs. while on the contrary if the contour on the sloping coastline the impact of the tsunami reaches becomes further inland. For example, the tsunami in Aceh reached a distance of 5 km inland from the coastline (Shunto, 1998).

2.2. Social Economy

The slowing down of the rate of economic growth which has experienced a post-disaster area is a negative impact of natural disasters. Natural disasters cause a decrease in production capacity on a very large scale impact on financial losses (Prantono, 2011).

Mitigation is an effort to reduce the risk of a natural disaster. Disaster risk is related to hazards that meet with

physical, social, economic, and environmental conditions that are vulnerable (Hyogo Framework for Action 2005-2015: Building the Resilience for Nations and Communities for Disasters, United Nations - International Strategy for Disaster Reduction (UN-ISDR), 2007).

2.3. Physical Elements of The City

According to Hamid Shirvani there are eight city-forming elements, namely Land use, Building and Mass Building, Circulation, Open Space, Signages, Pedestrian ways, Activity support and Preservation. In the city elements that have an effect on tsunami disaster mitigation are Land use, Building and Mass Building, Circulation. So these three elements will be discussed.

3. Research Method

The study area was Temon Subdistrict in Kulon Progo Regency which included Karangwuluh Village, Janten Village, Kebon Rejo Village, Temon Kulon Village, Kalidengen Village, Demen Village, Kedundang Village, Plumbon Village, Temon Wetan Village, Kaligintung Village, Kulur Village, Jangkaran Village Sindutan, Palihan Village, Glagah Village. Also included in the research area are the YIA Airport area (Yogyakarta International Airport) and Aerotropolis which are on the north side of the airport. With an area of 440,978 hectares which borders the north side is Kokap district and for the south side is the Indian Ocean. Temon District is located between the Bogowonto river on its east side and the Serang river on its west side.

In this study using data in the form of a google earth map in 2019 to determine the distribution of buildings, road networks in the YIA airport area and Temon District. For land-use use references from the RDTR map (Rencana Detail Tata Ruang). The population data in the Temon sub-district uses data from BPS in 2019. The software used in this study is Global Mapper and Autocad. To process contour maps from the SRTM worldwide elevation data, a global mapper is used and overlaid with images from Google Earth in 2019 so that you can see the position of the earth's height in the research area. The method used for this research is an overlay technique from a map of simulation results with a height of 15 meters and 20 meters which is overwritten with an existing Google Earth map image in 2019. From the map, an overlay can be produced a vulnerability map that can be seen areas affected by tsunami waves with a height of 15 meters and 20 meters. There are parameters used to determine areas that are vulnerable to tsunami waves with a GIS approach, namely: distance from the coastline, height of contour plains, productive land data, population density, and buildings. From these parameters, we can get physical vulnerability, economic vulnerability, environmental vulnerability, and social vulnerability. For physical vulnerability using building distribution data obtained from google earth and. The economic vulnerability calculates from the aspect of the loss of agricultural land affected, the loss of buildings which calculates the investment in building prices with the assumption of building prices based on the grade of vulnerability. For the assumption of the number of people affected by the loss of work, the productive age data is calculated using the regional minimum wage (UMR) in the Kulon Progo district. For social vulnerability, calculate the number of people affected by passengers per day at YIA airport and residents of the Temon sub-district from BPS data.

Figure 2. Research Boundary Map

Source: google earth

4. Results and Discussions

4.1. Land Use

In Temon sub-district, there are various land use functions that can influence the level of roughness when a tsunami wave hits land. It can be seen in the map below that land use for agriculture is very dominating with an area of 1,397 hectares and 795 hectares for the area of YIA and Aerotropolis airports. By 2020 the YIA Airport is fully operational and for Aerotropolis itself it is still within the design limits, not yet developed. Can be seen from the map below there is an empty/open land which is the runway of an aircraft whose position is from the shoreline of approximately 400 meters and for the airport building around 900 meters On the south side of the airport runway, there are ponds along the 3.6 kilometers along the boundary directly with a coastline of 89 hectares. For residential land/buildings, the position is spread in specific groups along Jalan Daendels Pantai Selatan and Jalan Wates - Purworejo as the main access.

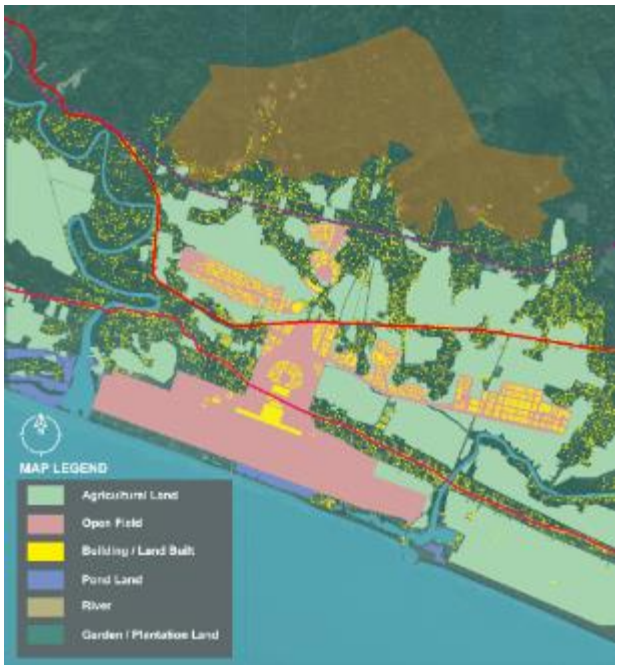

Figure 3. Land Use Map
Source: Author

In the mitigation of land use disaster affects the surface hardness. Surface roughness in determining tsunami hazard zones originating in coastal areas has different levels of resilience to the impact of tsunami waves when they hit land. On the surface roughness index by Berryman the following table is presented:

Table 2. Berryman Roughness Index (2006)

Land Cover	Roughness Coefficient Value
Water fields	0,007
Bush/shrub land	0,040
Forest	0,079
Plantation	0,035
Open field	0,015
Agricultural land	0,025
Settlement Land	0,045
Mangrove	0,025
Fishpond	0,010

The difference in surface hardness lies in plantation settlements, vacant land, and ponds. Land-use responses to tsunami inundation vary. Temon District itself is very much dominated by agricultural land with a small coefficient of the roughness of only 0.025. This is inversely proportional if you remember that the tsunami wave must be suppressed so that the impact area of the tsunami wave can be reduced. The following is a table of land uses in existing areas.

Table 3. Land Use Area

No.	Type Land	Area (Hectare)
1.	Settlement Land	361
2.	Agricultural land	1.397
3.	Fishpond	89
4.	Open field	782
5.	Water fields	136
6.	Plantation	2.765

For land use, the plantation has the most area of 2765 hectares, which is dominated by coconut trees whose position is on the north side of the airport and around residential areas. For agricultural land, it is ranked second for its total area of 1397 hectares. The agricultural land is located between Daendels road and Wates-Purworejo road with dry farming conditions. On the east side of the airport, there is agricultural land directly adjacent to the coast. This is when there is a tsunami disaster the waves that come crashing there is nothing to hamper so the waves can easily hit further. For open land with an area of 782 hectares more dominated by runways at YIA Airport and Aerotropolis area for the inter-building side. Open land has a small coefficient so that in the event of a tsunami disaster the airport runway area has very little roughness to reduce tsunami strength so that the side of an airport building can be affected. For residential land of 361 hectares which is dominated by residential buildings, residential land is concentrated on the side of major roads such as Daendels and Wates-Purworejo roads which orient the road parallel to the coastline to reduce the strength of the tsunami. For ponds located on the south side of the airport runway which is a direct barrier from the coastline which has the smallest coefficient value of 0.010. This is also very disadvantageous in terms of land use as a barrier from tsunami waves. For example, at the Sendai airport in Japan, the position of the airport building is located on the coast there is a Mangrove plant that is a barrier from the coast so that when a tsunami disaster can reduce the strength of tsunami waves. Judging from the Berryman table, the value is 0.025 higher than the pond area which is only 0.010. YIA Airport is located between two rivers, the Serang River and the Bogowonto River, if you see the roughness value of the water body has the smallest coefficient of all land roughness according to the Berryman index. According to GITEWS (German-Indonesia Tsunami Early Warning System) River is a freeway for tsunami waves from sea to land or land to sea. So that the tsunami waves come, the waves that pass through the river will come faster than those passing through the land. Areas around the river will be affected rather than those far from the river area. If a tsunami wave is large enough and crosses the river, the bridge in the wave path will be damaged or more severely destroyed by the tsunami wave. The plan of PT Angkasa Pura 1, which will replace the area of pond land located south of the airport runway, will be converted into a coastal forest that will withstand coastal abrasion and tsunami.

4.2. Elevation

Regional elevation data in Temon District were obtained from SRTM Worldwide Elevation Data. From the terrestrial height data processing, the area which has an altitude above 200 meters above sea level is on the north side of the Wates-Purworejo road which is 4 - 5 km away and on the side of the built area of the YIA Airport about 10 meters above sea level, this becomes vulnerable to tsunamis with altitudes above 10 meters. The low position also causes difficulties in the horizontal evacuation process. In the shoreline area, the average height is 9 meters above sea level so that for tsunami waves with a

height of 5 meters it will only affect the shoreline side. The area suitable for evacuation is on the north side with contour hilly. Estuary of the river that protrudes to the mainland can become a tongue in the event of a tsunami so that the sides of the river should be avoided in the event of a tsunami especially the Serang river. Physically, coastal areas have a high level of vulnerability to tsunamis, so there is a need for elevation as a tsunami barrier. From the pieces below, it can be seen that the south side is a flat area but the north side is steeply contoured.

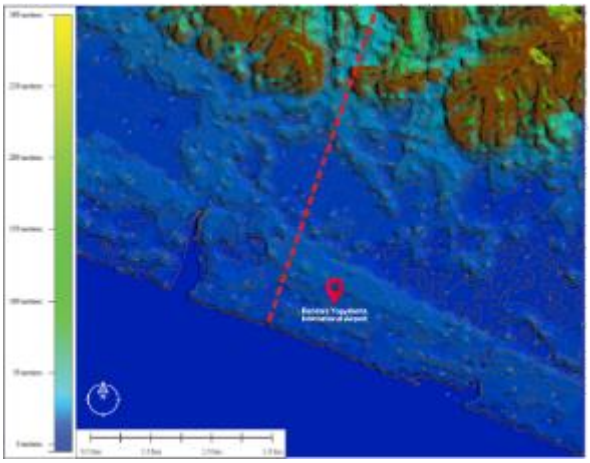

Figure 4. Topographic Map of Temon District

Source: Author

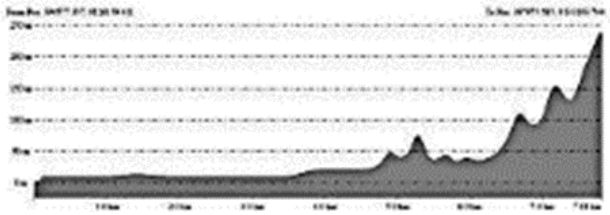

Figure 5. Contour Section

Source: Dhoni Wicaksono, 2015

4.3. Impact of Vulnerability

Tsunami Wave Height of 15 Meters

a. Physical Impact

The zone of a tsunami-affected area with a wave height of 15 meters is 2836 hectares from the research observation area of 440,978 hectares. For Temon Subdistrict, the affected villages are Jangkaran Village, Glagah Village, Plumbon Village, Kalidegen Village, Temon Kulon Village, Demen Village, Kendundang Village, part of Kebonrejo Village. The YIA Airport area in the Runway section was hit by a tsunami with a height of 11.25 m and the airport terminal within 900 meters of the coastline was hit by a tsunami wave as high as 7.5 meters. Aerotropolis area affected by damage is near the Serang river with a height of 11.25 meters to 7.5 meters. Aerotropolis areas affected by the tsunami are the Industrial Area, Residential Area, Trade in Services, and Public Service Facilities for Tourism. There are 6517 buildings affected by the tsunami wave height of 15 meters and the worst affected settlement area is on the Serang riverside and along the Daendels road.

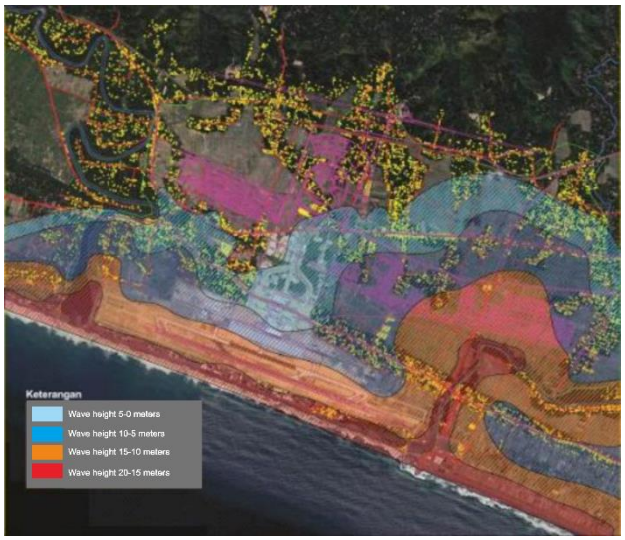

Figure 6. Tsunami Overlay Map Height of 15 meters

Source: Author

b. Social and Economic Impact

To estimate the social and economic impacts, indicators are used, namely population, agricultural land, and the value of an investment in buildings affected by the Tsunami. Economic Impacts concerning aspects of agriculture, building investment, and the impact of workers losing their jobs. Social impacts will calculate aspects For the impact of tsunami waves with a height of 15 meters according to the map below that some rice fields and settlements are flooded by tsunami waves.

1) Economy

a) Farming

Agriculture in Temon Subdistrict is a rice field with a surjan model. Surjan rice field is a rice field whose shape is seen from the top in the form of lines like a surjan shirt motif. This motif was formed because of the high and low differences in the different fields planted crops. Low level is used to plant rice and high level is used to plant crops / gardening. Surjan model agriculture with an area of 977 hectares which is 50% low slash (rice plants) and 50% high land (fruits / vegetables). Assuming a price of Rp5,000 and a paddy price per hectare producing Rp.35,000,000.

- Agricultural land area: 488x35,000,000 = Rp. 17,097,500,000 with 2 harvests per year to Rp. 34,195,000,000.
- Plantation land uses the greenhouse system: 488 x 487,500,000 = Rp237,914,640,000.

b) The investment value and affected house price

From the impact of economic losses in the residential building sector which are divided into low, medium, and high impacts the total amount is 4.9 trillion rupiahs and the construction of YIA Airport which reaches 9.3 trillion rupiahs. So if the total economic impact of buildings affected is a minimum of around Rp. 14,200,000,000,000.

c) Job Loss for 1 Year

From BPS data for 2019, the productive age in Temon Subdistrict is 17,572 people, with the UMR (Regional Minimum Wage) of Kulon Progo in 2019 amounting to Rp1,750,000, a month's loss is:

- 17,572x1,750,000 = Rp.30,759,786,000.

For the period of a year to become: 30,759,786,000x12 = Rp369,117,432,000

So the impact of job loss for a year is around Rp. 369,117,432,000 with the assumption of productive age in Temon sub-district losing its job.

Table 4. The Price of Compensation for Residential Buildings

Affected Zone	Impact Loss Low (IDR 300 Milion)	Medium (IDR 600 Milion)	High (IDR 800 Milion)	Total
Low	1117 buildings	-	-	Rp 335.100.000.000
Medium	-	1674 buildings	-	Rp 1.004.400.000.000
High	-	-	4.494 buildings	Rp 3.595.200.000.000
		Total Amount		**Rp 4.934.700.000.000**

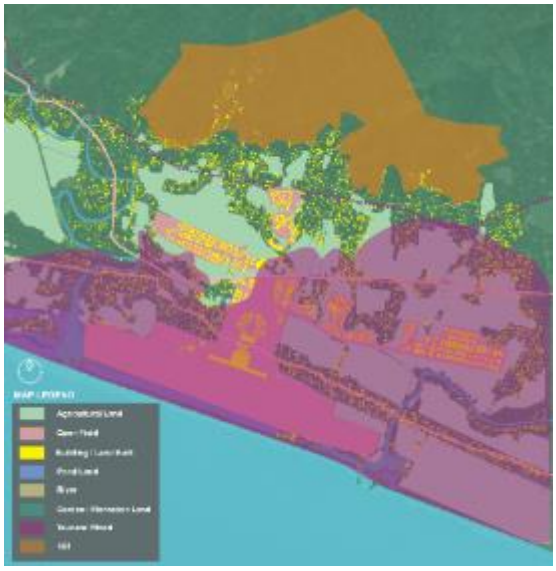

Figure 7. Map of Land Affected by a 15 Meter Tsunami

Source: Author

2) Social

For social impacts, namely the number of residents and households affected by the tsunami using data from BPS in 2019 for the population in Temon sub-district. The number of casualties will be displayed per the village and for the YIA airport will assume the amount of airport capacity each day.

Table 5. Tsunami Affected by 15 Meter

No.	Location	Population	Household
1.	Kalidengen Village	1.385	372
2.	Glagah Village	3.009	797
3.	Jangkaran Village	1.860	491
4.	Palihan Village	1.055	295
5.	Plumbon Village	2.306	623
6.	Sindutan Village	1.108	285
7.	Karangwuluh Village	-	-
8.	Jaten Village	-	-
9.	Kebonrejo Village	584	201
10.	Temonkulon Village	996	263
11.	Temonwetan Village	472	350
12.	Kaligintung Village	340	420
13.	Demen Village	1.325	372
14.	Kedundang Village	1.230	314
15.	Kulur Village	-	-
16	YIA Airport	54.800	-
17.	Aerotropolis	210.875	-
	Total Number	281.345	4.783

From the table above, it can be seen that the number of affected victims reached 281,345 people and around 4,783 households. From 15 villages in Temon sub-district, there are 3 unaffected villages namely Karang Wuluh, Jaten, and Kulur. For the YIA airport area completely inundated and for the Aerotropolis the inundated parts are: Public Service Areas Tourism, Trade in services, Settlement 2, Industry 1, industry 2 and industry 3.

Tsunami Wave Height of 20 Meters

a. Physical Impact

The zone of tsunami affected area with a height of 20 meters is 3612,4903 hectares from the research observation area of 4146,7402 hectares. For Temon Subdistrict, affected villages are Galagah, Jangkaran, Palihan, Plumbon, Sindutan, Karangwuluh, Jaten, Keborejo, Temonkulon, Temonwetan, Kaligintung, Demen and Kendundang villages. The Yia Airport area in the Runway section was hit by a tsunami with a height of 17.5 meters and the airport terminal within 900 meters of the coastline was hit by a tsunami wave as high as 20 meters. From the Aerotropolis area, only a part of the Aerotropolis Core Mixed area was not affected by the tsunami.

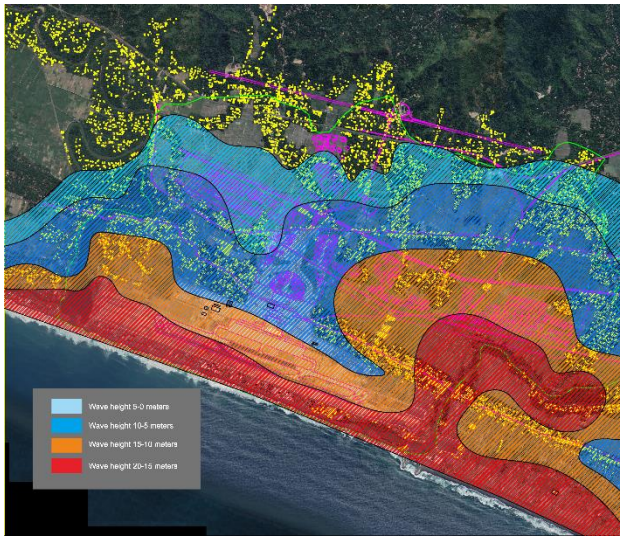

Figure 8. Tsunami Overlay Map Height of 20 meters

Source: Author

b. Social and Economic Impact

To estimate the social and economic impacts, indicators are used, namely population, agricultural land and the

investment value of buildings affected by the tsunami disaster. For the impact of tsunami waves with a height of 20 meters according to the map below that some rice fields and settlements are flooded by the tsunami waves.

1) Economy

a) Agriculture Surjan model agriculture with an area of 1138 hectares which is 50% low land (rice plants) and 50% high land (fruits / vegetables). Assuming a price (GKP) of IDR 5,000 and a price per hectare of IDR 35,000,000.

- Agricultural land area: 569x35,000,000 = Rp19,915,000,000 with 2 harvests a year to Rp39,830,000,000.
- Plantation land uses the greenhouse system: 569x487,500,000 = Rp277,387,500,000

b) The investment value and affected house price

From the impact of economic losses in the residential building sector which are divided into low, medium, and high impacts the total amount is 6.9 trillion rupiahs and the construction of YIA Airport which reaches 9.3 trillion rupiahs. So if the total economic impact of buildings affected is a minimum of around Rp. 16,200,000,000,000

Table 6. The Price of Compensation for Residential Buildings

Affected Zone	Impact Loss Low (IDR 300 Milion)	Medium (IDR 600 Milion)	High (IDR 800 Milion)	Total
Low	566 buildings	-	-	Rp 169.800.000.000
Medium	-	535 buildings	-	Rp 321.000.000.000
High	-	-	8.083 buildings	Rp 6.466.400.000.000
		Total Amount		**Rp 6.957.200.000.000**

c) Job Loss for 1 Year

From BPS data for 2019, the productive age in Temon Subdistrict is 17,572 people, with the UMR (Regional Minimum Wage) of Kulon Progo in 2019 amounting to Rp1,750,000, a month's loss is:

- 17,572x1,750,000 = Rp.30,759,786,000.

For the period of a year to become: 30,759,786,000x12 = Rp369,117,432,000

So the impact of job loss for a year is around Rp. 369,117,432,000 with the assumption of productive age in Temon sub-district losing its job.

2) Social

For social impacts, namely the density of the population affected by the tsunami using data from BPS in 2019 for the population in Temon sub-district. The number of casualties will be displayed per data on the number of villagers, Aerotropolis and the YIA airport will assume the amount of airport capacity each day. Tsunami waves with a height of 20 meters, there is 1 village in Temon District that is not affected, namely the village of Kulur. Kulur Village is located north of the Wates - Purworejo street, the altitude of which is in the hilly area. Unlike the area that is on the coastline of the coastline.

Table 7. Tsunami Affected by 20 Meter

No.	Location	Population	Household
1.	Kalidengen Village	1.385	372
2.	Glagah Village	3.009	797
3.	Jangkaran Village	1.860	491
4.	Palihan Village	2.327	592
5.	Plumbon Village	2.306	623
6.	Sindutan Village	2.050	578
7.	Karangwuluh Village	140	38
8.	Jaten Village	220	23
9.	Kebonrejo Village	666	202
10.	Temonkulon Village	1.021	335
11.	Temonwetan Village	420	127
12.	Kaligintung Village	721	223
13.	Demen Village	1.325	372
14.	Kedundang Village	2.162	175
15.	Kulur Village	-	-
16	YIA Airport	59.800	-
17.	Aerotropolis	220.084	-
	Total Number	295.554	4.948

There are 14 villages that were entirely affected by the Tsunami, namely Karangwuluh Village, Janten Village, Kebon Rejo Village, Temon Kulon Village, Kalidengen Village, Demen Village, Kedundang Village, Plumbon Village, Temon Wetan Village, Kaligintung Village, Kulur Village, Jangkaran Village Sindutan Village, Palihan Village, Glagah Village For the YIA Airport Area all areas affected by the Tsunami wave and for Aerocity all affected parts are the Public Education Service Facility Area, Resettlement Region 1, Some of the Aerotropolis Core Mixed Areas, Angkasa Pura Mixed Area, Tourism Public Service Facility Area, Regional Trade and Services, Resettlement Zone 2, Industrial Designation Areas 1,2 and 3.

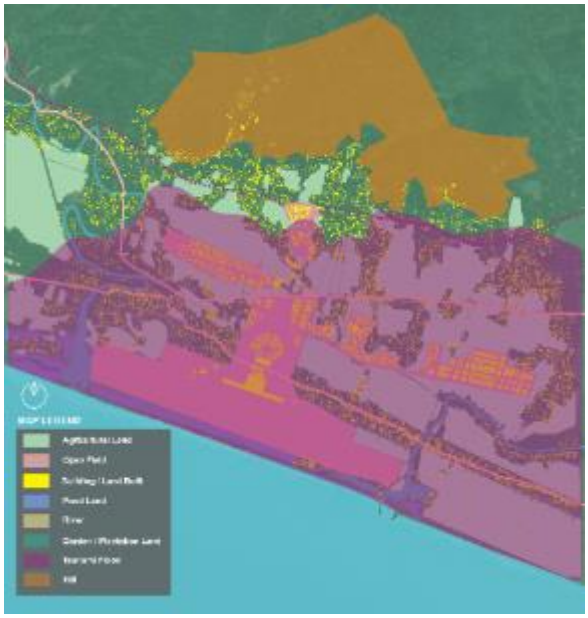

Figure 9. Map of Land Affected by a 20-meter Tsunami

Source: Author

4.4. Road Network

The road network is an important part of the context of disaster mitigation for evacuation aspects. The road is a link from the initial position to a safer place and makes a factor that influences safety in the event of a disaster.

Evacuation time is influenced by several aspects, namely the topography of the area, the function of land use, and the speed of humans to walk. The speed and effectiveness of evacuation are influenced by the physical form of a city.

The level of accessibility is determined by the road network in an area. The easier it is to reach a place the easier it will be to evacuate. On the map of the overlay inundation height of 15 meters and 20 meters, it can be seen that the location of the study area submerges the Primary Arterial Road, Primary Collector, and Environment. However, based on the level of accessibility, there are only 2 road network corridors, namely:

a. Jalan Purworejo - Jogja, Primary Arterial street class
b. Jalan Daendels Pantai Selatan, Primary Collector class

The two road links connect the study area with the outer area and are the main roads leading to this area. But the direction structure of Jalan Purworejo - Jogja and Daendels road south coast are parallel with the coastline so that it is less effective as the main evacuation route. For evacuation routes, people must be immediately away from the disasters they face. Tsunami disaster must be evacuated from the coastline immediately so that people away from the source of the disaster, the tsunami waves. The distance from the coastline to the Purworejo - Jogja road is only 2.6 kilometers and the Daendels road is about 1.3 kilometers.

Figure 10. Map of Main Road of Temon District

Source: Author

On the south side of the airport runway that runs along the coastline, there is a road used to access the glagah beach that does not have an intersection that leads away from the coastline. The crossing distance is about 5 kilometers because it directly borders the runway and airport area so that in the event of a tsunami disaster it becomes difficult to evacuate. The planned road in the Aerotropolis area that connects the Purworeko - Jogja road with the Daendels South Coast road directly leads away from the coastline giving residents the choice to immediately move away from the coastline during the tsunami. With so many roads that are not parallel to the coastline will provide many choices for residents to choose an easier evacuation route.

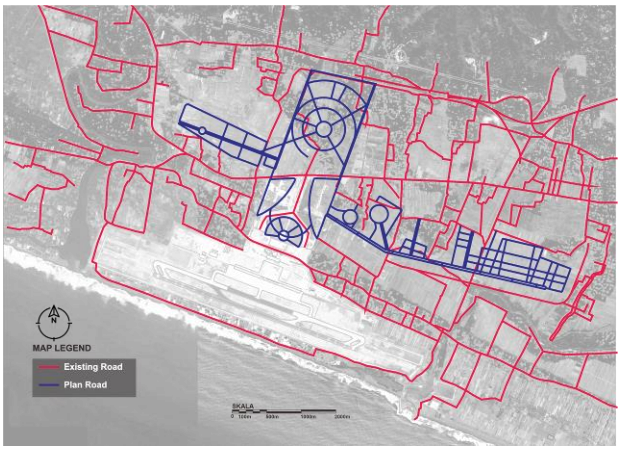

Figure 11. Road Network

Source: Author

From the picture, the road network is divided into two, namely the existing road and the planned road. The planned road is a road network from Aerotropolis that has not been developed. From the planned road, two roads lead directly away from the coastline.

4.5. Evacuation Plan

The principle in evacuation is to leave the affected area to a safe area. In the evacuation for the tsunami disaster is to leave the area near the coastline to the mainland to stay away from tsunami waves coming from the sea to be safe. There are two methods for evacuation, namely:

a. horizontal evacuation: to move residents to a safer or higher location.
b. vertical evacuation: move residents to a higher floor in the building in the case of very little evacuation time.

From the picture below it can be seen from the impact of tsunami waves with a height of 20 meters of flooded buildings, mostly in the Aerotropolis zone which has a building height of more than 20 meters so that it can be used as an evacuation site. The airport building is not submerged and can also be used as a temporary evacuation site.

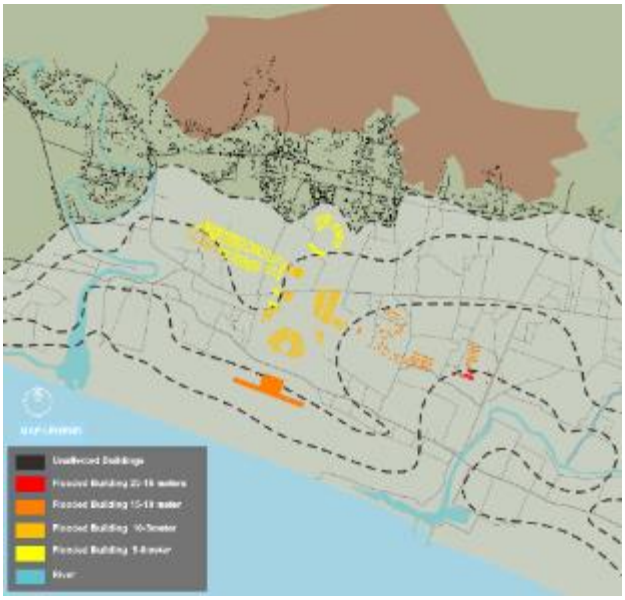

Figure 12. Map of Buildings not Flooded by Tsunami 20 meters

Source: Author

In the picture is divided into 3 color zones, namely high impact zone, low impact zone, and buffer zone. In the affected zone it is closer to the coastline so that the time for evacuation is faster. So that the method used is vertical evacuation so that users are buildings that have a high number of floors so that when a tsunami occurs this building is not flooded. For the low affected zone, the height of the wave run-up is lower for this case study 5 meters. The buffer zone, which is 500 meters away from the maximum range of the tsunami wave, is used to avoid traffic jams that trap refugees from the danger zone. For TES (Temporary Evacuation Sites) and TEA (Final Evacuation Sites) have rules for distance from each other. Referring to the Japan Institute of Fire Safety and Disaster Preparedness described:

The speed of evacuation is 0.751 m / sec (speed of old age) The evacuation process takes 12 minutes = 12x60 seconds = 720 seconds. Calculation of the distance is:

TES & TEA distance: 720 seconds x 0.751 m / sec = 540.72m = 541m

From this calculation, the distance between TES / TEA is 541 m.

Figure 13. Evacuation Route

Source: Author

From the map of buildings that are not inundated which is used as a reference for vertical evacuation sites. for the evacuation route, use existing roads and planned roads from the Aerotropolis. 8 evacuation routes lead directly away from the coastline. Of these 8 lines have different distances depending on the safety area of the 20-meter tsunami wave. Lines D and E are evacuation routes that do not use existing roads so that the shape of the path is straight.

Table 8. Evacuation Route Distance

No	Evacuation Route	Jarak Evakuasi
1	Route A	2.377 meter
2	Route B	3.325 meter
3	Route C	3.325 meter
4	Route D	3.114 meter
5	Route E	3.218 meter
6	Route F	3.566 meter
7	Route G	4.448 meter
8	Route H	4.453 meter

4.6. Building Form Orientation

Building orientation on the aspect of tsunami resistance is a way to reduce the force generated from tsunami waves when striking buildings. The smaller the plane that is parallel to or facing the coastline, the smaller the risk of force being received by the building. The long side of the building should be directed as far as possible in anticipation of the direction of the propagation of tsunami waves from the sea so that the lateral strength of the building structure is relatively greater and the force of the tsunami wave pressure is smaller. From the picture below there are two patterns of buildings facing the cross-section of the building affected by different tsunami waves.

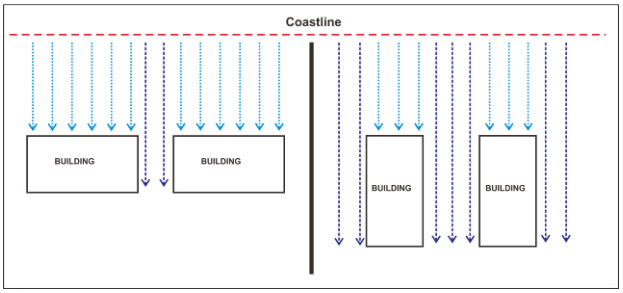

Figure 14. Building Form Orientation

Source: Author

For the dark blue line is the tsunami wave current that is not obstructed by the building, directly to the sidelines of the building and for the light blue line is the current from the tsunami wave is blocked by the cross-section of the building. A tsunami wave that is blocked by a building will look for gaps so that it can pass through the building so that it can cause an increase in inundation on the building walls. The ideal condition is the building facing pattern shown in the picture to the right.

The ideal width between buildings is greater than the cross-section of buildings parallel to the coastline. This is useful so that water from tsunami waves can directly pass through buildings through the distance between buildings so that the height of inundation does not increase or increase. The distance between buildings can also be used as a place to evacuate or escape from a tsunami disaster that is most appropriate is to move away from the beach with a short time.

On the building orientation map in Temon Subdistrict, YIA Airport Area and Aerotropolis plan, it can be seen that the red building is a building with an orientation that extends the building facing the coastline and the black building is a building whose direction towards the building is not long in line with the coastline. The shape of the YIA Airport terminal which has a long cross-section of the building parallel to the coastline is not suitable for reducing the force generated by tsunami waves and is also exacerbated by the terminal position which is only limited by a runway from the coastline. The distance of the terminal which is only 900 meters is very risky by the compressive force generated by the tsunami waves.

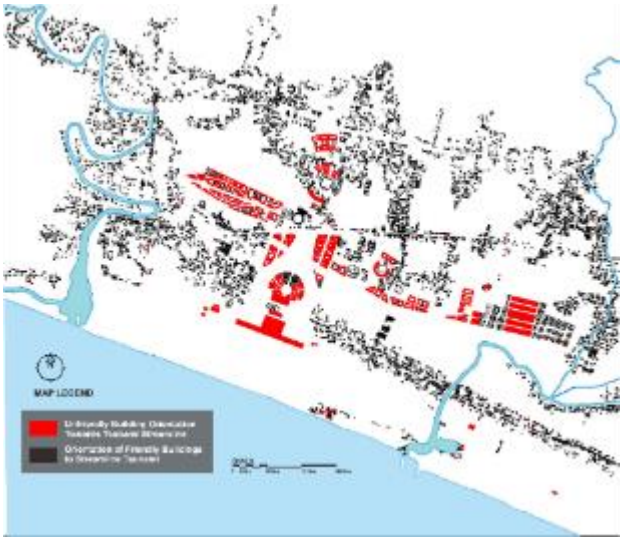

Figure 15. Orientation of Building Shape Not Friendly towards Tsunami Streamline

Source: Author

Figure 16. Building Openings Facing the Coastline

Source: Author

In the Aerotropolis plan in the industrial zone, the building extends parallel to the coastline, although the distance is approximately 2.5 kilometers from the coastline but is on the edge of the Serang river. When viewed from the map the tsunami-affected by the height of 15 meters and 20 meters, the area is at a high level different from the area on the side of the Bogowonto river. The industrial zone building in the planned Aerotropolis area is rectangular in line with the coastline, making it difficult for evacuation to stay away from the coastline and the Serang River.

4.7. Typology of Building Open Directions

In Indonesia, most of the building faces lead to access roads, this is common because it makes it easy to access the road leading to the building. Buildings in Temon District are settlements with a maximum height of two floors. There are doors and windows on the face of the building which when hit by a tsunami wave becomes a place where a puddle of water enters the building. Doors and windows are not the main structure so they are immediately destroyed so that it becomes the entry point for tsunami wave water. Buildings with facades facing the direction of the tsunami coming up to 45 ° are more prone to be destroyed by tsunamis than buildings with backing or perpendicular coastlines.

On Daendels Pantai Selatan road and Wates-Purworejo road the main access is to Temon District so that the right and left sides of the road become congested. The side of the road that faces the coastline is vulnerable to being destroyed by the tsunami. From the study area, there were 12,172 buildings and 2,563 buildings facing the coastline were vulnerable to collapse. If the position of the building which is in the low impact class and facing the back of the coastline, the potential for destroyed buildings is smaller.

5. Conclusion

From the results of the research that has been discussed in the results and discussion, it can be concluded that physically the Kulon Progo coastal area has a fairly high vulnerability. seen from topographic conditions, most of which are land with 5-10 m elevation located on the coast. Meanwhile, the use of land use functions in the Temon sub-district is dominated by agricultural land around the YIA airport and for the coastline, the land is used for fish ponds with very low levels of roughness. YIA Airport Area is located between two major rivers namely Serang and Bogowonto rivers which incidentally are large rivers whose direction is perpendicular to the Indian Ocean. So that it becomes an entry point when the tsunami hit the coast.

From the economic and social aspects of the impact of the tsunami height of 15 meters with 6517 flooded buildings, 977 hectares of rice fields and 17,572 people lost their jobs, the total loss amounted to Rp11,541,227,072,000. households that have to evacuate. From the economic and social aspects of the tsunami impact of a height of 20 meters with 9697 flooded buildings, 1138 hectares of rice fields and 17,572 people lost their jobs, the total is Rp12,386,334,932,000. The social aspects of the tsunami impact were 290,554 people and around 4948 households who had to evacuate.

For Evacuation, there are TES (Temporary Evacuation Sites) and TEA (Final Evacuation Sites), totaling 19 points, TES centered on Aerocity which has a tall building. For TEA, it is located on the side of a hilly which is far from the coastline as far as 4 km. Eight evacuation routes can be used to go to a safer area and away from the coastline. Each route has a vertical evacuation shelter point that can be used.

From the discussion of buildings concerning the orientation of the shape of the building and the typology of the direction of the building opening it can be concluded that many buildings are vulnerable when a tsunami wave hits. The shape of a rectangular building whose long sides are parallel to the shoreline will make the building to overload when the waves hit this building. Compounded if the opening of the building in the form of

doors and windows also leads to the coastline.

There have been many studies that discuss the tsunami at YIA airport and in this study, it is more focused on how big the impact will be from the tsunami disaster with a wave height scenario of 15 and 20 meters. In addition, it also provides an evacuation route plan where there is an Aerotropolis development plan that has not yet been built so that it can be an evaluation for the future. For the aerotropolis plan, the shape of the building is not friendly to tsunami waves because its shape has a wide side facing the coastline.

From this research it can be concluded that the YIA Airport area and Aerotropolis located in the Temon sub-district are vulnerable to tsunami disasters, the amount of loss and damage is very large so that disaster mitigation is needed in order to reduce the impact of the damage.

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