Disaster Evacuation Point and Evacuation Road Plan Kedunglarangan River Flood at Bangil Sub-District Pasuruan Regency

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Disaster Evacuation Point and Evacuation Road Plan Kedunglarangan River Flood at Bangil Sub-District Pasuruan Regency

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Abstract: Bangil district, passed by Kedunglarangan River, has been designated as a flood-prone area of Pasuruan Regency. In fact, the flooding of the river due to high rainfall, shallowing river and lack of water absorption result in submerged houses, loss of life, damage to ponds, agricultural land, and dam. As such, this condition provides the background for planning temporary evacuation sites (TES) and evacuation routes as an effort to reduce disaster risk. COVID-19 is currently a concern in Pasuruan Regency as it has been designated as one of the high-risk areas in 2021, impacting disaster management efforts. COVID-19 changes the TES planning approach and Kedunglarangan River flood evacuation route in order to be adaptive to pandemic conditions. This research aims to map the flood risk area of Kedunglarangan River and develop an adaptive TES and evacuation route for floods in Bangil District, Pasuruan Regency. This research applies quantitative approach with disaster risk analysis, capacity analysis, network analyst, overlay, and travel time analyst. The results of the analysis exhibit Kedunglarangan River flood risk area of 1,449.21 ha, dominated by a moderate level area covering 684.61 ha. Kalianyar Village has the largest total area of Kedunglarangan River flood risk covering 967.58 Ha. The TES planning results in 25 TES plans for Kedunglarangan River flood with the following specification: public land use, low-no impact level flood hazzard, adequate capacity and covering all flood-affected settlements. Evacuation route planning produces 28 evacuation route plans that are safe from river/bridge crossings and have the fastest travel time. This research is expected to provide valuable insights into flood disasters, disaster risk mapping, and adaptive disaster evacuation planning in the context of COVID-19.

Keywords: COVID-19, Disaster Risk, Evacuation Point, Evacuation Road, Flood

1. Introduction

Disaster potentially threatens the health, safety, welfare or economic wheels of the community as well as the wider unity of government apparatus [1)]. As a disaster-prone country [2)], Indonesia due to its location on the equator has a tropical climate with high rainfall with flood potential [3–5)]. Flood is a discharge of river water that exceeds normal conditions, caused by relentless rain falling in the upstream or in a location that a river cannot accommodate thus overflowing and inundating the surrounding area [6,7)]. Floods occuring almost every year in Indonesia is generally caused by high rainfall, soil infiltration rates, soil types, rock types, watershed types and shapes, human activities and spatial planning [8–10)].

Pasuruan Regency includes ten districts in Pasuruan Regency that are prone to flooding, one of which is Bangil district as it is passed by the downstream of Kedunglarangan River (RTRW of Pasuruan Regency, 2009-2029) [11)]. The flood disaster on River is a result of extremely high rain intensity ranging from 116 to 500 mm/day in the upstream area and reducing Kedunglarangan watershed due to dense built-up area [12)]. The overflow of Kedunglarangan River causes inundated houses, paralyzed community daily activities [13)], submerged agricultural areas up to 30-50 cm, damaged ponds due to the collapse of Kedunglarangan River dam [12)]. and 1,398 affected residents (BPBD Kabupaten Pasuruan, 2020) [14)]. Kedunglarangan River flood provides context for the need for research on TES planning and evacuation routes as part of efforts to mitigate the risk of Kedunglarangan River flood catastrophe.

A worldwide health crisis has unfolded with the emergence of the novel coronavirus, known as COVID-19 pandemic, commencing in December 2019 [15)]. In accordance with this prevailing trend, the COVID-19 pandemic has impacted nearly 200 countries globally [16)]. COVID-19 is currently anticipated due to Pasuruan

Regency's designation as one of the high-risk regencies in 2021 [17]. The occurrence of this epidemic has impeded the progress of global health, social, economic, political, cultural, energy, infrastructural, technological advancements, and also disaster managements [18,19]. Disaster management entails the preparation, response and recovery of victims and their commodities, achieved by effective readiness, mitigation, response, recovery, and assessment measures [20]. Therefore, COVID-19-adaptive TES and disaster evacuation routes must be planned.

Various studies on TES planning and evacuation routes have been conducted to examine Flood Disaster Risk Mitigation in Manado, analysing physical, social, economic, and environmental vulnerability variables [21]. Another study focused on Disaster Aspects in Bolagintang District, considering hazard, vulnerability, and capacity variables[22]. Additionally, research has been conducted on Planning for Flood Evacuation Sites Based on GIS, investigating evacuation sites and routes[23,24]. Furthermore, a study in Kobe, Japan, explored designing shopping street buildings to serve as disaster evacuation shelters during the COVID-19 pandemic, examining evacuation locations during the pandemic [25].

The COVID-19 pandemic has impacted various systems, such as TES planning and evacuation routes. On an annual basis, the Kedunglarangan River in Bangil District, Pasuruan Regency experiences flooding, highlighting the need for strategic planning and evacuation routes that consider the challenges posed by the COVID-19 Pandemic. This research aims to map the flood risk area of the Kedunglarangan River, design an adaptive TES, and evacuation route for the Kedunglarangan River flood in Bangil District, Pasuruan Regency, and enhance awareness and preparedness for future disasters.

2. Data and Method

This research employs a quantitative approach involving descriptive statistics. Data, processed by ArcGIS software, are collected through a primary survey utilizing capacity questionnaires to 8 villages affected by Kedunglarangan River Flood in Bangil District, Pasuruan Regency, including Manaruwi, Tambakan, Gempeng, Kalianyar, Kalirejo, Kiduldalem, Kolursari, and Kresikan villages (Fig. 1). The questionnaires were distributed to samples through the implementation of purposive sampling, a non-probability sampling technique that encompassed the following: 1) Engage in active participation within both formal and informal village institutions; and 2) Have occupied the study location for a minimum of five years.

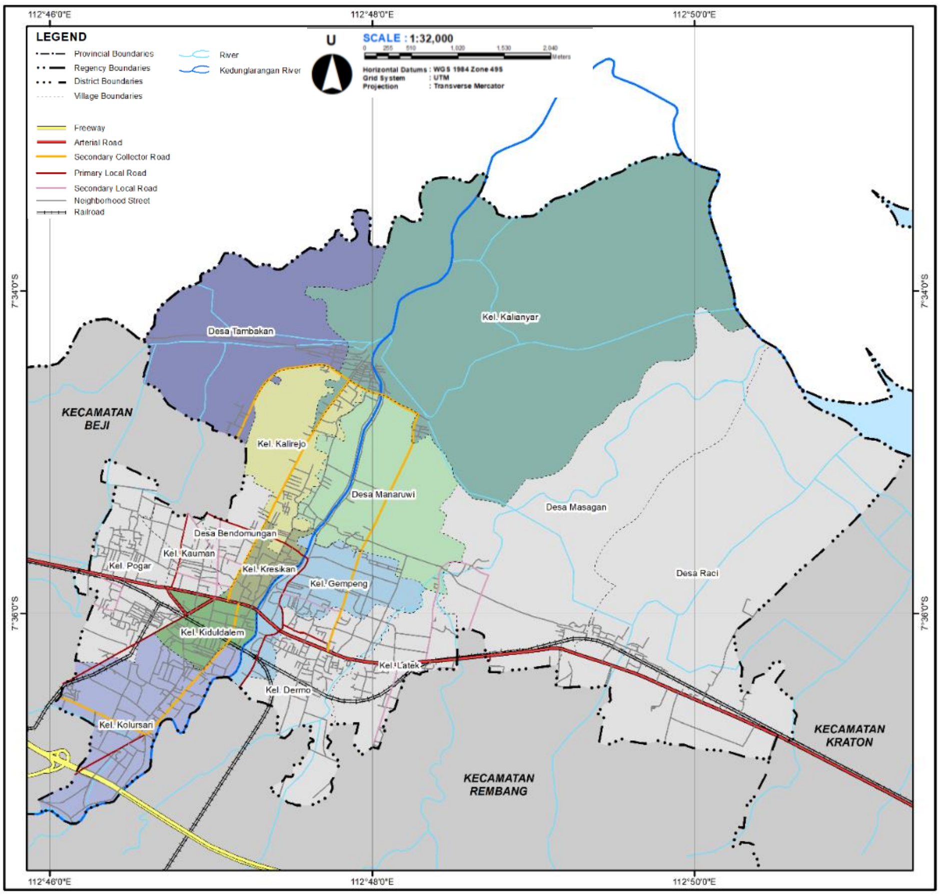

Fig. 1: The Research Area

The secondary survey is conducted by collecting data and information from several related agencies Data and information for the secondary survey were gathered from previous literature studies and several relevant agencies (Geospatial Information Agency, Central Statistics Agency, Public Works and Spatial Planning Agency, Regional Development Planning Agency, and Regional Disaster Management Agency). and previous literature studies. Disaster risk mapping is conducted using disaster risk analysis techniques. TES planning and evacuation routes is carried out using overlay analysis, service area analysts, capacity analysis, and travel time analysts.

2.1 Disaster Risk Analysis

Disaster risk analysis refers to a technique used to assess potential losses from a disaster, and must be prepared in the disaster risk reduction documents. The level of disaster risk is obtained by calculating hazards, vulnerabilities and capacities.

$$R = \frac{HxV}{C} \quad (1)$$

Details:

R: Disaster Risk H: Hazard

V: Vulnerability C: Capacity

Equation 1 highlights the interplay between disaster risk analysis's hazards, vulnerabilities, and capacities. Since disaster risk is proportional to the product of the severity of potential hazards and the degree of exposure such hazards present, it follows that reducing either one should reduce disaster risk. The lesser an area's capacity, the higher its disaster risk because the capacity and disaster risk are inversely related. Operationalization of Equation 1 is formulated by overlaying the hazard-vulnerability maps (Table 1 and Table 2).

Table 1. Hazard-Vulnerability Matrix (BNPB, 2012)[26].

Hazard / Vulnerability	High	Moderate	Low
Low	Moderate	Low	Low
Moderate	High	Moderate	Low
High	High	High	Moderate

Table 2. Risk Matrix (BNPB, 2012)[26].

Hazard-Vulnerability / Capacity	High	Moderate	Low
High	Moderate	Low	Low
Moderate	High	Moderate	Low
Low	High	High	Moderate

2.1.1 Hazard Analysis

Hazard constitutes event, whether natural or non-natural in origin, that have the potential to result in negative consequences such as harm, loss, and damage [27]. The potential for disasters can be categorized into two distinct groups, including primary and secondary risks.

This research employs the concept of major hazard potential as a metric for assessing risk. The present research employs secondary data obtained from a flood hazard assessment completed by the Municipal Disaster Management Board (BPBD) of Pasuruan Regency in 2020 to analyze the prospective occurrence of Kedunglarangan River flood in Bangil District, Pasuruan Regency.

2.1.2 Vulnerability Analysis

Vulnerability represents a significant factor in comprehending the risk associated with disasters, since it entails the disturbance of environmental conditions, communities, infrastructure, and services, resulting in many forms of losses [28]. Vulnerability is characterized by a decline in the resilience of a community as a result of external forces that pose threats to individuals' well-being [29]. Both meanings indicate that vulnerability has a propensity to become ingrained in individuals' lives. Table 3 depicts the variables and parameters

Table 3. Vulnerability Classifiction [14,22,26,30]

Vulnerability Sub Variables	Parameter
Physical Vulnerability	Number of Buildings
	Number of Public Facilities
	Number of Critical Facilities
Economic Vulnerability	Ratio of People Working in Vulnerable Sectors
	Ratio of Poverty
Social Vulnerability	Ratio of Population Density
	Ratio of Sex Gender
	Ratio of People with Disability
	Ratio of Population in Vulnerable Age
Environmental Vulnerability	Scrubland area
	Swamp area (50%)

2.1.3 Capacity Analysis

Capacity refers to the inherent capability of a region and its society to undertake proactive measures aimed at mitigating the occurrence and minimizing the impact of hazards and resultant losses caused by catastrophes [31]. In addition, capacity refers to the inherent strength and resources available within a community and its environment, enabling effective and efficient prevention, preparedness, response, and recovery efforts in the face of a disaster [32,33], the assessment of community capability can be gauged by many characteristics, including the presence of an early warning system, evaluation of disaster risks, provision of disaster education, mitigation of fundamental risk factors, and readiness for potential disasters. Disaster capacity is calculated by distributing questionnaires in flood-affected villages. Furthermore, multiplication is carried out with the weights, as well as the total weighting of each factor to obtain capacity in an area (Table 4).

Table 4. Capacity Calculation [21,34)]

Capacity Sub Variables	Parameter
A. Institutional rules for disaster management at the local level	Guidance for village regarding the aspect of DRR in preparing village plans
	Formation of a DRR concern group
	Formation of a disaster preparedness village
	Facilitation for Government and NGO related to DRR
B. Early warning and disaster risk assessment	Assessment regarding a disaster at least at the district scale and the results are at least known by village officials
	Distribution of disaster maps
	Installation of an EWS system by the government
	Installation of an early warning system
C. Disaster Education	Public awareness regarding the threat of flooding, did not refuse to be evacuated
	Socialization of disaster risk reduction is carried out by the government
	Provision of disaster simulation
D. Mitigation of basic risk factors	Data collection from village government on vulnerable groups (toddlers, seniors and people with disabilities)
	Enforcement of the community's economy with training and providing assistance
	Enforcement of the social actions for community capacity
E. Development of preparedness on all fronts	Emergency response command system that involves village officials
	Existence of special volunteers for disaster management
	Access for volunteers to coordinate with the District BPBD

2.2 TES Determination

Four parameters, including the findings of a flood disaster risk analysis, land use, capacity (Equation 2), and service area, are considered when determining TES. A network analyst analyzes TES meeting these four criteria. In order to adapt TES to the COVID-19 pandemic, fifty percent of the building's capacity and a heterogeneous space system are allocated. Analysis of space requirements is predicated on the premise that 1m^2 is denoted for 1 person [35)].

$$Capacity = \frac{building\ area}{minimum\ proportion\ of\ space\ needs\ per\ person} \quad (2)$$

2.3 Evacuation Route Determination

The assessment of evacuation routes encompasses the evaluation of three key characteristics, including river/bridge crossings, road network infrastructure, and travel time. The identification of bridge crossings on the road network is achieved using the overlay technique. The determination of travel time is influenced by the pace at which an individual walks (**Equation 3**). The ideal evacuation time is <60 minutes [36)].

$$V(r) = \frac{S}{t} \rightarrow t = \frac{S}{V(r)} \quad (3)$$

Details:
T = travel time,
S = distance,
V(r) = walking speed

3. Results and Discussions

3.1 Disaster Risk Analysis

3.1.1 Hazard Analysis

Table 5 and Figure 2 exhibits 1,449.21 Ha of the area affected by Kedunglarangan River flood. The dominant distribution of the affected areas lies on the northern Bangil District, covering Kalirejo, Tambakan, Manaruwi, and Kalianyar Villages. Not only is the flood caused by high rainfall intensity and low topography, but it also results from the confluence of Kedunglarangan River and the Werati River, overflowing during high-intensity rains and high tides from the north preventing Kedunglarangan River from flowing into the sea.

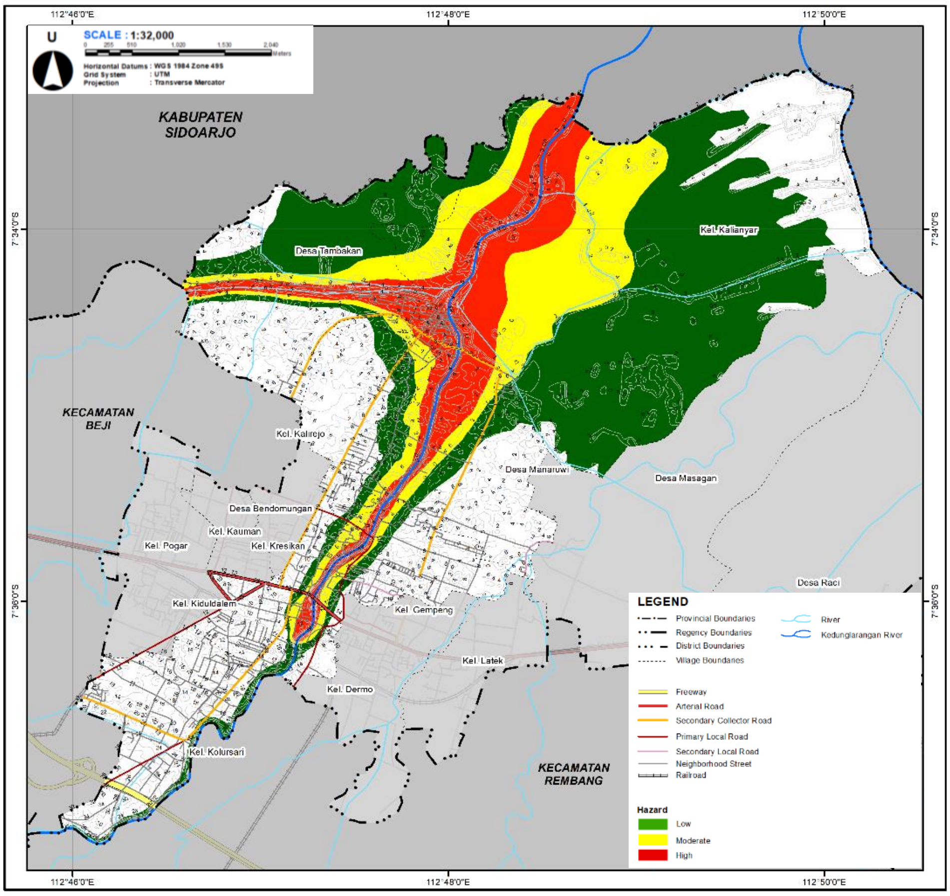

Fig. 2: Kedunglarangan River Flood Hazard Map.

Table 5. Kedunglarangan River Flood Hazard (BPBD Kab. Pasuruan, 2020) [14].

No.	Village	Flood Hazard Area (Ha)			
		Low	Moderate	High	Total
1	Manaruwi	48.8	34.23	56.68	139.7
2	Tambakan	147.62	35.68	39.06	222.3
3	Gempeng	14.33	11.03	9.19	34.55
4	Kalianyar	568.53	226.04	173.0	967.5
5	Kalirejo	23.31	8.89	2.41	34.61
6	Kiduldalem	2.5	3.35	5.33	7.83
7	Kolursari	19.65	-	-	19.65
8	Kersikan	6.65	9.93	6.34	22.92
Total Affected Area		**831.39**	**325.8**	**292.0**	**1,449.21**

3.1.2 Vulnerability Analysis

Physical Vulnerability is measured by the parameter of the number of houses, public facilities and critical facilities. The number of public facilities is determined based on the distribution of trade and service, and worship facilities. Critical facilities that function during an emergency is crucial, which at the research location include health facilities and terminals. Table 6 shows a moderate level of physical vulnerability in the dominant research area, high level in Kelurahan Kiduldalem due to the high distribution of buildings and facilities.

Economic Vulnerability is measured by the population working in vulnerable sectors and poverty. Table 6 reveals the domination of low level economic vulnerability. The high level vulnerability found in 3 villages (Manaruwi, Tambakan and Kalianyar). Many ponds and productive agricultural land causing the high ratio of the population working in vulnerable sectors is the reason for such condition.

Social Vulnerability is measured by demography and population. Social vulnerability in the research area is dominated by the low category (Table 6). Whilst, the high vulnerability in Kelurahan Kiduldalem and Kelurahan Kresikan is caused by high population density.

Environmental Vulnerability refers to environmental damage potentials due to disasters. Table 6 indicates the majority of moderate level of environmental vulnerability in the research area occurring in 5 villages (Manaruwi, Tambakan, Kalianyar, Kiduldalem and Kresikan).

Regional vulnerability is obtained from the results of weighing and overlaying among physical, economic, social, and environmental vulnerabilities in accordance with Perka BNPB 2/2012[26]. Table 6 and Figure 3 shows the distribution of regional vulnerabilities in Bangil District dominated by low vulnerability levels. A high level of vulnerability is found in 3 villages, including Kiduldalem, Kalianyar and Kresikan. Kresikan village has the highest regional vulnerability score in the research location. The influencing aspects are physical, social and economic vulnerability scores.

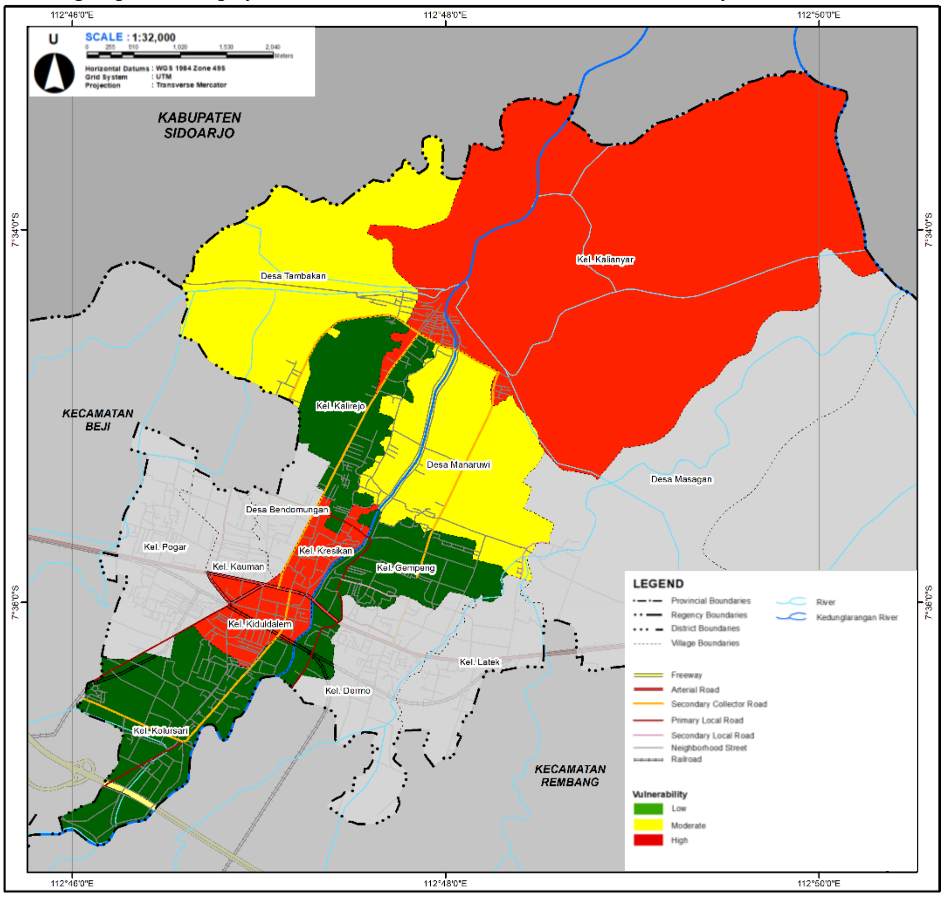

Fig. 3: Vulnerability Map.

Table 6. Area Vulnerability

Village	A	B	C	D	E	Classification
Manaruwi	1.3	2.5	1.5	2	1.75	Moderate
Tambakan	1.0	3	1.6	2	1.84	Moderate
Gempeng	2.0	1	1.75	2	1.65	Low
Kalianyar	1.7	3	1.45	2	1.96	High
Kalirejo	1.7	1.5	1.25	1	1.40	Low
Kiduldalem	3.0	1	2.2	2	2.08	High
Kolursari	2.0	1	1.5	3	1.65	Low
Kresikan	2.3	2	2.5	1	2.18	High

Details:

A: Physical Score (25%), B: Economic Score (25%), C: Social Score (40%), D: Environmental Score (10%), E: Area Vulnerability Score

3.1.3 Capacity Analysis

The ability of disaster management at the village level is influenced by various elements, including institutional regulations, early warning systems, risk assessment, disaster education, mitigation of underlying risk causes, and comprehensive preparedness efforts. Table 7 and Figure 4, it can be observed that three villages, including Kersikan, Kiduldalem, and Kolursari, exhibit a low capacity. On the other hand, the village of Kalianyar has a moderate capacity. Conversely, the villages of Gempeng, Kalirejo, Manaruwi, and Tambakan are characterized by a high capacity. The villages in the Bangil area exhibit a notable level of capacity, which can be attributed to the implementation of a comprehensive disaster preparedness village initiative. The Pasuruan Regency Government, in collaboration with the TNI-Polri, City Order Officers, BPBD, and the local community, organized a comprehensive simulation to enhance preparation in responding to disasters, with a particular focus on flood management.

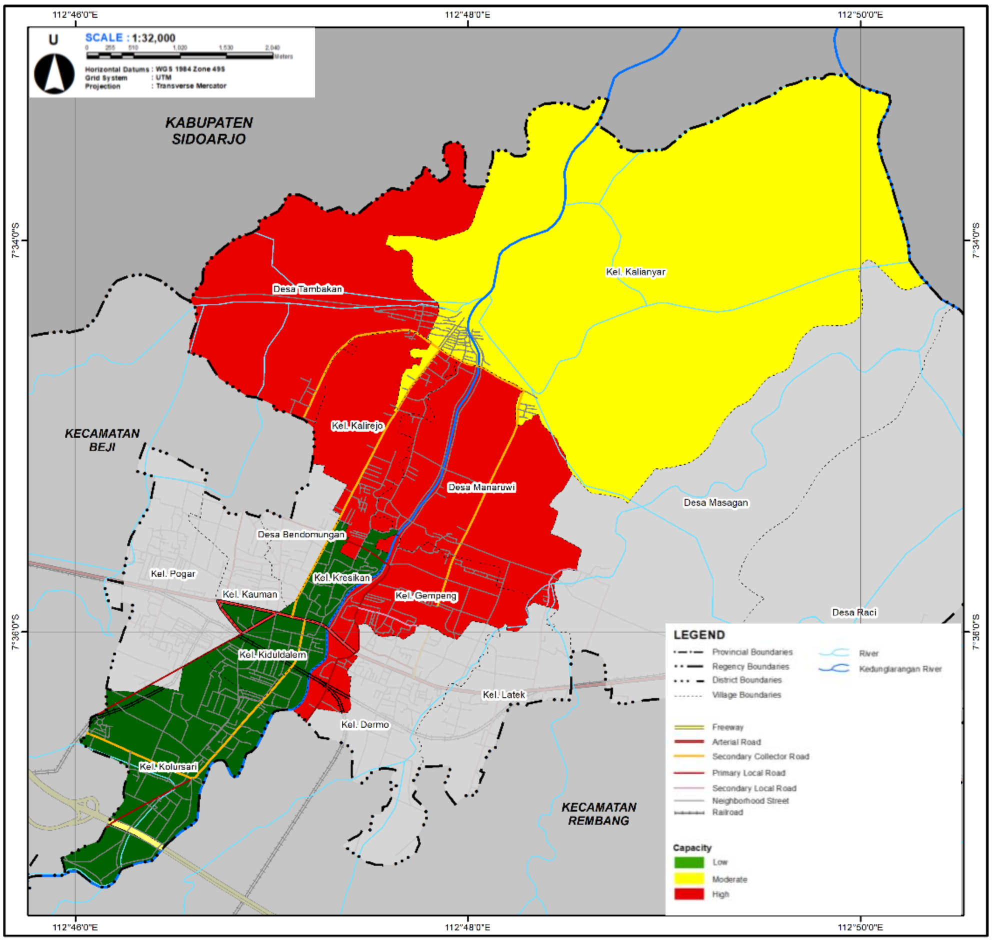

Fig. 4: Capacity Map.

Table 7. Capacity Assessment Result

Villages	Factor Score					Total Score	Capacity
	A	B	C	D	E		
Manaruwi	9	4	4	6	6	29	High
Tambakan	9	4	6	6	6	31	High
Gempeng	5	4	6	6	6	27	High
Kalianyar	5	4	6	3	6	24	Moderate
Kalirejo	9	4	6	6	6	31	High
Kiduldalem	6	4	1	1	0	12	Low
Kolursari	0	4	2	6	1	13	Low
Kersikan	4	4	3	0	1	12	Low

3.1.4 Kedunglarangan River Flood Risk Analysis

The assessment of the flood disaster risk in Kedunglarangan River is derived from the integration of hazard analysis, vulnerability assessment, and capacity evaluation. The term "map coloring" pertains to the regulation Perka BNPB No. 02 of 2012 [26]. According to Table 8 and Figure 5, the aggregate flood risk area of Kedunglarangan River is recorded as 1,449.21 hectares. Kedunglarangan River exhibits a predominance of moderate flood risk level, covering an area of 684.61 hectares. This is followed by a low flood risk level, encompassing 334.8 hectares, and a high flood risk level, spanning 429.8 hectares. Kalinyar Village exhibits the highest level of vulnerability, as evidenced by its allocation of 568.53 hectares at a moderate risk level and 399.05 hectares at a high risk level. The presence of numerous dangers and weaknesses within Kalianyar Village, along with an unmatched level of capability, accounts for this situation.

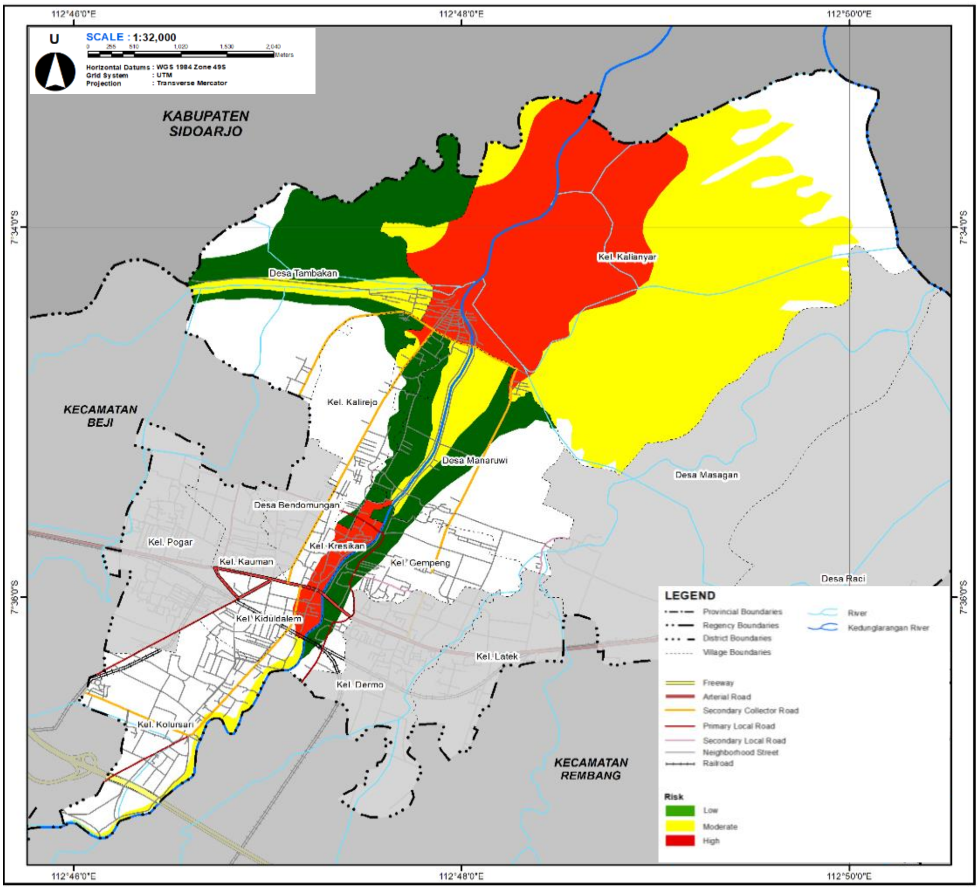

Fig. 5: Risk Map

Table 8. Risk Assessment Results

Village	Width of Disaster Risk Area (Ha)			
	Low	Moderate	High	Total
Manaruwi	83.03	56.68	-	139.71
Tambakan	182.61	39.75	-	222.36
Gempeng	34.55	-	-	34.55
Kalianyar	-	568.53	399.05	967.58
Kalirejo	34.61	-	-	34.61
Kiduldalem	-		7.83	7.83
Kolursari	-	19.65	-	19.65
Kresikan	-	-	22.92	22.92
Total	**334.8**	**684.61**	**429.8**	**1449.21**

3.2 TES Determination

3.2.1 TES Criteria

TES planning for Kedunglarangan River flooding considers the criteria, capacity and service area of the TES. The TES criteria include the level of risk of flooding and land use. TES cannot take place in areas with a high level of risk of flooding [24]. Types of land use that can be used as TES include fields & open land and public settlements [37]. Table 9 shows 25 TES locations that match the specified criteria.

Table 9. Planning of Criteria-based TES

No	Name	Flood Threat Level	Land Use
1	Tambakan Village Office	Unaffected	Office
2	Tambakan Volleyball Field	Low	Sport
3	Mujahideen Mosque	Low	Worship
4	Kalirejo Football Field	Low	Sport
5	Kalirejo Village Office	Low	Office
6	Jami' Kalirejo Mosque	Low	Worship
7	Ar-Rahmad Mosque	Unaffected	Worship
8	Ar-Rahmad Football Field	Not affected	Sport
9	Kalianyar Village Office	Unaffected	Office
10	Kalianyar Health Center	Unaffected	Health
11	Manaruwi Village Office	Low	Office
12	Al-Mubarak Mosque	Low	Worship
13	Baiturrahim Mosque	Unaffected	Worship
14	Gempeng Ward Office	Low	Office
15	Open field	Low	Open field
16	Syarif Hidayatullah Mosque	Unaffected	Worship
17	Sabilul Falah Mosque	Unaffected	Worship
18	Sabilillhah Mosque	Unaffected	Worship
19	Baitul Muttaqin Mosque	Unaffected	Worship

No	Name	Flood Threat Level	Land Use
20	Al Huda Mosque	Unaffected	Worship
21	Kollursari Village Office	Unaffected	Office
22	Rahmat Mosque	Unaffected	Worship
23	Kersikan Ward Office	Low	Office
24	Bangil Square	Unaffected	Public facilities
25	Kiduldalem Village Office	Unaffected	Office

3.2.2 TES Capacity

Kedunglarangan River Flood TES capacity has been modified in response to the prevailing circumstances of the COVID-19 epidemic. According to [25,38], it has been proposed that the ability to develop capacity during the COVID-19 pandemic is limited to 50% of the original total capacity. Accordingly, Kedunglarangan River Flood Test plan had a total evacuation capacity of 40,151 individuals, as indicated in Table 10. This capacity was deemed adequate to serve the population of 31,305 individuals affected by the flood. The adaption of the TES during the COVID-19 pandemic was implemented by employing the notion of heterogeneous space. This involved partitioning the TES room into many sections according on the varying degrees of exposure of the individuals there. Furthermore, it is advisable to implement the TES strategy in order to furnish health protocol resources. According to Decree Number HK.01.07/MENKES/382/2020 [39] stipulated by the Minister of Health of the Republic of Indonesia, a number of health protocol instruments have been identified. These tools encompass hand washing facilities, temperature monitoring devices/thermometers, masks, hand sanitizers, and personal protective equipment.

Table 10. TES Capacity during the COVID-19 Pandemic.

No	Site	Location	Capacity during the COVID-19 Pandemic	Allocated Villages	Number of Affected Population (Person)
1	Tambakan Village Office	Tambakan	447	1. Tambakan 2. Kalianyar 3. Kalirejo	11,152
2	Tambakan Volleyball Field	Tambakan	264		
3	Mujahideen Mosque	Kalianyar	545		
4	Kalirejo Football Field	Kalirejo	4,464		
5	Kalirejo Village Office	Kalirejo	1,223		
6	Al-Ishlan Mosque	Kalirejo	1892		
7	Ar-Rahmad Mosque	Kalirejo	1,502		
8	Ar-Rahmad Football Field	Kalirejo	1,768		
9	Kalianyar Village Office	Kalianyar	296		
10	Kalianyar Health Center	Kalianyar	542		
11	Manaruwi Village Office	Manaruwi	990	Manaruwi	3,148
12	Al-Mubarak Mosque	Manaruwi	821		
13	Baiturrahim Mosque	gempeng	603	Gempeng	4,715
14	Gempeng Ward Office	gempeng	601		
15	Open field	gempeng	1,189		
16	Syarif Hidayatullah Mosque	gempeng	401		
17	Sabilul Falah Mosque	gempeng	1,436		
18	Sabilillhah Mosque	Kolursari	1,172	Kolursari	3,030
19	Baitul Muttaqin Mosque	Kolursari	546		
20	Al Huda Mosque	Kolursari	1,073		
21	Kollursari Village Office	Kolursari	382		
22	Rahmat Mosque	Kolursari	942		
23	Kersikan Ward Office	Kersikan	493	1. Kersikan 2. Kiduldalem	9,260
24	Bangil Square	Kersikan	16,242		
25	Kiduldalem Village Office	Kiduldalem	320		

3.2.3 Service Area

The geographical scope of the TES service area has a significant impact on both the allocation of refugees and the establishment of evacuation routes leading to TES. The research area takes into account the distribution of TES, settlement dispersion, and the road network within the service region. The categorization of TES distances is classified into four distinct groups, respectively 10, 250, 500, and 1,000 meters. Figure 6 and Figure 7, it is evident that the proposed TES has the capacity to accommodate towns situated in regions characterized by a heightened susceptibility to flooding from Kedunglarangan River. Moreover, the TES is strategically located at a distance of less than 1000 meters from these at-risk places.

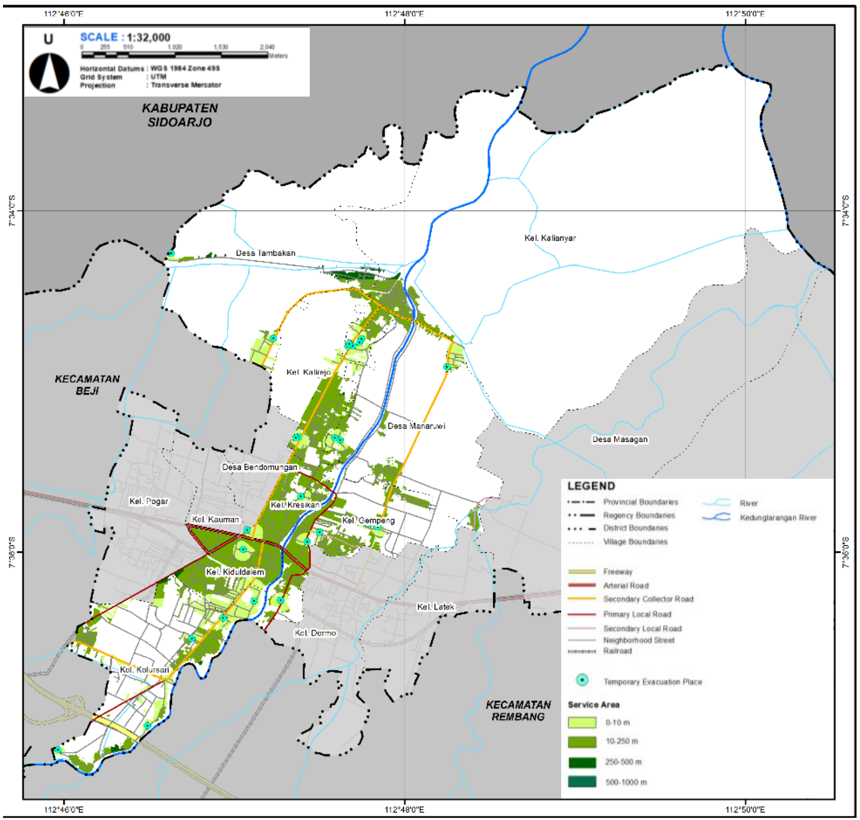

Fig. 6: Service Area Map

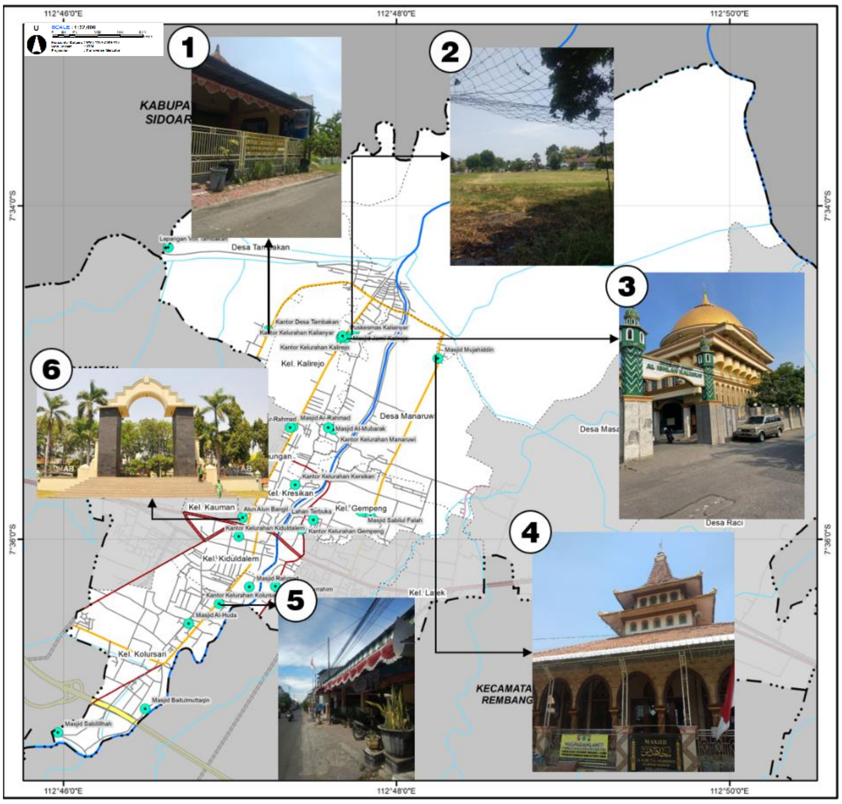

Fig. 7: TES Photomapping.

3.3 Evacuation Route Determination

The evacuation strategy for Kedunglarangan River flood takes into consideration various factors, including the status of the road network, the distribution of rivers or bridges, and the estimated travel time. The research area is traversed by two prominent rivers, including Kedunglarangan River and the Werati River, both of which possess the capacity to experience concurrent flooding events. The evacuation route for Kedunglarangan River flood does not incorporate areas traversed by rivers or bridges. Instead, it utilizes a principal arterial road of 14 meters in width, a collector road ranging 6-8 meters in width, and local and environmental roads with a width of 4-5 meters. According to the findings of network analysts, a total of 28 flood evacuation routes have been identified for Kedunglarangan River. The designated evacuation routes guide residents towards the predetermined TES (Fig. 8 and Fig. 9). Evacuation route planning considers evacuation travel time. According to [36], the ideal evacuation time is <60 minutes. The evacuation route for Kedunglarangan River flood disaster is in the span of under 60 minutes (Table 11).

Table 11. Kedunglarangan River Flood Evacuation Route (Analysis Result).

Village	Route	Evac.route-TES	Length (m)	Time (minutes)
Tambakan	1	T2-T4-TES Tambakan Village Hall (-7° 34' 44.866",112° 47' 13.838")	989	20
	2	T2-T3-B1-TES Kalirejo Football Field (-7° 34' 44.978",112° 47' 44.907")	861	15
	3	T1-TES Tambakan Volleyball Court (-7° 34' 14.969",112° 46' 37.740")	656	13
Manaruwi	1	M4-TES Al-Mubarok Mosque (-7° 35' 19.878",112° 47' 35.437")	872	16
	2	M1-M2-B1-TES Ar-Rahmad Football Field (-7° 35' 19.865",112° 47' 21.702")	970	17
	3	M3-M1-TES Manaruwi Village Office (-7° 35' 20.578",112° 47' 37.310")	294	5
	4	M5-M6-KA7-TES Mujahiddin Mosque (-7° 34' 54.903",112° 48' 14.916")	872	17
Kersikan	1	KR1-TES Office of Kresikan Village (-7° 35' 40.495",112° 47' 23.463")	417	7
	2	KR2-KR3-KR4-KR1-TES Kresikan Village Office (-7° 35' 40.495",112° 47' 23.463")	464	10
	3	KR5-KR6-KR7-B1-TES Bangil Square (-7° 35' 52.276",112° 47' 4.563")	880	17
Kiduldalem	1	KD1-KD2-KD3-TES Office of Kiduldalem (-7° 35' 59.069",112° 47' 3.143")	528	9
	2	KD3-KD4-KD5-B1-TES Bangil Square (-7° 35' 52.276",112° 47' 4.563")	561	11
Kalirejo	1	KJ2-B1-TES Ar-Rahmad Mosque (-7° 36' 17.230",112° 47' 6.992")	617	13
	2	KJ1-B1-TES Al-Ishlan Mosque (-7° 34' 47.511",112° 47' 41.783") / Kalirejo Kel. Office (-7° 34' 46.350",112° 47' 44.038")	656	12
Kalianyar	1	KA5-KA6-TES Mujahiddin Mosque (-7° 34' 54.903",112° 48' 14.916")	736	13
	2	KA1-B1-TES Kalirejo Football Field (-7° 34' 44.978",112° 47' 44.907")	701	13
	3	KA2-KA3-KA4-TES Office of Kalianyar Village (-7° 34' 47.522",112° 47' 40.063") / Kalianyar Health Center (-7° 34' 46.892",112° 47' 40.578")	846	16
Gempeng	1	G1-G2-TES Gempeng Village Office (-7° 35' 56.476",112° 47' 25.684")	645	13
	2	G2-G6-G7-TES Sabilul Falah Mosque (-7° 35' 50.033",112° 47' 47.179") / Syarif Hidayatullah Mosque (-7° 35' 51.115",112° 47' 50.538")	882	16
	3	G3-TES Open Land (-7° 35' 53.089",112° 47' 30.004")	342	6
	4	G4-G5-TES Baiturrahim Mosque (-7° 36' 16.994",112° 47' 16.365")	477	8
Kolursari	1	KS6-TES Baitul Muttaqin Mosque (-7° 37' 1.080",112° 46' 29.419")	560	12
	2	KS7-TES Baitul Muttaqin Mosque (-7° 37' 1.080",112° 46' 29.419")	579	13
	3	KS8-TES Masjid Sabilillah (-7° 37' 9.599",112° 45' 57.984")	443	10

Village	Route	Evac.route-TES	Length (m)	Time (minutes)
	4	KS5-TES Al-Huda Mosque (-7° 36' 30.431",112° 46' 45.121")	298	6
	5	KS9-TES Al-Huda Mosque (-7° 36' 30.431",112° 46' 45.121")	568	12
	6	KS4-KS1-TES Kolursari Kel. Office (-7° 36' 23.275",112° 46' 56.030")	465	8
	7	KS2-KS3-KS1-TES Ar-Rahmad Mosque/Kolursari Village Office (-7° 35' 19.458",112° 47' 22.748")	762	14

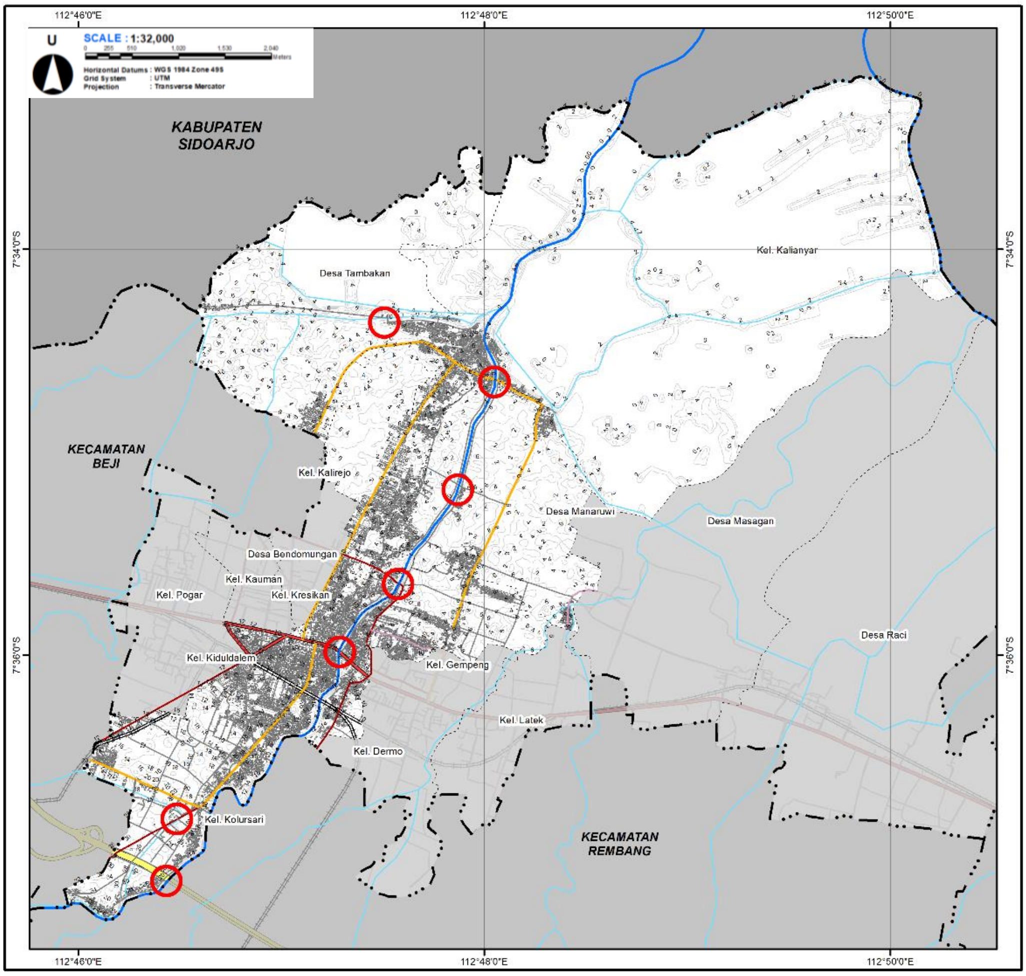

Fig. 8: Map of River Locations/ Bridges.

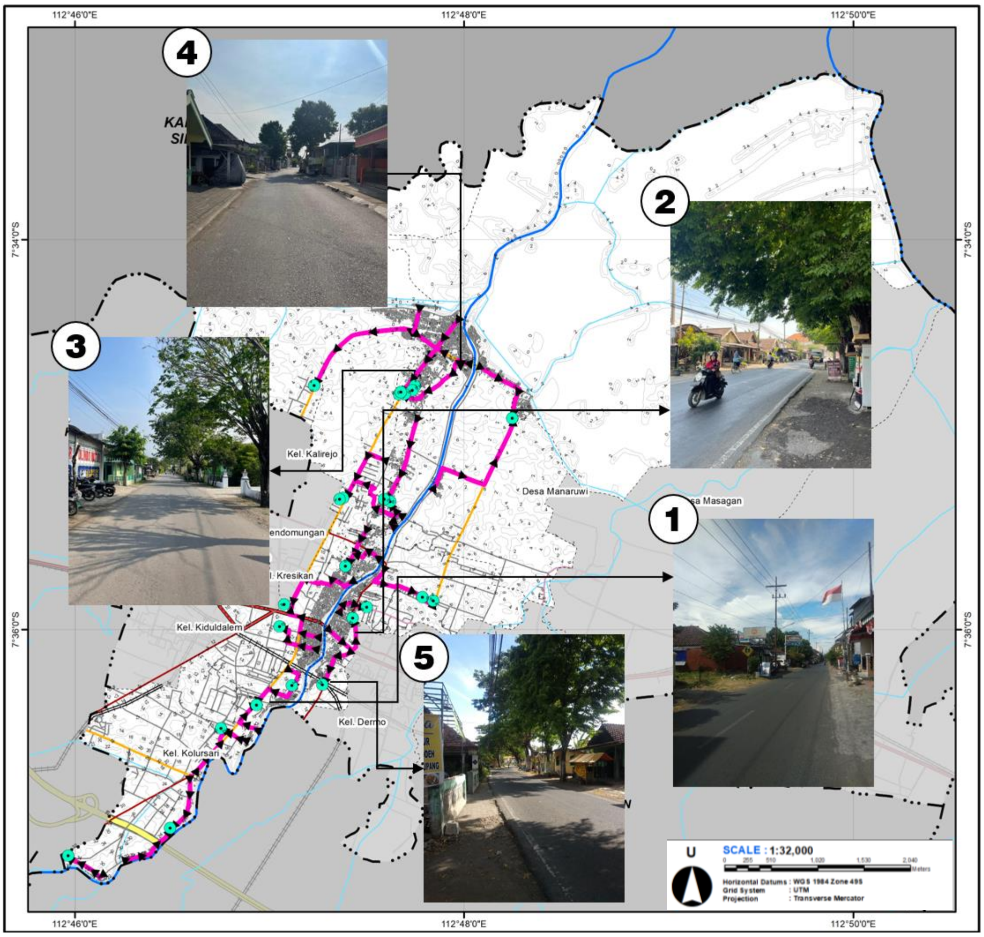

Fig. 9: Map of Evacuation Routes.

Nevertheless, a limitation of this study lies in its reliance on secondary data obtained from the Pasuruan Regency Regional Disaster Management Agency. Following the completion of the study, researchers might turn their focus towards analyzing the threat posed by flood disasters. Hence, further research is encouraged to understand the mutation and spread of the COVID-19 virus in the context of disaster management.

3. Conclussions

Kedunglarangan River situated in Bangil District encompasses a flood risk area of 1,449.21 hectares. The majority of this area is classified as having a moderate flood risk level, covering 684.61 hectares. The remaining portions are categorized as having a low flood risk level, covering 334.8 hectares, and a high flood risk level, covering 429.8 hectares. Among the affected villages, Kalinyar Village experiences the greatest impact from Kedunglarangan River floods. The total risk area in this village amounts to 967.58 hectares, with 568.53 hectares classified as medium risk and 399.05 hectares classified as high risk. The Kalianyar Village is characterized by a significant prevalence of the potential flooding hazard posed by Kedunglarangan River, hence rendering the area very susceptible to flooding events originating from this river. The vulnerability of Kalianyar Village at the regional level falls under the high category, with influences stemming from both economic and environmental factors. The Kalianyar Village exhibits a discrepancy between the level of hazard and vulnerability present and the corresponding level of capacity to effectively address these challenges. The findings of the capacity evaluation indicate that the capacity in Kalianyar Village remains within the moderate range. The lack of social engagement in enhancing community resilience and the limited dissemination of catastrophe studies within urban villages have had a significant impact on this phenomenon. The outcomes of the TES planning and Kedunglarangan River Flood Evacuation Route, aimed at mitigating the risk of Kedunglarangan River flood tragedy, generated 25 TES located in areas devoid of significant flood hazards and designated for public land usage. Furthermore, the capacity and range of TES align with established norms. In the interim, the formulation of evacuation pathways yielded a total of 28 flood evacuation routes for Kedunglarangan River, encompassing the most secure and efficient passageways. At last, the result of this study is expected to enhance the understanding on flood disaster risk mapping and adaptive disaster evacuation planning in the context of COVID-19.

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