COASTAL DISASTER EVACUATION ASSESSMENT IN THE COASTAL MPA SETTING OF PARIAMAN CITY, INDONESIA: INTEGRATING PTVA-3, GIS NETWORK ANALYSIS, AND MARINE–COASTAL ACTIVITY NODES

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ABSTRACT

Pariaman City is the second coastal municipality in West Sumatra Province, Indonesia, after Padang City. Geographically, Pariaman City is fronted by a chain of small offshore islands facing the Indian Ocean, namely Angso Duo, Kasiak, Tangah, Ujung, and Gosong Sibarat, which are part of the marine protected area (MPA) and support conservation, navigation, and coastal tourism. This study assesses evacuation accessibility, Vertical Evacuation Shelter (VES) suitability, Tsunami Evacuation Route (TER) connectivity, and Final Evacuation Site (FES) availability in Pariaman City using the Papathoma Tsunami Vulnerability Assessment Version 3 (PTVA-3) and Geographic Information System (GIS)-based network analysis. 40 existing buildings were assessed as candidate VES, and 28 horizontal evacuation routes were inventoried. Most candidate buildings were classified as having low to medium vulnerability, indicating that several public facilities may support vertical or temporary evacuation. North Pariaman has 7 existing FES, 8 feasible VES, and 15 TER. Central Pariaman has 36 FES and 14 feasible VES, but no TER was identified. South Pariaman has 7 FES, 3 feasible VES, and 1 TER. Evacuation distances range from 233 m to 2,155 m, with estimated travel times between 3 and 35 minutes, while only 6 of 22 route cases fall within the 541 m walking-distance threshold. Overall, effective evacuation planning in Pariaman City must integrate route connectivity, travel time, and shelter suitability with MPA management, particularly through the arrangement of conservation zones, evacuation infrastructure, and coastal tourism spaces. The assessment further indicates that evacuation planning must be connected to the real-life conditions of coastal communities and to activities occurring around the city's uninhabited small offshore islands, because warning response, shelter access, route choice, and evacuation timing are shaped by daily mobility.

Keywords: *Coastal mitigation; MPA; Pariaman City; Small Offshore Islands; Vertical Evacuation.*

1. INTRODUCTION

In marine–coastal environments, disaster risk is not only a physical hazard but also a socio-ecological issue because settlements, tourism activities, fisheries-related livelihoods, cultural attractions, conservation areas, and small offshore islands are embedded in the same coastal landscape (Ditya et al., 2026). Geographically, Pariaman City is fronted by a chain of small offshore islands facing the Indian Ocean, namely Angso Duo, Kasiak, Tangah, Ujung, and Gosong Sibarat, which are part of the Marine Protected Area (MPA) and support conservation, navigation, and coastal tourism.

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Studies on Indonesian coastal and small-island contexts show that coastal exposure cannot be interpreted only through physical infrastructure or hazard proximity. The experience of Bajau maritime communities demonstrates that coastal governance and preparedness are shaped by participation, local knowledge, and social inclusion (Ariando and Arunotai, 2022). These findings support the need to interpret evacuation planning in Pariaman City through shelter access, route choice, public safety, and the real-life conditions of coastal communities.

In this context, Pariaman City is important for strengthening coastal disaster mitigation, particularly in relation to potential tsunami impacts, because its coastal area is part of a protected marine and coastal zone that requires additional protection against adverse environmental impacts (Putra et al., 2023[a]). Coastal protected areas are spatially defined areas managed using a zoning system to realize sustainable management of natural resources and the environment (Lippi et al., 2024). Extreme rainfall and disturbances within upstream catchments may increase runoff and river discharge, with potential consequences for flooding, sediment transport, and downstream estuarine accessibility. In neighbouring Padang Pariaman Regency, official reports documented the overflowing of the Batang Anai and other rivers during 22–24 November 2025, followed by damage to transport infrastructure during the late-November flood and landslide emergency (BNPB, 2025[a], 2025[b]; Padang Pariaman Regency Government, 2025). Geographic Information System (GIS)-based flood-risk screening provides a related infrastructure perspective. Haidu and Nicoară (2011) developed a procedure to identify buildings and road sections located in flood-prone areas using elevation and infrastructure data. Their approach illustrates how spatial analysis can identify exposed transport assets, although the study does not model flooding along Pariaman City's evacuation routes.

The current regulatory framework for this study is set out in Law No. 1/2014, which amended Law No. 27/2007 on the Management of Coastal Areas and Small Islands and Law No. 26/2007 on Spatial Planning. Law No. 23/2014 on Regional Government, as amended, also governs the distribution of governmental authority. Spatial planning implementation is further regulated by Government Regulation No. 21/2021. For marine spatial planning, Regulation of the Minister of Marine Affairs and Fisheries No. 28/2021 on the Implementation of Marine Spatial Planning is currently in force and expressly revokes Regulation No. 23/PERMEN-KP/2016, which was cited in earlier coastal-planning documents. The conservation area in the waters of Pariaman City is formally established by Decree of the Minister of Marine Affairs and Fisheries No. 106/2021, which remains in force. Historically, the area had been allocated locally through Pariaman City Mayor Decree No. 334/523/2010 under a zoning system (Putra et al., 2023[a]). The current utilization framework is Regulation of the Minister of Marine Affairs and Fisheries No. 7/2025 on the Utilization of Conservation Areas, which revoked Regulation No. 47/PERMEN-KP/2016 and regulates sustainable utilization activities, including research, education, nature tourism, fisheries-related uses, transport, and other permitted activities subject to conservation objectives (Government of the Republic of Indonesia, 2007, 2014[a], 2014[b], 2021, 2023; MMAF, 2021[a], 2021[b], 2025). Thus, the Pariaman City MPA should be understood not only as a conservation area, but also as a multi-use coastal and marine space where conservation, education, tourism, fisheries activities, settlement patterns, small offshore island functions, and disaster preparedness are managed within the same coastal and marine setting.

To support sustainable coastal disaster mitigation for potential tsunami events integrated with coastal protected-area management, a GIS approach is an effective tool for disaster-risk analysis, vulnerability mapping, evacuation-route assessment, and mitigation planning. One relevant method is the Papathoma Tsunami Vulnerability Assessment Version 3 (PTVA-3) (Baouham et al., 2024), which provides a framework for assessing the vulnerability of buildings and exposed populations to tsunami impacts. The integration of GIS and PTVA-3 is useful for identifying vulnerable coastal zones, assessing the suitability of buildings as Vertical Evacuation Shelters (VES), and evaluating evacuation accessibility through spatial network analysis. Temporary Evacuation Sites (TES) may serve as initial gathering or short-term safety points during emergency response, while Final Evacuation Sites (FES) represent safer destination areas beyond the immediate tsunami-prone zone. VES, as elevated or multi-story structures, become essential where access to FES through horizontal evacuation is limited by distance, time, road conditions, coastal settlement density, or the concentration of visitors in coastal tourism areas. The distribution of VES, Tsunami Evacuation

Routes (TER), and FES reflects whether coastal communities, visitors, coastal tourism activities, boat operators, fishers, and other marine users can reach safe locations within a limited warning time. A different transport-risk perspective is offered by Ivan and Haidu (2012), who used GIS-based spatio-temporal analysis to map road-accident patterns along urban streets in Cluj-Napoca. Their research demonstrates the value of locating risk concentrations on road networks, but does not directly assess tsunami-evacuation performance.

In this study, marine–coastal activity nodes refer to spatially concentrated areas within the Pariaman City MPA setting where coastal settlements, beach tourism areas, boat-access points to nearby small offshore islands, conservation spaces, fisheries-related mobility, cultural-tourism locations, and public coastal facilities interact. For Pariaman City, these activity nodes also include culturally meaningful coastal spaces, especially the Gandoriah coastal area where *Tabuik*-related processions, boat departures to uninhabited small offshore islands, fishery mobility, informal trade, and visitor concentration occur in the same hazard-exposed coastal corridor. This study assesses evacuation accessibility, VES suitability, TER connectivity, and FES availability in Pariaman City using the PTVA-3 and GIS-based network analysis. The novelty of this study lies in integrating PTVA-3, GIS network analysis, and marine–coastal activity nodes within a coastal MPA framework for evacuation assessment.

2. STUDY AREA

The study area is located in the coastal region of Pariaman City, West Sumatra Province, Indonesia, between 00°33′00″ and 00°40′43″ S and 100°04′46″ and 100°10′55″ E (**Fig. 1**).

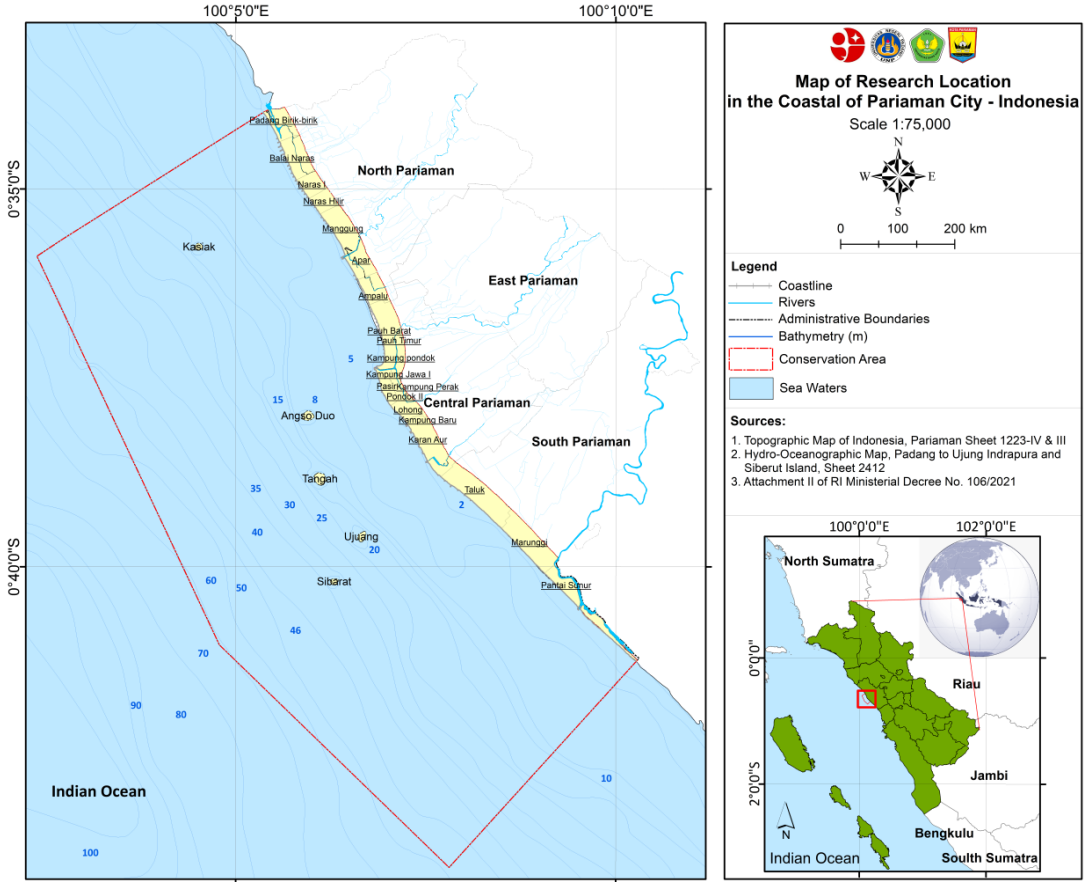


Fig. 1. Study area and marine protected area zoning in Pariaman City based on Decree of the Minister of Marine Affairs and Fisheries No. 106/2021.

Pariaman City covers approximately 73.36 km², has a coastline of about 12 km, and is situated approximately 56 km north of Padang City. The mainland coast faces directly toward the Indian Ocean and is administratively associated with North Pariaman, Central Pariaman, South Pariaman, and East Pariaman, while the evacuation analysis in this study is concentrated on the exposed mainland coastal sections of North, Central, and South Pariaman.

The MPA addressed in the study covers approximately 11,525.89 ha and includes a chain of nearby small offshore islands (MMAF, 2021[b]). Geographically, these islands are located close to the mainland, generally ranging from approximately 2 to 15 km, or about 1 to 8 nautical miles, from local coastal departure points such as Gandoriah Beach. Angso Duo Island is located about 2 km from Gandoriah Beach and can be reached in approximately 15 minutes by tourist motorboat. Kasiak Island is located about 2.8 km from the nearest mainland area in North Pariaman and can be reached in approximately 20 minutes by boat. Tangah Island and Ujung Island are located about 3–5 km from the nearest coastline and generally require approximately 25–30 minutes of boat travel. Although these islands are not permanently inhabited, they remain important to the cultural, ecological, tourism, maritime navigation, and strategic identity of Pariaman City. Kasiak Island has strategic maritime importance because it hosts a lighthouse used for marine navigation, as well as maritime observation (Putra et al., 2023[a]; Putra et al., 2023[c]).

3. METHODS

3.1. Assessment of buildings for VES

Papathoma-Köhle and Dominey-Howes (2003) developed an alternative method for estimating building vulnerability to potential tsunami impacts in coastal disaster-prone areas, hereafter referred to as the Papathoma Method. This method quantifies a vulnerability index based on several building and environmental parameters. The vulnerability index is divided into two categories, namely Building Vulnerability (BV) and Human Vulnerability (HV). BV refers to the susceptibility of a structure to tsunami impacts based on building materials, foundation strength, number of floors, surrounding protection, and its spatial relationship with the inundation zone. HV refers to the susceptibility of the exposed population based on evacuation accessibility, population, shelter capacity, and the spatial distribution of evacuation infrastructure. In the context of Pariaman City, this spatial relationship is important because candidate VES may serve coastal communities, visitors, coastal tourism activities, boat operators, fishers, and other marine users with small-island tourism activities within the MPA setting. This formulation is relevant to Pariaman City because VES suitability must be assessed not only based on the physical condition of buildings but also in relation to their accessibility and connections with coastal settlements, MPA zones, tourism spaces, and evacuation routes. BV was calculated using Eq. (1):

$$BV = 7a + 6b + 5c + 4d + 3e + 2f + 1g \quad (1)$$

where:
a = load value related to building materials, such as reinforced concrete, brick, or wood;
b = load value associated with rows of buildings or degree of exposure to tsunami flow;
c = load value related to surrounding building and environmental conditions;
d = load value related to soil conditions;
e = load value related to the number of building floors;
f = load value associated with coastal defense or marine protection systems, such as seawalls, vegetation barriers, or other protective structures;
g = load value related to the natural coastal environment, including beach width and tidal-zone characteristics.

In this study, HV is expressed as the ratio between the exposed population and the available shelter capacity. Therefore, a higher HV value indicates greater shelter demand and lower evacuation adequacy. By combining BV and HV, decision-makers can assess both the structural and human

safety aspects of buildings within tsunami-prone areas, making it easier to designate appropriate VES and ensure comprehensive disaster preparedness. The weighting criteria used for the VES assessment are presented in **Table 1**.

Table 1.

Loading factors for VES assessment.

Criteria	Loading factor value
Building materials	7
Rows of buildings/exposure position	6
Surrounding environment	5
Soil conditions	4
Number of floors	3
Coastal or marine protection	2
Natural coastal environment	1

Source: Papathoma-Köhle and Dominey-Howes (2003).

Madani et al. (2017) explained that the PTVA version 3 method was developed to estimate the spatial vulnerability of buildings used as potential VES. The Relative Vulnerability Index (RVI) accounts for spatial and physical aspects directly related to building vulnerability. These aspects are grouped into three main categories as follows: 1) physical characteristics of buildings, including building materials, number of floors, foundation strength, hydrodynamic form, and the presence of movable objects; 2) surrounding environmental conditions, including natural and artificial protection; and 3) estimated inundation depth around the building. The resulting RVI classification was then used to distinguish buildings with low, medium, and high vulnerability, which later supports the interpretation of feasible and less feasible VES. The reference classification divides RVI values into five vulnerability classes (see **Table 2**) (Dall'Osso et al., 2010).

Table 2.

RVI classification used for interpreting candidate VES in Pariaman City.

RVI range	Category	Interpretation for VES suitability
1.0 to <1.8	Low/small vulnerability	More suitable as candidate VES
1.8 to <2.6	Medium vulnerability	Potentially suitable, but requires accessibility and capacity checking
2.6 to <3.4	Average vulnerability	No candidate VES in this class
3.4 to <4.2	High vulnerability	Requires reinforcement or should not be prioritized
4.2 to 5.0	Very high vulnerability	No candidate VES in this class

Source: Adapted from Dall'Osso et al. (2010).

3.2. Building selection for VES

The field assessment included three spatial assessment criteria: BV for the vulnerability of the building structure, Protection (Prot) for the protection system around the building, and Exposure (Ex) for the estimated inundation depth around the building (Dall'Osso et al., 2009; Tarbotton et al., 2012). Field observations were used to record the physical characteristics of candidate buildings, including construction material, number of floors, foundation condition, building orientation, maintenance condition, and surrounding protection. Geographic data were used to examine the position of each building relative to coastal hazard zones exposed to potential tsunami impacts, coastal settlements, road networks, existing evacuation facilities, tourism-related coastal spaces, and the MPA boundary. Coastal exposure and inundation were considered through the established PTVA-3 exposure and protection components, whereas the mapped river-estuary setting provides geographic context rather than an independently quantified flood or watershed parameter.

The Prot assessment considered surrounding protection conditions that may reduce building exposure to coastal hazards, including rows of buildings, natural protection, seawall height and shape,

and brick-fence coverage around the building. In the scoring system, BV values range from -1 to +1, where -1 indicates very low vulnerability and +1 indicates very high vulnerability. Prot values range from 0 to 1, where 0 indicates maximum protection and 1 indicates no or very low protection. This classification supports the comparison of candidate VES across North, Central, and South Pariaman based on RVI values, building functions, and spatial position within the coastal hazard zone.

3.3. Network analysis using GIS

GIS-based network analysis for evacuation routes was conducted using spatial parameters related to walking speed, travel time, road accessibility, and the distribution of settlements and evacuation facilities, based on evacuation-time assumptions from the Institute of Fire Safety and Disaster Preparedness Japan (Budiarjo, 2006; Zhang et al., 2023). The assumed evacuation speed was 0.751 m/s, representing the walking speed of elderly evacuees or vulnerable groups. The evacuation process time was set at 12 minutes, or 720 seconds. Therefore, the maximum geographic distance from a VES was calculated as follows: 720 seconds × 0.751 m/s = 540.72 m ≈ 541 m. Accordingly, a 541 m service radius was used as the maximum walking-distance threshold for identifying whether coastal settlements could reach a VES within the assumed evacuation time (Putra and Mutmainah, 2016). GIS-based network analysis has also been applied to identify shortest-route access to emergency medical facilities (Nicoară and Haidu, 2014).

4. RESULTS

Based on the spatial data inventory, 28 existing horizontal evacuation routes were identified as leading to identified evacuation destinations, including routes to Kurai Taji Market and Padusunan Community Health Center. In addition, 40 existing buildings were assessed as candidate VES using the RVI derived from the PTVA-3 assessment. These buildings were evaluated in relation to potential tsunami impacts, with emphasis on their relative physical vulnerability. The assessed buildings include government offices, educational facilities, service buildings, places of worship, health facilities, and public facilities. Junior High School 21 Pariaman and Vocational School 25 Pariaman were classified as low vulnerability (RVI = 1.0) and may warrant further evaluation as evacuation facilities. However, structural capacity, building elevation, inundation exposure, access, and occupancy capacity must be verified before either building can be designated as a VES. The vulnerability graph for the 40 candidates is presented in **Fig. 2**.

In Pariaman City, disaster preparedness is supported by evacuation signs and GIS maps. However, the candidate evacuation buildings show substantial variation in their RVI-based physical vulnerability. Of the 40 buildings, 29 (72.5%) were classified as low vulnerability, seven (17.5%) as medium vulnerability, and four (10.0%) as high vulnerability, with RVI values ranging from 1.0 to 4.0. These findings provide an initial basis for further evaluation of buildings in relation to settlement patterns, tourism concentrations, the MPA setting and coastal accessibility. Based on **Fig. 2**, the vulnerability classes vary across the assessed subdistricts. South Pariaman contains two assessed buildings (both medium, RVI = 2.0); Central Pariaman contains 29 buildings (21 low, four medium and four high); and North Pariaman contains nine buildings (eight low and one medium, RVI = 2.3). All four high-vulnerability buildings are in Central Pariaman. Government buildings including the Social Agency, Population Agency, Fisheries Agency, Pariaman City Hall and Pariaman City Attorney Office have RVI values between 1.0 and 2.0. Regent House in Karan Aur recorded the highest RVI (4.0); Piala Sakti Health College in Kampung Pondok, a shophouse in Karan Aur and St. Rajo Bujang Sports Arena in Karan Aur each recorded 3.7. These results do not alone establish whether a building is safe or sufficiently accessible for shelter use.

Overall, the RVI results indicate differing levels of physical vulnerability among the candidate VES. Low-vulnerability buildings may merit further assessment, while high-vulnerability buildings should not be prioritized without independent engineering verification and hazard-specific evaluation. The concentration of four high-vulnerability candidates in Central Pariaman supports prioritizing detailed building-level and evacuation-access assessments in that subdistrict. Evacuation planning should also consider MPA zoning, coastal tourism safety, conservation functions, small offshore islands and community accessibility.

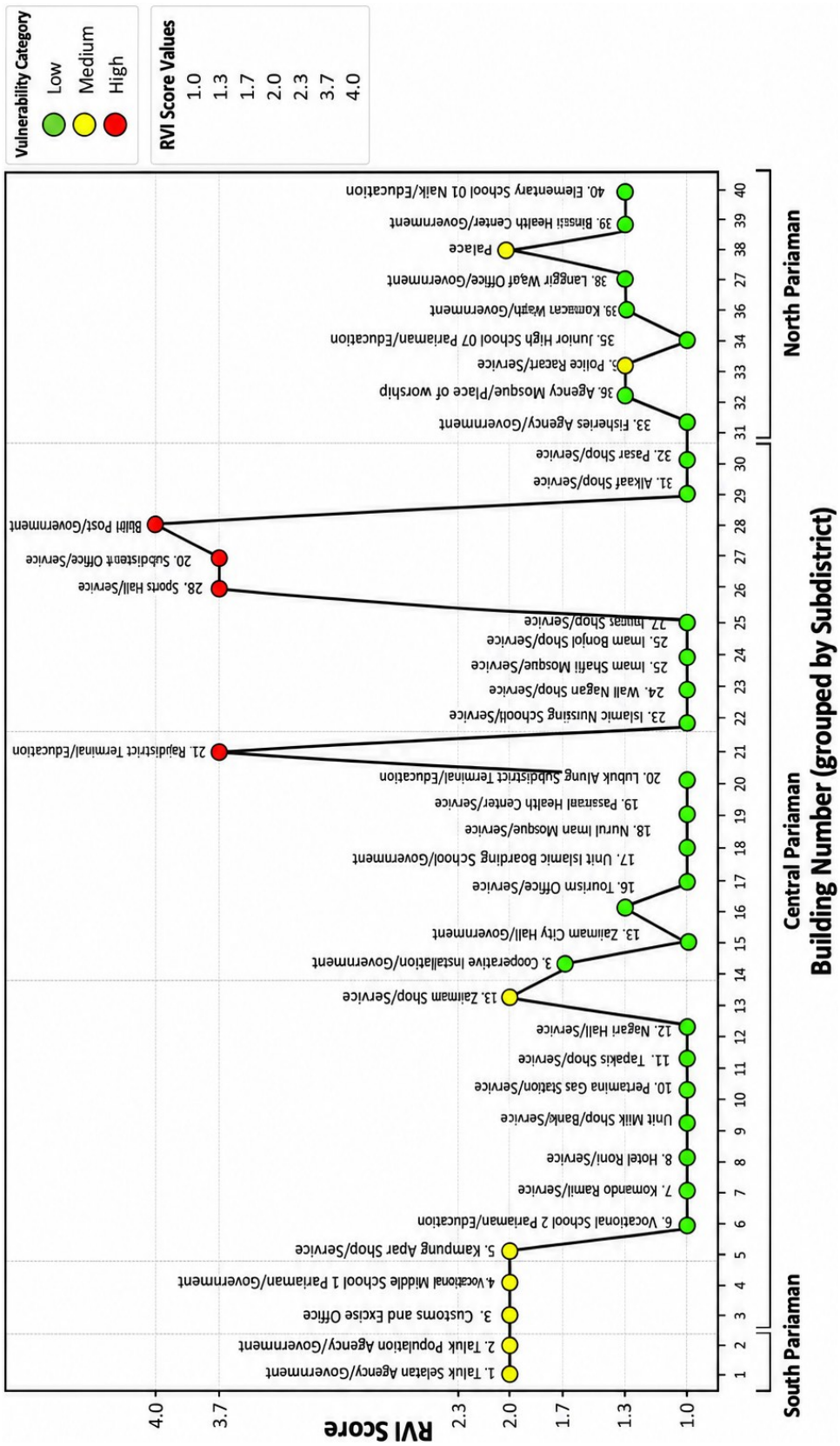


Fig. 2. The RVI for 40 candidate VES in Pariaman City, grouped by Subdistrict. Green, yellow, and red markers identify low, medium, and high vulnerability categories, respectively.

4.1. VES, TER, and FES in North Pariaman

The coastal area of North Pariaman lies within a coastal disaster-prone zone, is exposed to potential tsunami impacts, and is supported by coastal protection functions. Therefore, it requires special attention in disaster mitigation planning. Several VES and TER have been provided in this area, with 8 feasible VES and 15 TER, as well as 7 existing FES. However, the distribution of these facilities needs to be reviewed further, considering that some areas are still not served by the existing TER. Therefore, the assessment of North Pariaman needs to consider not only the number of VES, TER, and FES, but also how these facilities serve coastal settlements, tourism areas, and protected coastal ecosystems. This relationship is important because evacuation facilities in North Pariaman must serve exposed communities while remaining compatible with the function of coastal protection areas. Details are presented in **Table 3** and **Fig. 3**.

Table 3.

Findings of FES, feasible VES, proposed FES, and TER in North Pariaman.

FES		Feasible VES	Proposed FES	TER
7		8	-	15
Location	Village	Capacity (persons)	Capacity allocation (persons)	Distance from coastline (m)
Village office (Field)	Ampalu	1000	750	500
	Pauh Barat		250	

Source: Data analysis results, 2025.

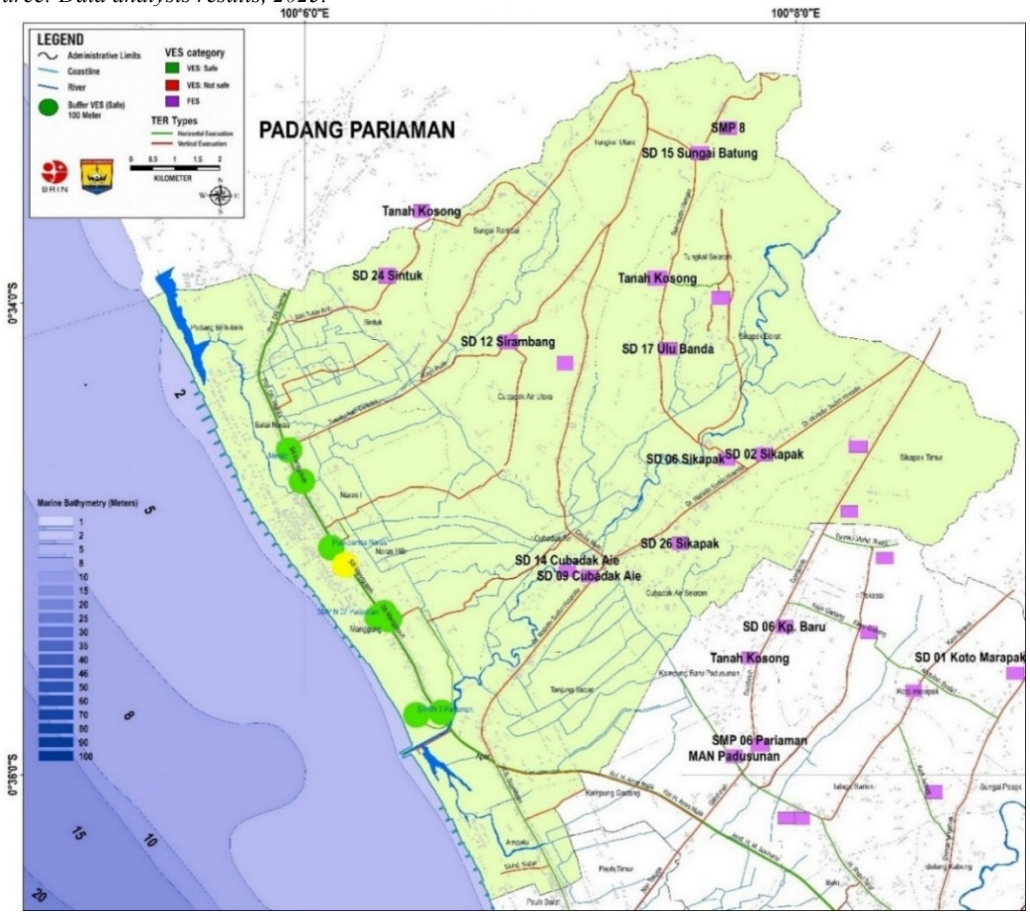


Fig. 3. Distribution map of VES, TER, FES, and proposed VES in North Pariaman.

According to Sotelo-Salas et al. (2024), the strategic placement of evacuation shelters in areas exposed to potential tsunami impacts is essential to minimize evacuation time and ensure that vulnerable populations have quick access to safe zones. In North Pariaman, this means that the availability of 8 feasible VES and 15 TER should be interpreted together with the accessibility of coastal communities and visitors to 7 existing FES. Where access to FES is limited by distance, time, or road-network conditions, VES and TES become important intermediate safety points during the initial emergency response. Thus, the main issue in North Pariaman is not only the existence of evacuation facilities, but also whether exposed coastal settlements can reach these facilities within the available evacuation time. Furthermore, as highlighted by Simarmata et al. (2024), coastal conservation efforts, including mangrove restoration and the protection of natural barriers, play a crucial role in reducing the impact of coastal hazards, including potential tsunami impacts, and ensuring long-term sustainability in coastal disaster management.

In addition to serving as a turtle conservation site, the mangrove ecosystem in Apar Village plays a crucial role as a greenbelt that protects the coastline from abrasion (Putra et al., 2023[b]). These mangroves also help mitigate the impact of high-energy coastal waves and potential tsunami inundation by absorbing wave energy, thus reducing potential damage to coastal areas (Husrin et al., 2015). Moreover, the presence of these mangroves supports coastal tourism activities around Talao Pauh and the Batang Mangau watershed, while simultaneously contributing to coastal conservation and local economic activities in the region. Within the same North Pariaman MPA context, Kasiak Island also has an important maritime-navigation function through its 40 m lighthouse, which serves as a marine navigation aid for large vessels and fishing boats crossing the waters of Pariaman City and the Indian Ocean. Therefore, the function of Kasiak Island within the MPA setting should be understood not as a direct object of PTVA-3 or GIS network analysis, but as part of the broader marine–coastal activity-node context that links navigation safety, small-island tourism, conservation, and the public-safety needs of coastal communities, fishers, boat operators, visitors, and other marine users. These findings indicate that coastal disaster evacuation planning, particularly for potential tsunami events, in North Pariaman should not be separated from coastal conservation and community livelihoods. Therefore, the ongoing conservation of mangroves and the sustainable management of coastal environments are critical to maintaining the balance of coastal ecosystems and minimizing disaster risk. The results show that North Pariaman already has a basic evacuation-resource structure, but its effectiveness depends on improving the accessibility and coordination of feasible VES, TER, TES, and FES while maintaining the protective function of mangroves, maritime-navigation facilities, small-island tourism functions, and other coastal ecosystems.

4.2. VES, TER, and FES in Central Pariaman

The coastal area of Central Pariaman is a tourism center, including destinations such as Gandoriah Beach, and also serves as the economic and administrative center of Pariaman City along the Batang Piaman watershed. This area is located along the coastline, which is part of the coastal hazard zone exposed to potential tsunami impacts, making an effective and safe evacuation system essential. Hermon et al. (2019, 2020) highlight that developing an effective disaster evacuation system involves not only physical infrastructure but also local community awareness and preparedness, ensuring that local populations know how to respond during an emergency. This is particularly relevant in Central Pariaman because the area combines coastal settlements, public services, government facilities, tourism destinations, daily community mobility, and boat-access points associated with coastal and small-island tourism activities within a relatively dense coastal space. A number of VES have been identified in Central Pariaman, with 14 feasible VES, including Nan Tongga Hotel and several government buildings. Although Central Pariaman has 36 existing FES, no TER was identified in this section of the analysis. Therefore, the main planning issue in Central Pariaman is not the absence of final safe destinations, but the lack of clearly identified TER that connect exposed coastal activity areas, TES, VES, and FES. Details are presented in **Table 4** and **Fig. 4**. Febriandi et al. (2019) emphasize that integrated coastal zone management should combine ecological conservation with infrastructure resilience to strengthen sustainability and disaster mitigation.

Table 4.

Findings of FES, feasible VES, proposed FES, and TER in Central Pariaman.

FES	Feasible VES		Proposed FES	TER
36	14		-	0
Location	Village	Capacity (persons)	Capacity allocation (persons)	Distance from coastline (m)
Simpang Piluang	Kampung Jawa	2200	500	1.2 km
			750	
			200	
Simpang Taratak	Taratak	1650	400	800 m
			750	
			500	
Simpang Jalan Baru	Jalan Baru	17000	300	800 m
			700	
			700	

Source: Data analysis results, 2025.

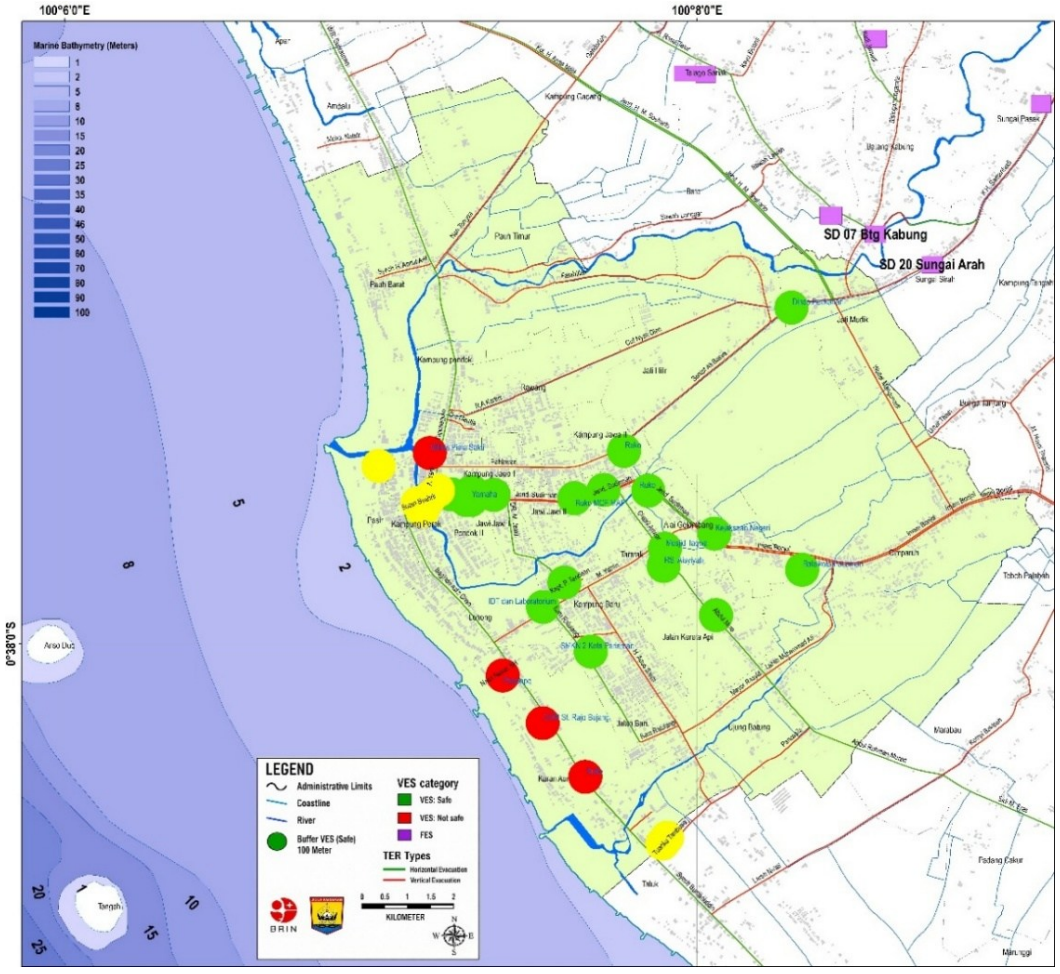


Fig. 4. Distribution map of VES, TER, FES, and proposed VES in Central Pariaman.

In Central Pariaman, this integration is crucial because the area concentrates government, economic, settlement, tourism, and small-island access functions within the same coastal space. Therefore, evacuation planning must not only identify the number of VES and FES but also clarify how communities move from exposed coastal areas to temporary safety points and final safe destinations. Within the administrative area of Central Pariaman, three small offshore islands are directly associated with the coastal frontage of Gandoriah Beach, namely Angso Duo Island, Tangah Island, and Ujung Island.

Angso Duo Island is the most popular small island and serves as one of the main tourism icons of Pariaman City, supported by facilities such as a jetty, water-based recreational activities, and religious tourism associated with the grave of *Sheikh Katik Sangko*. Tangah Island is an uninhabited small island located in the middle of the island chain, characterized by white-sand beaches. Ujung Island, also uninhabited, lies at the outer end of the group and has flat sandy terrain with relatively natural fringing coral-reef ecosystems. In addition to coastal tourism, Central Pariaman also offers cultural attractions, including the *Tabuik*, held annually on the 10th of Muharram in the *Hijri* calendar (**Fig. 5**). The *Tabuik ritual*, which commemorates *Ashura*, is a unique cultural event that attracts both domestic and international tourists and contributes significantly to the local economy (Rianty and Asty, 2021). Because these tourism and cultural activities increase public concentration in coastal spaces, evacuation accessibility becomes an important part of visitor safety and local communities.

Spiritual tourism in Pariaman City illustrates that religious travel can concentrate visitors and small-scale economic activity in culturally significant coastal spaces (Hidayat, 2023). The *Tabuik* festival also contributes to tourism development and local economic activity in Pariaman City (Rianty and Asty, 2021). Cultural entrepreneurship among fishers in West Sumatra shows how coastal livelihoods and tourism practices are linked to community identity (Zamzami et al., 2025). During large coastal gatherings, route visibility, multilingual signs, crowd-flow control, temporary evacuation-site information, and coordination with cultural leaders become as important as the technical identification of VES, TER, and FES.



Fig. 5. *Tabuik* cultural procession and coastal crowd concentration. (A–B) show *Tabuik* processions at the beach and sea area; (C) shows a dense coastal crowd during *Tabuik*; (D) presents historical *Tabuik* cultural documentation. Sources: Large News (2012); Kompas.com (Gischa, 2021); Negeri Kami (Ananda, 2025).

The integration of coastal conservation, greenbelts, coastal tourism, cultural attractions, and small offshore island functions makes Central Pariaman a strategic area for strengthening coastal resilience through well-coordinated evacuation planning. However, because Central Pariaman attracts a high concentration of visitors, coastal tourism activities, and local communities, the absence of an identified TER in **Table 4** should be treated as a critical planning gap. Clear TER are needed to connect coastal activity spaces, TES, VES, and FES so that evacuation can occur quickly and safely during an emergency related to coastal disaster risk, particularly potential tsunami warning conditions. These measures align with sustainable development principles that balance economic, social, and environmental needs (Adanma and Ogunbiyi, 2024). This balance supports local economic growth while safeguarding the sustainability of both natural and cultural resources for future generations. Thus, the results for Central Pariaman show that the priority is to strengthen the missing TER network so that the existing 36 FES and 14 feasible VES can function as an integrated evacuation system rather than as separate spatial facilities.

4.3. VES, TER, and FES in South Pariaman

The coastal area of South Pariaman functions as a buffer zone for the Sunua River estuary, which borders Pariaman City and Padang Pariaman Regency. In terms of coastal disaster risk, Sunur Beach is located in a high-risk coastal zone exposed to potential tsunami impacts. Based on the spatial coverage radius of VES and existing evacuation routes, the analysis indicates that the coastal area of South Pariaman has access to VES through existing evacuation routes. South Pariaman has 7 existing FES, 3 feasible VES, and 1 TER, as shown in **Table 5**. However, the limited number of feasible VES and TER indicates that additional evacuation facilities and better route integration are still needed, particularly for coastal settlements located near the Sunua River estuary and Sunur Beach. This condition suggests that South Pariaman has a weaker evacuation-resource structure than Central and North Pariaman, especially because the estuary landscape may constrain horizontal evacuation movement. Details are presented in **Table 5** and **Fig. 6**.

Table 5.

Findings of FES, feasible VES, proposed FES, and TER in South Pariaman.

FES		**Feasible VES**	**Proposed FES**	**TER**
7		3	-	1
Location	Village	Capacity (persons)	Capacity allocation (persons)	Distance from coastline (m)
Simpang Binasi	Sunur	1200	300 500 400	500

Source: Data analysis results, 2025.

In South Pariaman, the presence of 7 FES does not automatically guarantee effective evacuation if the number of feasible VES and TER remains limited. TES may therefore be important as short-term safety points during the initial evacuation process, especially where access to FES is constrained by distance, time, road-network conditions, or estuary-related barriers. Thus, the main issue in South Pariaman is limited connectivity among coastal settlements, feasible VES, TER, TES, and FES within the available evacuation time. The Sunur Beach area is located along the coastline and falls within both the coastal hazard zone and the Sunua River estuary zone, so it requires special attention in disaster mitigation planning. According to Rasoli et al. (2023), evaluating the effectiveness of evacuation routes and the number of VES in high-risk areas is critical for minimizing casualties in emergencies. Therefore, the coastal area of South Pariaman requires additional VES and better-connected TER based on the spatial network system at road intersections. This is particularly important because estuary landscapes may constrain evacuation movement, while coastal settlements and tourism activities require clear, recognizable, and accessible routes to VES, TES, and FES.

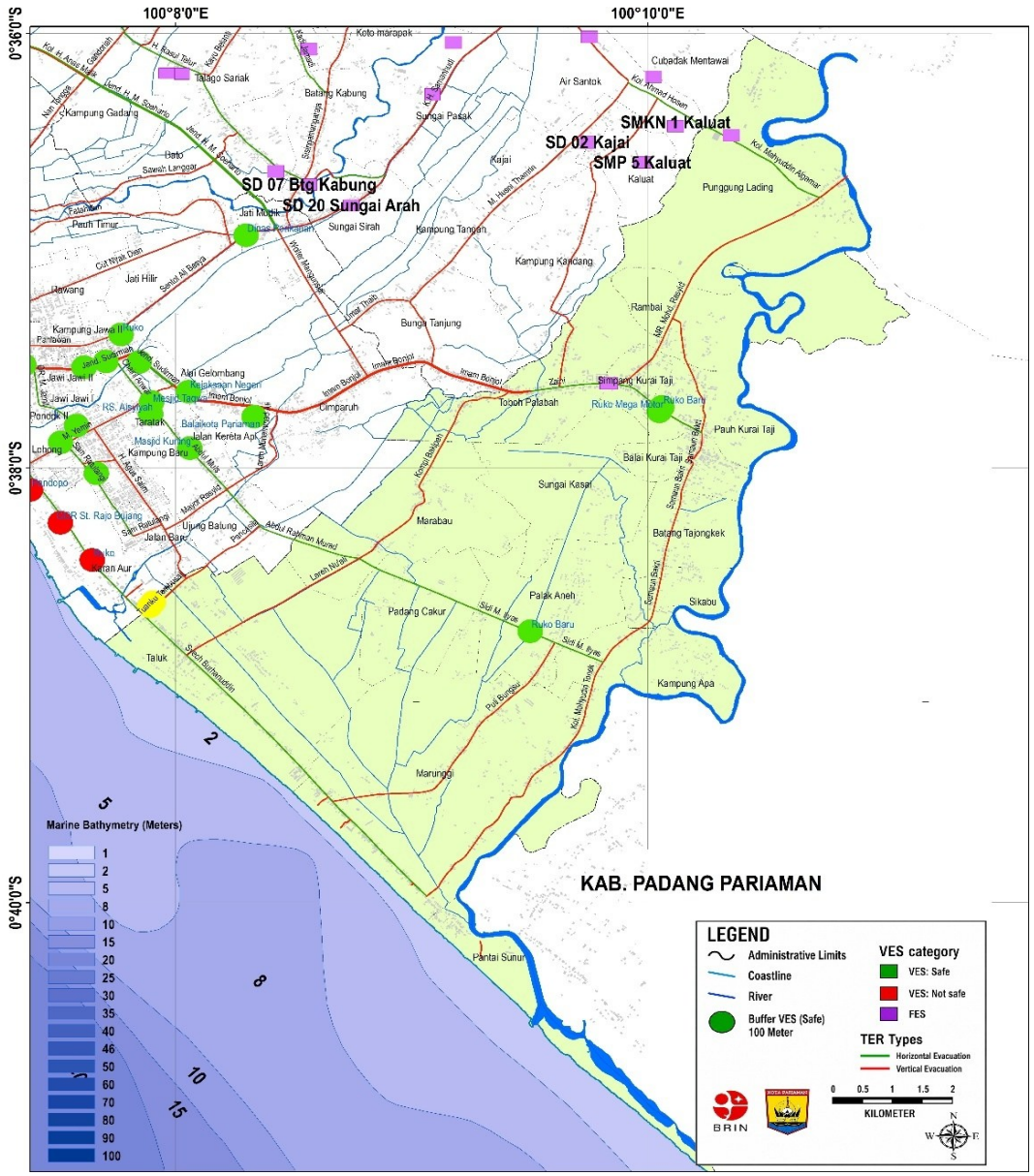


Fig. 6. Distribution map of VES, TER, FES, and proposed VES in South Pariaman.

Coastal conservation in the Sunua River estuary is also important for maintaining the sustainability of the coastal ecosystem. Mangrove planting around the river estuary can increase soil stability and reduce the risk of wave-induced erosion. According to Setyawan et al. (2020), mangrove conservation not only helps prevent abrasion but also provides breeding grounds for fish and shrimp species that are important for the ecosystem and the local economy. In the broader southern marine area of Pariaman City, Gosong Sibarat Island, locally known as Gosong Subareh or Gosong Sumbareh, also strengthens the ecological and tourism function of the MPA setting. It covers approximately 1.04 ha and has a very shallow reef crest, approximately 0.5 m below the sea surface under normal conditions (Putra et al., 2023[a]). During the lowest tidal conditions, parts of the sandbar may emerge above the sea surface, allowing visitors to walk on its white-sand surface surrounded by

breaking waves. Although Gosong Sibarat Island has no permanent landmass or vegetation like other small islands, it supports productive fringing-reef habitats, clear waters, and diverse reef-fish communities, making it important for diving, snorkeling, marine tourism, and coastal biodiversity conservation.

In addition to conservation efforts, developing coastal tourism on available land around the Sunua River estuary could also improve local livelihoods. Putra et al. (2024) explained that the development of ecotourism in coastal areas supports environmental sustainability and increases local community and visitor awareness of the importance of preserving natural resources. Therefore, evacuation infrastructure in South Pariaman should be planned as part of an integrated coastal management strategy, ensuring that VES, TES, TER, and FES support coastal disaster safety, particularly for potential tsunami events, while avoiding damage to mangrove habitats, estuary functions, shallow reef ecosystems, and potential ecotourism landscapes. Thus, the results for South Pariaman indicate that the priority is to strengthen the limited TER network and add accessible evacuation facilities while maintaining the ecological function of the Sunua River estuary, Gosong Sibarat Island reef system, and their potential for community-based coastal and marine tourism.

4.4. Evacuation Distance, Accessibility, and Route Connectivity in the MPA Setting

The GIS network analysis was used to measure evacuation-route distance, road type, road condition, and estimated travel time from each coastal village to the nearest VES or FES. In this evacuation system, TES may function as short-term safety points during the initial emergency response, while FES represent final safe destinations beyond the immediate coastal hazard zone. Therefore, the route-distance analysis is important for evaluating whether coastal communities, visitors, coastal tourism users, boat operators, fishers, and other marine users can move efficiently from exposed coastal areas to TES, VES, and FES. The results are summarized in **Table 6**, which presents the 22 evacuation-route cases by village, route distance, road type, road condition, and estimated travel time.

At this stage, the analysis focused on the inventory and spatial evaluation of evacuation resources in the coastal area of Pariaman City. After identifying the distribution of VES, TER, and FES in North, Central, and South Pariaman, the next analysis evaluated evacuation distance and travel time from coastal villages to VES or FES.

This step was necessary to determine whether the available evacuation facilities can be reached within a practical evacuation period during coastal disaster emergencies, particularly potential tsunami events. **Table 6** lists the 22 route cases sequentially, with each row representing an evacuation-route alternative from a coastal village to the corresponding VES or FES. The evacuation-route data in **Table 6** show that distances from coastal villages to VES or FES range from 233 m to 2,155 m, with estimated travel times ranging from 3 to 35 minutes. Although all recorded routes are in good condition, travel time varies according to distance and road type. The 541 m threshold represents the walking-distance limit derived from the 12-minute evacuation-time framework. Only 6 of 22 route cases fall within this limit, indicating that several coastal settlements face accessibility constraints. Padang Birik-birik has three routes of 694–904 m, with travel times of 12–15 minutes. Ampalu has five routes of 381–716 m, requiring 6–12 minutes. Kampung Jawa has two routes of 520 m and 679 m, requiring 8–11 minutes. Jalan Baru has one route of 1,180 m, requiring approximately 19 minutes. Karan Aur has three routes of 842–1,147 m, requiring 14–19 minutes. Taluak has four routes of 1,144–2,155 m, with travel times of 19–35 minutes, while Marunggi has four routes of 233–937 m, requiring 3–15 minutes.

Overall, evacuation accessibility remains uneven across Pariaman City. Marunggi has the shortest route, whereas Taluak has the longest and most critical routes. This finding shows that VES or FES availability alone is insufficient when evacuation routes are too long or poorly connected to exposed settlements. Therefore, additional TES and VES, improved TER connectivity, and clearer route signage are needed in areas with long evacuation distances.

The results from North, Central, and South Pariaman show that VES, TER, TES, and FES influence coastal disaster safety within the MPA setting. North Pariaman has 8 feasible VES, 15 TER, and 7 FES, indicating a basic evacuation-resource structure.

Table 6.

Estimated distance of evacuation routes to VES or FES locations.

No	Villages	Evacuation route distance (m)	Road types	Conditions	Estimated travel time (minutes)
1	Padang Birik-birik	694	Central road	Good	12
2	Padang Birik-birik	762	Rural road	Good	13
3	Padang Birik-birik	904	Central road	Good	15
4	Ampalu	716	Rural road	Good	12
5	Ampalu	394	Rural road	Good	7
6	Ampalu	544	Rural road	Good	9
7	Ampalu	621	Rural road	Good	10
8	Ampalu	381	Rural road	Good	6
9	Kampung Jawa	679	Central road	Good	11
10	Kampung Jawa	520	Central road	Good	8
11	Jalan Baru	1180	Central road	Good	19
12	Karan Aur	842	Rural road	Good	14
13	Karan Aur	1090	Rural road	Good	18
14	Karan Aur	1147	Rural road	Good	19
15	Taluak	1144	Rural road	Good	19
16	Taluak	2155	Rural road	Good	35
17	Taluak	2135	Rural road	Good	35
18	Taluak	1849	Rural road	Good	30
19	Marunggi	937	Rural road	Good	15
20	Marunggi	414	Rural road	Good	6
21	Marunggi	233	Rural road	Good	3
22	Marunggi	507	Rural road	Good	8

Source: Regional Disaster Management Agency (BPBD) of Pariaman City (2011); modified using field-survey data and GIS network analysis (2023).

Central Pariaman has 36 FES and 14 feasible VES, but no TER was identified, making route connectivity the main planning gap in an area characterized by government activities, Gandoriah Beach tourism, *Tabuik* cultural events, and boat departures to Angso Duo, Tangah, and Ujung Islands. South Pariaman has limited VES and TER, especially around the Sunua River estuary and Sunur Beach, where estuary landscapes may constrain evacuation. North Pariaman is associated with Apar coastal conservation, mangrove greenbelts, turtle conservation, and the maritime-navigation function of Kasiak Island, including its lighthouse that supports navigation safety for large vessels, fishing boats, and other marine users. Central Pariaman is characterized by dense coastal tourism and cultural mobility around Gandoriah Beach, including boat access to uninhabited small offshore islands and *Tabuik*-related cultural activities. South Pariaman is connected to the Sunua River estuary, Sunur Beach, mangrove and estuary conservation, and the shallow reef and sandbar system of Gosong Sibarat, locally known as Gosong Subareh or Gosong Sumbareh, which supports snorkeling, diving, reef conservation, and marine tourism.

When interpreted through the marine-coastal activity-node perspective, the uneven distribution of VES, TER, TES, and FES has direct implications for public safety in areas where coastal communities, visitors, boat operators, fishers, and cultural-tourism participants are concentrated. This

is particularly evident in Central Pariaman, where Gandoriah Beach, boat access to Angso Duo and nearby uninhabited small offshore islands, public facilities, and *Tabuik*-related cultural activities create dense coastal mobility, but no TER was identified. Therefore, the absence of identified TER in Central Pariaman is not only a technical route-connectivity problem, but also a public-safety concern for a dense coastal tourism, cultural-event, and small-island activity zone within the MPA setting. Similarly, in North and South Pariaman, evacuation planning should also consider the wider MPA functions associated with navigation safety, coastal conservation, fisheries-related mobility, estuary protection, reef-based tourism, and marine-user movement. This means that evacuation infrastructure should be planned not only to serve mainland coastal settlements, but also to support the safety of visitors, fishers, tourism actors, boat operators, and other marine users who interact with the small-island, reef, and coastal tourism spaces of the MPA.

These findings reinforce the need to integrate evacuation planning with MPA management in Pariaman City, a coastal municipality whose MPA includes uninhabited small offshore islands that support conservation, navigation, coastal tourism, and coastal identity. Hamid et al. (2021) explained that MPA planning in coastal and small-island-related settings depends on local social, economic, and cultural characteristics. Kurniawan et al. (2016) showed that tourism pressure in small islands should be assessed within integrated small-island management. Nicolini (2021) argued that islandness can be understood through physical, legal, and geographic connections. This study therefore interprets the small-island dimension cautiously as an MPA activity context, rather than as evidence of permanent island settlement. This is reflected in the functional connection between Pariaman City's mainland coast, uninhabited small offshore islands, reef and sandbar features, navigation, tourism movement, cultural identity, and public-safety needs within the same protected coastal and marine setting.

4.5. Implications for Coastal Communities, Small-Island Activities, Livelihoods, and Cultural Practices

Daily life in coastal communities and activities around uninhabited small offshore islands are not only hazard-exposed physical spaces, but also corridors for work, schools, public services, informal trade, beach visitation, fishery-related mobility, and religious-cultural events. Boat departures from Gandoriah Beach to Angso Duo and other small islands also create temporary concentrations of visitors, boat operators, and tourism workers in areas exposed to coastal hazards. Thus, VES, TER, TES, and FES should be communicated through routes and landmarks that are familiar to fishers, traders, boat operators, tourism workers, students, worshippers, visitors, and the elderly. Fishers, small traders, tourism workers, women involved in fish processing or coastal micro-enterprises (Nissa' et al., 2026), and low-income households may require different evacuation-support strategies because emergency decisions can be influenced by the need to protect boats, fishing gear, market goods, vehicles, documents, and household assets. Therefore, evacuation planning in Pariaman City should prioritize socially vulnerable activity nodes and not only the shortest technical routes.

Fishing, tourism, boat services, and port-related activities shape livelihoods and coastal mobility. In Pariaman City, the absence of identified TER in Central Pariaman is critical because this area concentrates Gandoriah Beach tourism, small-island boat departures, fishery mobility, informal trading, and public services. Marine conservation area tourism in West Sumatra demonstrates that tourism-based livelihoods need to be balanced with conservation benefits. Cultural entrepreneurship among fishers in West Sumatra highlights the role of coastal ecotourism in diversifying household income (Hasmira et al., 2025). These findings suggest that evacuation routes should be designed to protect both life safety and the continuity of coastal livelihoods, especially where fishing, tourism, boat operations, and port-related activities overlap.

Cultural practices and local habits are especially important for Central Pariaman. *Tabuik*, Gandoriah Beach tourism, Basapa-related spiritual tourism in the wider Pariaman City cultural landscape, and maritime identity indicate that coastal space is also a cultural landscape. During cultural or religious gatherings, evacuation demand can increase sharply because many visitors may not know the nearest VES, TER, TES, or FES. Spiritual tourism in Pariaman City demonstrates that religious travel and coastal visitation can shape visitor movement, local income, and the social meaning of coastal space (Hidayat, 2023).

Coastal plant-use traditions in Pangandaran also show that everyday resource practices may support the continuity of maritime culture under tourism and social change (Sobarna et al., 2025). For this reason, disaster-risk communication should involve local cultural actors, religious leaders, tourism managers, youth groups, and neighborhood organizations.

Recent floods in neighbouring Padang Pariaman Regency show why evacuation plans for tsunami hazards should also account for potential hydrometeorological disruption. Official reports by the National Disaster Management Agency (BNPB, 2025[a], 2025[b]) document flooding in Padang Pariaman Regency during 22–24 November 2025, including the Batang Anai area and damaged roads and bridges. The Padang Pariaman Regency Government (2025) subsequently reported three collapsed bridges in the regency during the late-November flood and landslide emergency. These reports concern documented events in Padang Pariaman Regency, not measured damage to the routes in Pariaman City assessed in this study. Potential implications for Pariaman City include interrupted transport connections, impaired bridge redundancy and reduced accessibility to tourism activities, coastal livelihoods and designated evacuation facilities, particularly near downstream river and estuarine corridors. This consideration is relevant to the analysed TER connectivity gaps and evacuation travel times up to 35 minutes. However, this tsunami-oriented PTVA-3 and GIS study does not model or quantify flooding along its recorded evacuation routes. Future field verification should evaluate flood-season road passability, alternative bridges, and evacuation drills.

In a watershed-to-coast interpretation, heavy rainfall and upstream landscape disturbance can potentially accelerate runoff and sediment transfer, while downstream flooding may alter estuarine conditions and reduce road or bridge accessibility to coastal settlements and evacuation facilities. The implications are most relevant to tsunami evacuation where route alternatives are limited: the inventory found no identified TER in Central Pariaman, one TER in South Pariaman, and only six of 22 evaluated route cases within the adopted 541 m walking-distance threshold. Thus, potential loss of road connectivity could further constrain access to candidate VES and FES during a compound or sequential emergency.

Coastal community disaster preparedness requires that the technical outputs of PTVA-3 and GIS network analysis be translated into participatory evacuation planning for coastal communities. The proposed use of VES, TER, TES, and FES should be accompanied by evacuation drills, cultural-event crowd-management scenarios, coastal signage, boat-operator briefings, visitor information at departure points to Angso Duo and other uninhabited small offshore islands, and community-based route familiarization. Coastal co-management experience among Bajau communities emphasizes that preparedness planning gains legitimacy when marginalized maritime groups are included in decision-making and communication processes (Ariando and Arunotai, 2022).

Overall, the added value of this study lies in integrating PTVA-3, GIS network analysis, and marine-coastal activity nodes into a coastal MPA framework that supports not only disaster mitigation but also culturally sensitive, livelihood-aware, and community-based coastal resilience. The study therefore connects route connectivity, travel time, and shelter suitability to the real-life conditions of coastal communities and to activities in the small-island area, without implying that Pariaman City's uninhabited small offshore islands have permanent settlements.

5. CONCLUSIONS

The MPA setting, which includes uninhabited small offshore islands that support conservation, navigation, coastal tourism, and coastal identity, requires evacuation planning that is aligned with conservation zones, coastal tourism spaces, boat-access points, protected ecosystems, and public safety. In this context, the Pariaman City MPA is reflected in the interaction between the mainland coast, uninhabited small offshore islands, tourism movement, navigation functions, and coastal identity within the MPA management framework. This setting is also represented by different marine-coastal activity nodes across the city, including the navigation and conservation context of Kasiak Island in North Pariaman, the tourism and cultural concentration around Gandoriah Beach and boat access to Angso Duo, Tangah, and Ujung Islands in Central Pariaman, and the estuary, mangrove, reef, and sandbar context of Sunua River, Sunur Beach, and Gosong Sibarat in South Pariaman.

The assessment of 40 candidate VES shows that most public facilities fall within low to medium vulnerability categories, indicating their potential to support vertical or temporary evacuation. However, high-vulnerability buildings, especially facilities in Karan Aur and the Regent's Official Residence of Padang Pariaman Regency, should not be prioritized as VES without further structural evaluation or reinforcement. The spatial distribution of evacuation resources is uneven across North, Central, and South Pariaman. North Pariaman has 7 FES, 8 feasible VES, and 15 TER, indicating a basic evacuation-resource structure. Central Pariaman has 36 FES and 14 feasible VES, but no TER was identified, making evacuation-route connectivity the main planning gap in this dense area of government activities, coastal tourism, Gandoriah Beach, cultural events, and boat departures to nearby uninhabited small offshore islands. South Pariaman has 7 FES, 3 feasible VES, and 1 TER, showing a weaker evacuation-resource structure, especially near the Sunua River estuary and Sunur Beach. Evacuation distances range from 233 m to 2,155 m, with travel times ranging from 3 to 35 minutes, and only 6 of 22 route cases fall within the 541 m walking-distance threshold. Therefore, additional TES and VES, improved TER connectivity, and clearer route signage are needed.

These improvements should be prioritized in areas where evacuation demand overlaps with the daily mobility of coastal communities, socioeconomic vulnerability, fishing and tourism livelihoods, port and boat activities, *Tabuik*-related cultural gatherings, spiritual and local-art practices, estuary landscapes, mangrove conservation, reef-based tourism, and small-island activity spaces. It also shows that evacuation planning in Pariaman City should be understood not only as a technical shelter-and-route problem, but also as part of sustainable coastal MPA management that connects disaster safety, tourism mobility, cultural identity, navigation safety, marine conservation, and the protection of coastal communities and marine users.

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REFERENCES

Adanma, U.M. and Ogunbiyi, E.O., 2024. A comparative review of global environmental policies for promoting sustainable development and economic growth. International Journal of Applied Research in Social Sciences 6(5): 954-977. https://doi.org/10.51594/ijarss.v6i7.1269.

Ananda, R., 2025. *Tabuik* Pariaman: Festival budaya dan tradisi penuh makna. Negeri Kami. https://negerikami.id/budaya/*Tabuik*-pariaman-festival-budaya-dan-tradisi-penuh-makna/.

Ariando, W. and Arunotai, N., 2022. The Bajau as a left-behind group in the context of coastal and marine co-management system in Indonesia. Journal of Marine and Island Cultures 11(1): 260-278. https://doi.org/10.21463/jmic.2022.11.1.18.

Baouham, A., Cherif, S.E. and Sakami, S., 2024. A review of structural vulnerability assessment methods in the advent of a tsunami. E3S Web of Conferences 502: 03013. https://doi.org/10.1051/e3sconf/202450203013.

Budiarjo, A., 2006. Evacuation shelter building planning for tsunami-prone area: A case study of Meulaboh City, Indonesia. Master's thesis. International Institute for Geo-Information Science and Earth Observation, Enschede. https://essay.utwente.nl/essays/101910.

Dall'Osso, F., Gonella, M., Gabbianelli, G., Withycombe, G. and Dominey-Howes, D., 2009. A revised PTVA model for assessing the vulnerability of buildings to tsunami damage. Natural Hazards and Earth System Sciences 9(5): 1557-1565. https://doi.org/10.5194/nhess-9-1557-2009.

Dall'Osso, F., Maramai, A., Graziani, L., Brizuela, B., Cavalletti, A., Gonella, M. and Tinti, S., 2010. Applying and validating the PTVA-3 model at the Aeolian Islands, Italy: Assessment of the vulnerability of buildings to tsunamis. Natural Hazards and Earth System Sciences 10(7): 1547-1562. https://doi.org/10.5194/nhess-10-1547-2010.

Ditya, Y.C., Krisanti, M., Utomo, A.D., Ramdhan, M., Purnomo, S.J., Mudjiono, Adrianto, L., Hariyadi, S., Putra, A., Dermawan, A. and Wahyono, A., 2026. Other effective area-based conservation measures (OECMs) in marine and island social-ecological systems: A PRISMA-guided SLR 2014-2024. Journal of Marine and Island Cultures 15(1): Article 22. https://doi.org/10.21463/jmic.2026.15.1.22.

Febriandi, Lanin, D., Hermon, D., Fatimah, S. and Putra, A., 2019. A dynamics condition of coastal environment in Padang City-Indonesia. IOP Conference Series: Earth and Environmental Science 314(1): 012006. https://doi.org/10.1088/1755-1315/314/1/012006.

Gischa, S., 2021. Tari *Tabuik*, tarian tradisional di Sumatera Barat. Kompas.com. https://amp.kompas.com/skola/read/2021/03/15/124208769/tari-*Tabuik*-tarian-tradisional-di-sumatera-barat.

Government of the Republic of Indonesia, 2007. Law No. 26 of 2007 on Spatial Planning (Undang-Undang Nomor 26 Tahun 2007 tentang Penataan Ruang). JDIH BPK RI. https://peraturan.bpk.go.id/Details/39908/uu-no-26-tahun-2007.

Government of the Republic of Indonesia, 2014[a]. Law No. 1 of 2014 amending Law No. 27 of 2007 on the Management of Coastal Areas and Small Islands (Undang-Undang Nomor 1 Tahun 2014 tentang Perubahan atas Undang-Undang Nomor 27 Tahun 2007 tentang Pengelolaan Wilayah Pesisir dan Pulau-Pulau Kecil). JDIH BPK RI. https://peraturan.bpk.go.id/Details/38521/uu-no-1-tahun-2014.

Government of the Republic of Indonesia, 2014[b]. Law No. 23 of 2014 on Regional Government (Undang-Undang Nomor 23 Tahun 2014 tentang Pemerintahan Daerah). JDIH BPK RI. https://peraturan.bpk.go.id/Details/38685/uu-no-23-tahun-2014.

Government of the Republic of Indonesia, 2021. Government Regulation No. 21 of 2021 on the Implementation of Spatial Planning (Peraturan Pemerintah Nomor 21 Tahun 2021 tentang Penyelenggaraan Penataan Ruang). JDIH BPK RI. https://peraturan.bpk.go.id/Details/161851/pp-no-21-tahun-2021.

Government of the Republic of Indonesia, 2023. Law No. 6 of 2023 on the Stipulation of Government Regulation in Lieu of Law No. 2 of 2022 on Job Creation into Law (Undang-Undang Nomor 6 Tahun 2023 tentang Penetapan Peraturan Pemerintah Pengganti Undang-Undang Nomor 2 Tahun 2022 tentang Cipta Kerja Menjadi Undang-Undang). JDIH BPK RI. https://peraturan.bpk.go.id/Details/246523/uu-no-6-tahun-2023.

Haidu, I. and Nicoară, M.E., 2011. GIS procedure for the identification of existing infrastructure in the flooding areas. Geographia Technica 6(2): 30-34.

https://technicalgeography.org/pdf/2_2011/04_ionel_haidu_monica_elena_nicoara__gis_procedure.pdf.

Hamid, S.K., Teniwut, W.A., Renhoran, M. and Teniwut, R.M.K., 2021. A novel framework for marine protected areas in small island regions using integrated local wisdom. Regional Studies in Marine Science 45: 101819. https://doi.org/10.1016/j.rsma.2021.101819.

Hermon, D., Erianjoni, Dewata, I., Putra, A. and Oktorie, O., 2019. Liquefaction vulnerability analysis as a coastal spatial planning concept in Pariaman City-Indonesia. International Journal of Recent Technology and Engineering 8. https://doi.org/10.35940/ijrte.B3265.078219.

Hermon, D., Ikhwan, Putra, A. and Oktorie, O., 2020. Spatial analysis of tsunami vulnerability zones as a basic concept of coastal disaster mitigation in development planning of Pariaman City. Journal of Advanced Research in Dynamical and Control Systems 12(7-Special Issue): 681-690. https://doi.org/10.5373/jardcs/v12sp7/20202158.

Hasmira, M.H., Zamzami, L., Harahap, J., Putra, A., Erianjoni, Febrianto, A. and Saputra, H., 2025. Integrating disaster mitigation and ecotourism: A model of sustainable development and turtle conservation in Nagari Ampiang Parak. GeoJournal of Tourism and Geosites 59(2): 703-713. https://doi.org/10.30892/gtg.59217-1449.

Hidayat, Z., 2023. Tariqa Shattariyya (TS) and spiritual tourism in Pariaman, Indonesia. International Journal of Religious Tourism and Pilgrimage 11(2): 125-134. https://arrow.tudublin.ie/ijrtp/vol11/iss2/8.

Husrin, S., Kelvin, J., Putra, A., Prihantono, J., Cara, Y. and Hani, A., 2015. Assessment on the characteristics and the damping performance of coastal forests in Pangandaran after the 2006 Java tsunami. Procedia Earth and Planetary Science 12: 20-30. https://doi.org/10.1016/j.proeps.2015.03.007.

Ivan, K. and Haidu, I., 2012. The spatio-temporal distribution of road accidents in Cluj-Napoca. Geographia Technica 7(2): 32-38.
https://technicalgeography.org/pdf/2_2012/04_kinga_ivan_ionel_haidu_the_spatio_temporal_distribution_of_road_accidents_in_cluj_napoca.pdf.

Kurniawan, F., Adrianto, L., Bengen, D.G. and Prasetyo, L.B., 2016. Vulnerability assessment of small islands to tourism: The case of the Marine Tourism Park of the Gili Matra Islands, Indonesia. Global Ecology and Conservation 6: 308-326. https://doi.org/10.1016/j.gecco.2016.04.001.

Large News, 2012. Upacara *Tabuik* dari Sumatera Barat. Large News Blog. https://large-news.blogspot.com/2012/09/upacara-*Tabuik*-dari-sumatera-barat.html.

Lippi, S., Piroddi, C., Graziano, M. and Di Franco, A., 2024. Highlighting the gap on spatial regulatory data in the official MPAs databases. Frontiers in Marine Science 11: 1369447. https://doi.org/10.3389/fmars.2024.1369447.

Madani, S., Khaleghi, S. and Jannat, M.R.A., 2017. Assessing building vulnerability to tsunami using the PTVA-3 model: A case study of Chabahar Bay, Iran. Natural Hazards 85: 349-359. https://doi.org/10.1007/s11069-016-2567-7.

Ministry of Marine Affairs and Fisheries (MMAF), 2021[a]. Regulation No. 28 of 2021 on the Implementation of Marine Spatial Planning (Peraturan Menteri Kelautan dan Perikanan Nomor 28 Tahun 2021 tentang Penyelenggaraan Penataan Ruang Laut). JDIH KKP. https://jdih.kkp.go.id/Homedev/DetailPeraturan/954.

Ministry of Marine Affairs and Fisheries (MMAF), 2021[b]. Decree No. 106 of 2021 on the Conservation Area in the Waters of Pariaman City, West Sumatra Province (Keputusan Menteri Kelautan dan Perikanan Nomor 106 Tahun 2021 tentang Kawasan Konservasi di Perairan di Wilayah Kota Pariaman di Provinsi Sumatera Barat). JDIH KKP. https://jdih.kkp.go.id/Homedev/DetailPeraturan/3097.

Ministry of Marine Affairs and Fisheries (MMAF), 2025. Regulation No. 7 of 2025 on the Utilization of Conservation Areas (Peraturan Menteri Kelautan dan Perikanan Nomor 7 Tahun 2025 tentang Pemanfaatan Kawasan Konservasi). JDIH KKP. https://jdih.kkp.go.id/Homedev/DetailPeraturan/6772.

National Disaster Management Agency (BNPB), 2025[a]. Banjir Menerjang Kabupaten Padang Pariaman [Flood hits Padang Pariaman Regency], 23 November 2025. https://bnpb.go.id/berita/banjir-menerjang-kabupaten-padang-pariaman.

National Disaster Management Agency (BNPB), 2025[b]. Perkembangan Situasi dan Penanganan Bencana di Tanah Air per 24 November 2025 [Disaster situation and response update, 24 November 2025]. https://www.bnpb.go.id/berita/perkembangan-situasi-dan-penanganan-bencana-di-tanah-air-24-november-2025.

Nicoară, P.S. and Haidu, I., 2014. A GIS based network analysis for the identification of shortest route access to emergency medical facilities. Geographia Technica 9(2): 60-67.
https://technicalgeography.org/pdf/2_2014/07_nicoara.pdf.

Nicolini, M., 2021. Geographical connections: Law, islands, and remoteness. Liverpool Law Review 42: 97-110. https://doi.org/10.1007/s10991-020-09259-8.

Nissa', Z.N.A., Sari, A.K., Ajri, M., Al Rosyid, A.H. and Rini, W.D.E., 2026. Assessing livelihood vulnerability and socioeconomic impact of climate change on women fish processors in Depok Beach, Parangtritis Village, Southern Coast of Yogyakarta. Journal of Marine and Island Cultures 15(1): 1-23. https://doi.org/10.21463/jmic.2026.15.1.14.

Padang Pariaman Regency Government, 2025. Banjir dan Longsor Meluas, Tiga Jembatan di Padang Pariaman Roboh [Floods and landslides expand; three bridges collapse in Padang Pariaman], 28 November 2025. https://padangpariamankab.go.id/blog/berita_tampil/banjir-dan-longsor-meluas-tiga-jembatan-di-padang-pariaman-roboh-bupati-saksikan-rumah-terseret-arus?tahun=2020.

Papathoma-Köhle, M. and Dominey-Howes, D., 2003. Tsunami vulnerability assessment and its implications for coastal hazard analysis and disaster management planning, Gulf of Corinth, Greece. Natural Hazards and Earth System Sciences 3(6): 733-747. https://doi.org/10.5194/nhess-3-733-2003.

Putra, A. and Mutmainah, H., 2016. The mapping of temporary evacuation site (TES) and tsunami evacuation route in North Pagai Island, Mentawai Islands Regency-Indonesia. IOP Conference Series: Earth and Environmental Science 47(1): 012020. https://doi.org/10.1088/1755-1315/47/1/012020.

Putra, A., Dewata, I., Hermon, D., Barlian, E., Umar, G., Widodo, T. and Damanhuri, H., 2023[a]. Activity recommendations based on an environmental approach in zoning of marine protected areas (MAPS) Pariaman City-Indonesia. EnvironmentAsia 16(3): 57-67. https://doi.org/10.14456/ea.2023.35.

Putra, A., Darwis, R., Dewata, I., Tanto, T.A., Mustapha, M.A., Razi, P. and Zainul, R., 2023[b]. Suitability of mangrove ecosystems as a protected zone based on land-use changes. Physical Oceanography 30(6): 866-881. https://physical-oceanography.ru/repository/issues/2023/06/11/.

Putra, A., Dewata, I., Hermon, D., Barlian, E. and Umar, G., 2023[c]. Sustainable development-based coastal management policy development: A literature review. Journal of Sustainability Science and Management 18(1): 237-245. https://doi.org/10.46754/jssm.2023.01.015.

Putra, A., Hermon, D., Yulius, Prarikeslan, W., Syarief, A., Ridwan, N.N.H., Arifin, T., Febriandi, Damanhuri, H., Widodo, T. and Dermawan, A., 2024. Assessment of seawater quality and environmental sustainability for shipwreck diving tourism: A case study of MV Boelongan Nederland in Mandeh Bay, Indonesia. Geography, Environment, Sustainability 17(4): 171-182. https://doi.org/10.24057/2071-9388-2024-3469.

Rasoli, M., Saidpour, S., Ghalehteimouri, K.J., Mousavi, M. and Khedmatzadeh, A., 2023. Identification of optimal routes in urban physical vulnerable textures for emergency evacuation in Saqez City. Journal of Arts Management 7(1): 205-226. https://so02.tci-thaijo.org/index.php/jam/article/view/259413.

Rianty, R. and Asty, W., 2021. Analysis of internal and external factors to design a *Tabuik* Festival development strategy in Pariaman City, West Sumatera. TRJ Tourism Research Journal 5(2): 134-153. https://doi.org/10.30647/trj.v5i2.118.

Setyawan, Y.P., Wakhid and Suhadi, 2020. The denser canopy of mangrove drives the structure of insect communities. Tropical Life Sciences Research 31(3): 77-90. https://doi.org/10.21315/tlsr2020.31.3.6.

Simarmata, N., Wikantika, K., Tarigan, T.A., Aldyansyah, M., Tohir, R.K. and Putra, A., 2024. Comparative analysis of reflectance values on Sentinel-2A image with field spectroradiometer in mangrove forest on East Coast Lampung. AIP Conference Proceedings 3001(1): 090001. https://doi.org/10.1063/5.0184159.

Sobarna, C., Afsari, A.S. and Ampera, T., 2025. Tradition of utilizing dahon plants in supporting the strengthening of maritime culture in Pangandaran, West Java, Indonesia. Journal of Marine and Island Cultures 14(3): 233–249. https://doi.org/10.21463/jmic.2025.14.3.14.

Sotelo-Salas, C., Monardes-Concha, C.A., Pérez-Galarce, F. and Santa González, R., 2024. A multi-objective optimization model for planning emergency shelters after a tsunami. Socio-Economic Planning Sciences 93: 101909. https://doi.org/10.1016/j.seps.2024.101909.

Tarbotton, C., Dominey-Howes, D., Goff, J.R., Papathoma-Köhle, M., Dall'Osso, F. and Turner, I.L., 2012. GIS-based techniques for assessing the vulnerability of buildings to tsunami: Current approaches and future steps. Geological Society, London, Special Publications 361(1): 115-125. https://doi.org/10.1144/SP361.10.

Zhang, Y., Zhang, X. and Huang, X., 2023. Design a safe firefighting time (SFT) for major fire disaster emergency response. International Journal of Disaster Risk Reduction 88: 103606. https://doi.org/10.1016/j.ijdrr.2023.103606.