Rapid Disaster Risk Assessment of Coastal Communities: A Case Study of Mutiara Village, Banda Aceh, Indonesia[1]

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ABSTRACT

A rapid disaster risk assessment was carried out to identify major hazards, assess vulnerabilities and analyze risks of future disasters and recommend key mitigating measures to make prospective communities in Mutiara village resilient to disasters. This paper is prepared based on a rapid reconnaissance survey of the area where Canadian Red Cross (CRC) is planning to build houses for December 2004 tsunami-affected people. Data were collected both from primary sources in consultation with the people residing nearby resettlement area and local leaders, and secondary sources. For the analysis of the hazard and vulnerability of the prospective communities, the crunch and release models were used. Risk analysis was done using risk matrix.

The study revealed that earthquake, tsunami, flooding, inundation, river cutting, cyclone, climate change and epidemics were the major natural hazards in the locality. Vulnerability analysis showed that this area had a very high damage potential to tsunami and flooding. Risk assessment based on the hazard potential and vulnerability analysis shows that the area falls within the very high risk zone.

However, since no alternatives are available for the resettlement of the December 2004 tsunami-affected people and their strong willingness to stay in the same area due to other socio-economic and cultural reasons; it is strongly advised that risk mitigating measures are employed together with the permanent shelter and other development initiatives.

The key mitigating measures include the construction of dykes along the coastline, formulation of community disaster preparedness plan, provision of escape routes, elevated houses, plantation of mangroves and palm trees, construction of seismic resistant houses with the slight change in the shape horizontal to the tsunami waves, community awareness programs, and launch of the integrated community-based disaster risk reduction program in the community.

Key words: Rapid disaster risk assessment, coastal villages, Canadian Red Cross, tsunami, HVCA, disaster resilient communities, Banda Aceh

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Background

On Sunday, 26 December 2004, the greatest earthquake in 40 years with 9.3 magnitudes occurred about 150 kilometers off the west coast of northern Sumatra Island in Indonesia. The earthquake generated a disastrous tsunami that caused destruction in 18 countries bordering the Indian Ocean. The massive tsunami waves up to 30 meters high resulted in the losses of properties estimated at US $ 9.9 billion (Oyola-Yemaiel 2006), and human causalities of more than 300,000. The highest number of deaths occurred in Indonesia followed by Sri Lanka, India and Thailand. More than half a million people were directly affected by the disaster in Indonesia alone.

After the tsunami event, the Canadian Red Cross (CRC), along with a number of international organizations including UN agencies, IFRC, National Red Cross and Red Crescent Societies and Non-Governmental Organizations, launched immediate response and recovery operations. CRC initiated interventions in five key areas: shelter, water and sanitation, livelihoods, health and disaster preparedness. This study is carried out to assess the severity of the future tsunami and other major disasters on the prospective community in Mutiara sub-village of the CRC shelter program area.

Objectives

The purpose of this rapid assessment was twofold:

1. To identify major hazards, assess vulnerabilities and analyze risks of future disasters
2. To recommend key mitigating measures to make prospective communities resilient to disasters

Methodology

Due to the time constraint, the report is prepared based on a rapid reconnaissance survey of the field, consultation with the community people living nearby resettlement areas and the local leaders, and the review of secondary literatures. Altogether 17 villagers, of them 40% were women, were contacted during the consultation process. For the analysis of the prospective communities' vulnerability the famous crunch and pressure and release models were used. Risk analysis was done using risk matrix. Earthquake and tsunami recurrence periods were estimated based the past disaster events in Aceh and North Sumatra provinces. A number of mitigating measures have been proposed based on the likelihoods of disaster impacts and consultation of the various stakeholders. A general methodology adopted during the study is shown in Figure 1.

Limitations of the Study

Time was the major constraint in this study. Usually a multi-disciplinary team and the active participation of local people are required to conduct a detailed disaster risk assessment; however both were not possible in this study. The methodology of this study could not be made fully participatory as the prospective owners of the houses that are going to be built were not living in the area. Discussion among the disaster risk management experts and communities was necessary to estimate the recurrence period, which lacked in this study.

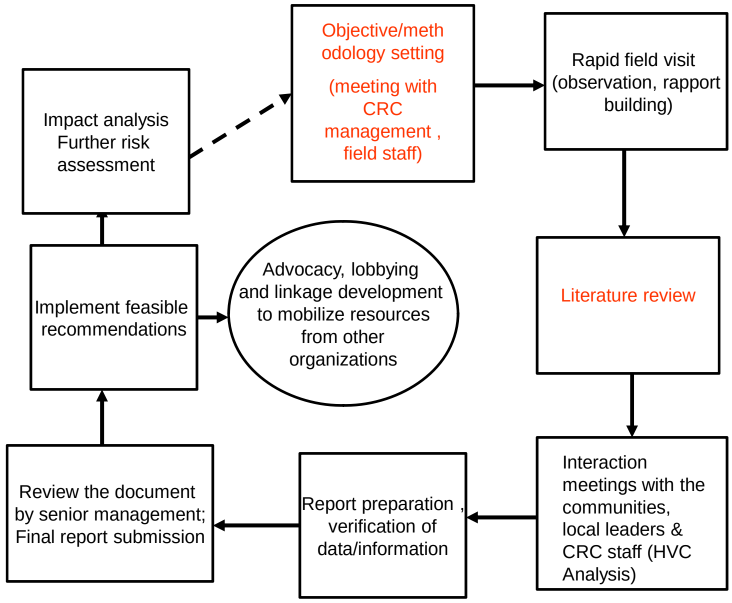

Figure 1. General methodology for rapid disaster risk assessment adopted during the study.

Disaster risk assessment

Hazard Analysis

Location

Mutiara sub-village is situated in Kajhu village in Aceh Besar district of Aceh Province. The village lies in the coastal area of Indian Ocean and is surrounded by a river in the north and the ocean in the west. The proposed house construction site is within 200m of the coastline. The altitude of the construction site is below 100 m from the mean sea level (msl). Dykes have been built by the Government, however it needs to be repaired and the height should be elevated. A portion of the coastline has been planted with mangroves.

Figure 2. CRC housing construction site- some portion is very close to ocean and is swampy

Figure 3. Too close to construct the houses.


Figure 4. Alluvial soil- good ecological environment for mangroves

Major hazard types

Earthquakes, local and regional tsunamis, flooding, volcanoes, inundation, river cutting, sea level rise due to climate change, epidemics, tropical cyclones and water and land pollution are the major hazards facing the communities in Mutiara sub-village. Since the village is too close to the coastline, the village is highly vulnerable to tsunami disaster. Tsunamis in this area can be triggered by earthquake, volcanoes and landslides.

Recurrence period

Although the danger of another major tsunami has passed, however the possibility of occurrence of another tsunami is not over. No scientific studies or practice have been able to predict the exact recurrence period of the earthquake or tsunamis. Since earthquake is not the only cause of tsunamis, it is very difficult to forecast exact period between two tsunamis at a particular location.

Indonesia is surrounded by four major tectonic plates, the pacific, the Eurasian, the Australian and the Philippines plates. All these major tectonic plates and their sub plates are presently active. Major earthquakes and tsunamis can be expected in the semi-enclosed seas and along the Indian Ocean side of Indonesia. Major earthquakes in the semi-enclosed seas can generate destructive local tsunamis in the Sulu, Banda and Java seas. Major earthquakes along the Sunda Trench can generate tsunamis that can be destructive not only in Indonesia but to other countries bordering the Indian Ocean (Pararas-Carayannis, 2006).

"Furthermore, though the stress in the region off Northern Sumatra has been released by the 26 December 2004 earthquakes- this does not necessarily mean that another earthquake further south or further north cannot occur. In the North, a repeat of the 1881 Nicobar Islands or of the 1941 Andaman Islands earthquakes and tsunamis can be expected in the future- although it is difficult to say how soon. Such events seem to occur on the average of every 50 years" (Pararas-Carayannis, 2006).

Table 1. History of Tsunami in Aceh and Western Coast of Sumatra, Indonesia

Location	Date	Magnitude	Damage/Loss
Central part of Western Sumatra	10 February 1797	8	More than 300 fatalities
South western Sumatra	24 November 1833	8.8-9.2	Flooded all the southern part of west Sumatra
Central Sumatra and Nias	5 January 1843	7.2	Many fatalities
Western coast of Sumatra	16 February 1861	8.2	Several thousands fatalities
Krakatau	27 August 1883	Volcano-caused	Over 36000 deaths
Banda Aceh	1941	-	-
Aceh and Nias island (Indian ocean tsunami)	26 December 2004	9-9.3	More than 270,000 (in Indonesia, India, Sri Lanka, Thailand, Maldives etc)

Over the last 170 years, there had seven big earthquakes occurred in North and west of Aceh province with the magnitudes more than 7.5 which could trigger tsunamis. In general, it is regarded that earthquakes with more than 6.5 magnitudes can create tsunamis. Since people had no enough knowledge about tsunamis, sometimes the tsunami waves were wrongly called tropical cyclones and tidal waves.

Table 2. Earthquakes in north and west of Aceh in the last 170 years

Year	Richter scale	Location
1833	M9	West of Aceh
1861	M 8.5	West of Aceh
1881	n/a	North of Banda Aceh
1907	M 7.5	West of Aceh
1935	M7.7	West of Aceh
1941	n/a	North of Banda Aceh
2004	M 9.3	West of Aceh

Although many Geologists suggest that tsunami is a 100 year event, past disaster events in Aceh Province suggests that tsunamis can occur at the interval of 28.5 years. However, the magnitude of the earthquake does not necessarily the same as December 2004 event. This estimate is valid only if the assumption that all earthquakes greater than 7.5 magnitude trigger tsunamis is correct. However, this has not been the case in practice. Usually the return period for the December 2004 tsunami is in a 100 years (Potangaroa 2005). Furthermore, the local people had seen the continuous falling of heavenly bodies (meteorites?) two weeks before the tsunami happened in Banda Aceh. The link between these two events is yet to be studied.

Considering the potential of occurrence of the regional or tele-tsunamis and local tsunamis and sources of tsunamis such as earthquakes, volcanoes, landslides, meteorites and nuclear explosions, it is considered that the chance of occurrence of tsunami and tidal wave is high.

For details of recurrence period of tsunami disaster, see: Shepherd (2001), Harjono, (2005), Kulikov et al. (2005), Kulikov et al. (2005) and Satake (2005).

Tsunami height and warning time

The Tsunami heights in the Aceh and North Sumatra provinces were more than the computer projected heights for the December 2004 tsunami. However, it varies by topography, shape of the sea coast (U, V and W shaped land shaped are more dangerous than the straight one). The tsunami heights of various locations in Indonesia are as follows (Wilkinson, 2005):

- Banda Aceh: 10 m
- Lhohnga: 13 m
- Calang: 10 m
- Meulaboh: 5m

Tsunami warning time (time of arrival; 10 min- 70 min):

- Banda Aceh: 45 min.
- Lhohnga: 40 min.
- Calang: 30 min.
- Meulaboh: 60 min.

In a conservative estimate, usually one meter tsunami height creates 100 meters inland inundation.

Table 3. Hazard matrix

Hazard type	Force	Warning signs	Fore warning	Spee d of osent	Frequenc y	Duration	When
Tsunami	Seismic, landslid e	Earthquak e volcanoes or landslides	Maximum 45 minutes earlier depending on the location of the epicenter	High onset	Once in 30 to 50 years; usually in every hundred years	15 minutes	Anytime of the year
Earthquake	Seismic	Shaking of land, building	No	High onset	Since not all stress has been released in the nearby area, it might come any time in future	5-10 minutes aftershoc ks might come even after months	Anytime of th year
Flood/inun dation	Water Typhoo n	Heavy rain News on	2 hours to days	Relati vely fast	Every year	2 days to months	Septemb er to January

		radio Rhythm of high tide Tsunami					
Volcanoes	Seismic geological	Smoky, ashes	Years	Relatively fast	Once in decades	weeks	Any time of the year
High winds	Pressure winds	Low pressure, hot weather, wind	hours	Fast	Once in a decade in a big scale	hours	Hot season

Vulnerability and Capacity Assessment (VCA)

Damages

A survey of the December 2004 tsunami showed that first 500 meters in all areas irrespective of tsunami heights were totally destroyed except some highly engineered mosques. Although the future tsunamis will be unlikely to happen as the December 2004 tsunami, however it gives a scenario of the damage and losses (Wilkinson, 2005, Pontangaroa 2005).

● First 500 meters in all areas were nearly total destroyed irrespective of tsunami height (5 to 13 meters).
● Debris generated from this initial destruction magnified the death toll and destruction
● At Banda Aceh- 10 m tsunami height flat area:
  - Considerable damage over the next 1.5 kilometers (0.5 km to 2 km)
  - At 3.5 km inland velocities slowed sufficiently not to destroy most brick houses.
  - Timber housing for most part destroyed to edge of inundation (4.5 km)
● At Meulaboh- 5m tsunami height flat area:
  - Considerable damage in the first kilometer
  - Most brick buildings survived beyond 1.5 km
  - Inundation was about 2km inland
● Earthquake damage was minimal:
  - 2 to 3% in Banda Aceh and 5% in Meulaboh

The projection of the wave height and velocity inland from the foreshore for a 10 meter tsunami on flat land 1.5 m above MSL is as follows (RedR 2005):

- Up to 500 m inland the height is 9 m and velocity is 8m/sec
- 1 km: 7.5 m and 7m/sec
- 1.5 km: 6m and 6m/sec
- 2 km: 5m and 5.5m/sec
- 2.5 km 4m and 4.5 m/sec
- 3 km: 2.5m and 3.5m/sec
- 3.5 km: 1.5m and 2.5 m/sec

The forces derived from these velocities can be doubled for debris loading.

Table 4. Tsunami magnitude

Magnitude of the Tsunami (m)	Maximum wave height (m)	Description of damage
0	1 to 2	No damage
1	2 to 3	Houses are flooded
2	4 to 6	Timber houses and earthen buildings are damaged
3	10 to 20	Timber buildings, vessels and people are swept away
4	More than 30	Serious damage along more than 500 km of coast

(Kuroiwa 2004)

Poor house quality, community dependence on coastal resources for their livelihoods, lack of community awareness on local hazards and disaster risks, depletion of coastal and aquatic resources, and lack of institutionalized efforts for environmental conservation of coastal areas were the major vulnerabilities in the study area. Majority of the respondents expressed their opinion that the depletion of coastal resources has limited the livelihoods options and exacerbated the impact of flooding, earthquake and other natural hazards. The study also showed a clear link between natural hazards and environmental degradation (Table 5).

Table 5. Environment and disaster linkages in the study area

Key hazards in the study area	Potential environmental impacts	Exacerbating environmental factors
Flood, High tide, tsunami	• sewage overflow • chemical release from farm, factories and roads • hazardous debris • water-damaged households chemicals (paint, pesticides, solvents etc) • loss of top soil and run off • ground and surface water contamination	• habitat and ecosystem destruction (coral reef, flora and fauna) • water siltation, deforestation • Land use and land cover changes
Earthquake	• natural gas leaks, household and chemical release from damaged containers • building waste debris and potential mix of hazardous materials • land destabilization	• topography and land cover • building codes and urban planning and urbanization processes

Table 6. Vulnerability and Capacity analysis (VCA)

Sectors	Vulnerabilities	Capacities	Recommendations
Social	• Very close to coastline and river • Vulnerable groups and individuals • Poverty	• Memory of past events • Local and international NGOs	• Create safe zones and safer routes • Launch livelihoods programs • Launch community

	• Lack of education • Poor resource management • Lack of disaster planning and preparedness • Lack of VCA • Low perceptions of risks even though they remember the tsunami event of December 2004		disaster awareness programs • Conduct detailed VCA and identify mitigating activities accordingly
Physical	• Lack of community-based early warning system • Buildings at risk • Unsafe critical facilities such as hospital, schools, police office etc. • Unsafe infrastructure to tsunami disaster	• Resilient buildings and infrastructures to cope with earthquake disasters (but not tsunamis)	• Establish and strengthen community based early warning system • Elevate height of buildings so that there will be minimal damage by tsunami events
Economic	• Insecure livelihoods • Relief/welfare dependency • Non-diversified economy • No land ownerships • Lack of capital to start business • Lack of job opportunity • No organized fishing •	• NGOs/donor agencies to support livelihoods • Market availability to sell local product • Possibility of organized fishing • Traditional knowledge in Identifying natural early warning sign before earthquake & Tsunami	• Launch livelihoods program • Promote skills and self employment opportunities in the locality • Provide credit capital to the needy • Initiate organized fishing
Environment	• Pollution of ground water • Destruction of natural storm barriers such as mangroves • Global climate change	• Initial activities to create natural barriers to wave/storm action such as mangrove plantation	• Lunch massive plantation activities along the coastline

Results of vulnerability assessment using crunch model are shown in Table 7 below:

Table 7. Vulnerability analysis using crunch model

Hazard type	Elements at risk (Disaster)	Unsafe conditions	Dynamic pressures	Root causes
Tsunami, Earthquake, Flooding, Inundation	Elderly, children, women, sick people; Crops damage; Complete damage of buildings, infrastructures, critical facilities such as hospitals, police office, schools and mosques; Coastal ecosystem damaged	Unstable livelihoods; Damage of critical facilities, buildings, infrastructures, and development assets; Damage of coastal resources such as mangroves/ palms and coral reefs Land degradation; Low agriculture productivity; Disruption of societal cohesiveness;	No secure land rights for marginalized people Coastal ecosystem under pressure Disruption of societal values and system;	Lack of proper land-use planning Poverty Unequal distribution of resources and services; marginalized people compelled to live in coastal region for their livelihoods;

Risk analysis and Evaluation

People living nearby areas perceive the livelihood as more risk than the risks from tsunami, cyclone and flooding. They do not want to migrate from the area to safer areas because of the fear of livelihood alternatives in the new areas. Instead, they would like to be aware of the disaster events and adopt mitigating measures. The risk analysis using risk ranking (Table 8, Table 9) suggests that there is very high disaster risk in the locality.

Table 8. Risk ranking

Exposure	Probability	Consequence	Risk rating
Unlikely (1)	Unlikely to occur (1)	Insignificant (1)	3
Occasionally (2)	Some chance (2)	Minor property damage (2)	6
Often (3)	Could occur (3)	Lost time, injury or significant properly damage (3)	9
Frequent (4)	**High chance (4)**	Severe injury and	12

		property damage (4)	
Continuous (5)	Will occur if not attended to (5)	**Significant human land property damage/loss (5)**	15

Table 9. Risk rating

Total score	Status	Recommendations	Mutiara case
3-5	Low	Requires monitoring	Since Mutiara receives 14 scores and falls in the serious status, therefore it requires immediate attention
6-10	Moderate	Requires attention	
11-15	Serious	Requires immediate attention	

Since it is not possible to mitigate Tsunami hazard, immediate attention should be given to enhance the capacity and reduce vulnerability thereby reducing disaster impacts.

Disaster Risk Reduction Measures

A number of risk mitigating measures have been proposed to reduce the future risk from tsunami, tidal waves and tropical cyclones. It is strongly advised to carry out these activities along with the other resettlement schemes.

1. Construct/Repair dykes along the coastline in the north and west part of the Mutiara area.
2. Plant or enrich tree plantation (e.g. Mangroves, Palms, Casuarinas and bamboos etc). This can reduce the speed of tsunami wave thereby reducing the human and property losses. Tree plantation can reduce the impact of tsunami, support community livelihoods and maintain coastal ecosystem. Mangroves in Phang Nga in Thailand saved thousands of life during 26 December 2004 tsunami. Palm trees in Aceh were survived from tsunami waves.
3. Higher design and construction standards needed; elevate houses that can help reduce the flood and tsunami disaster losses;
4. Provision of escape routes (hills, safe structures- schools and public buildings; but not hospitals). (Safer places should be within a distance of half an hour walk/vehicle). The essential feature of an escape route (evacuation route) is that it will get people to high ground as quickly as possible. Sites with a moderate upward slope should be chosen, where people can walk without much difficulty. Escape routes need to be perpendicular to the contour lines to gain elevation. This may not be feasible in Mutiara case. However, an elevated safer zone can be developed in inland area. Escape routes may be principal or secondary. Principal routes should be sufficiently wide to ensure that the rubble from collapsed buildings will not obstruct them completely and vehicles will be able to circulate. The secondary routes are narrower and rule could hinder the circulation of vehicles, so these routes should be used for pedestrian evacuation only.

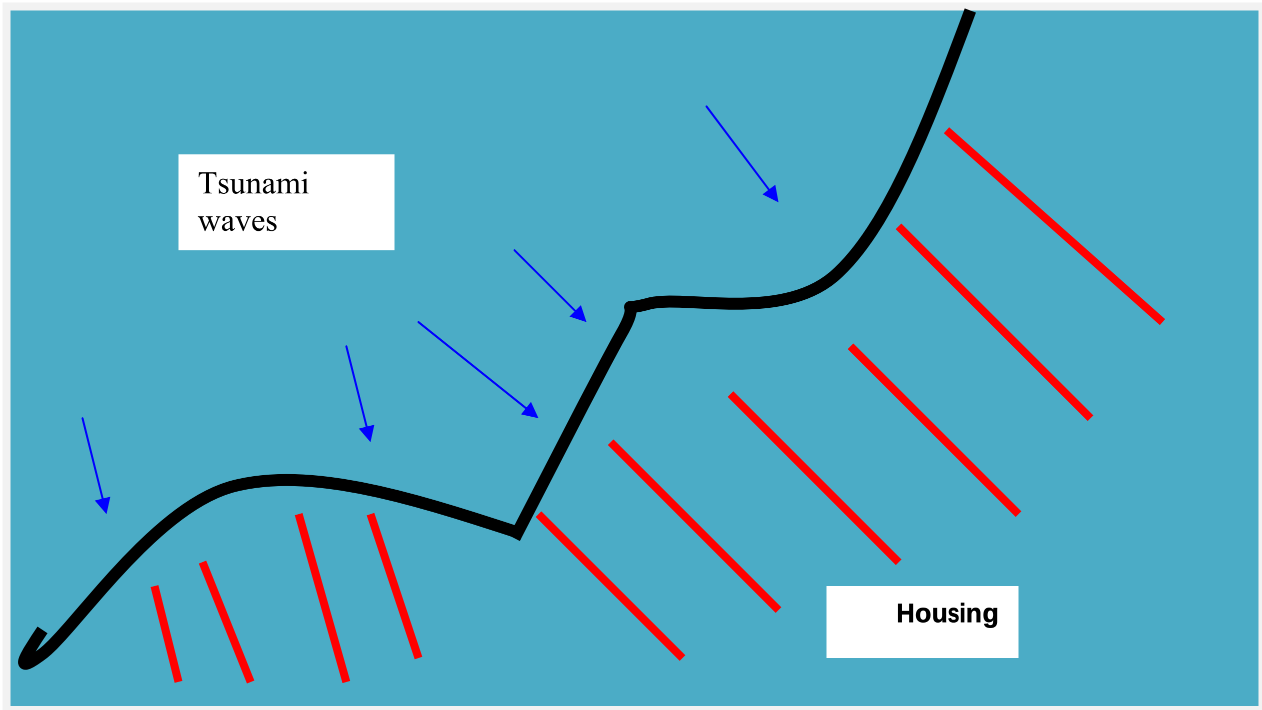

Figure 5. Houses constructed parallel to the Tsunami waves can mitigate the losses.

5. Provision of community-based early warning system linked with PMI early warning system.
6. Road realignment to avoid inundation: Avoid damage and reconstruction, available for disaster relief, provide escape route for coastal villages (Standard width of the road, possible critical points, electricity poles etc)
7. Make communities aware of the escape routes and safer places.
8. Encourage households and communities to prepare contingency plan and land use planning and follow accordingly
9. Please think about the livelihood alternatives of the local communities, if not this might further make them vulnerable.
10. There is highly unlikely to strike another Earthquake-triggered tsunami in Aceh Province in near future, but Volcano, landslides and meteorite-triggered Tsunamis can occur at any time in the region. People living in coastal areas within 500m of sea coast can be affected by the tropical cyclones as well. Launch community awareness program from the very beginning of the settlement.
11. Land use planning- simply leave a strip of a land by the sea that is to be occupied by fishing, shipping, aquaculture and so.
12. Reinforced cement concrete and brick buildings with foundations protected against erosion and walls parallel to the direction the waves are traveling, which offer the smallest possible front to hydraulic pressure, can resist tsunamis well.
13. Launch integrated community based disaster risk reduction program in the community. Form community based action teams (CBATs) and coordinate disaster risk management activities in the community. Conduct awareness raising/training programs.

Conclusion

Earthquake and volcanoes-triggered tsunamis and flooding are two biggest natural hazards with high damage potential in Mutiara sub-village. High tide, inundation and epidemics are also prevalent in the area. From all the aspects of vulnerability, i.e. social, physical, economic and environmental, this village is highly vulnerable to the future disasters risks. However, since the decade old livelihood pattern of the local community relies on the coastal ecosystem, the people in this community do not want to move elsewhere. Instead, they are eager to adopt the mitigating measures and cope with disasters themselves. Therefore, a number of risk mitigating measures have been proposed based on the local socio-economic circumstances. Permanent shelter program is recommended together with the proposed disaster risk mitigation measures. Besides, Disaster Risk Reduction concerns should be integrated into Environmental Risk Assessments (EIA).

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