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# Tsunami Hazard Mapping in Developing Countries

## An effective way of raising awareness for tsunami disaster risk reduction

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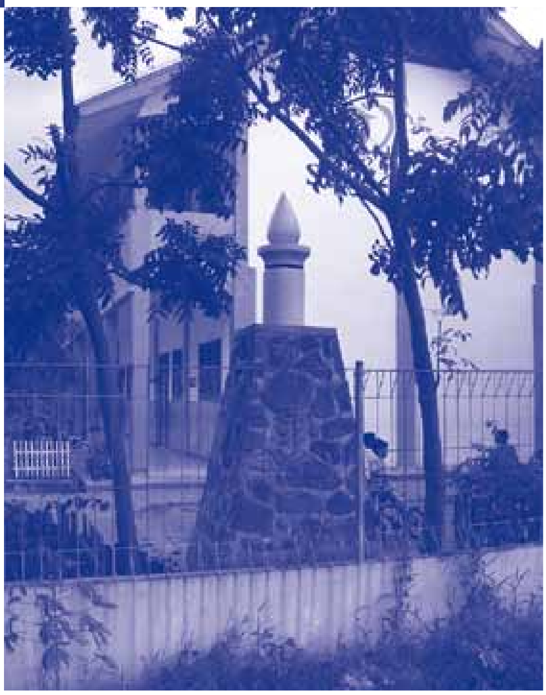

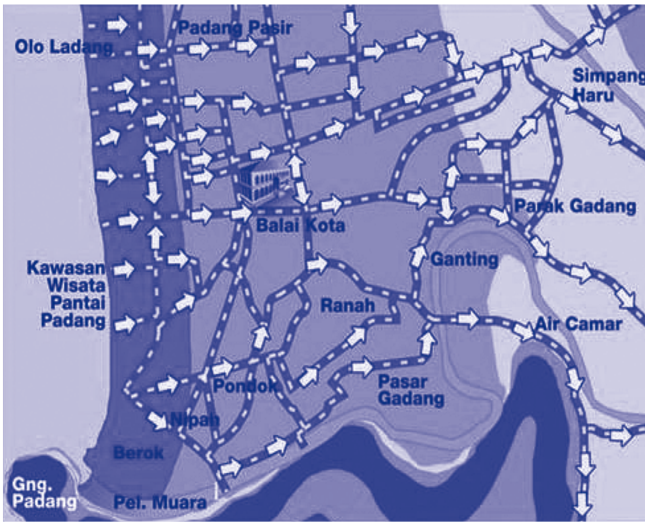


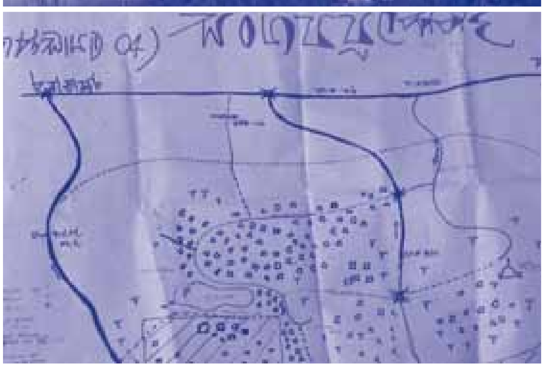

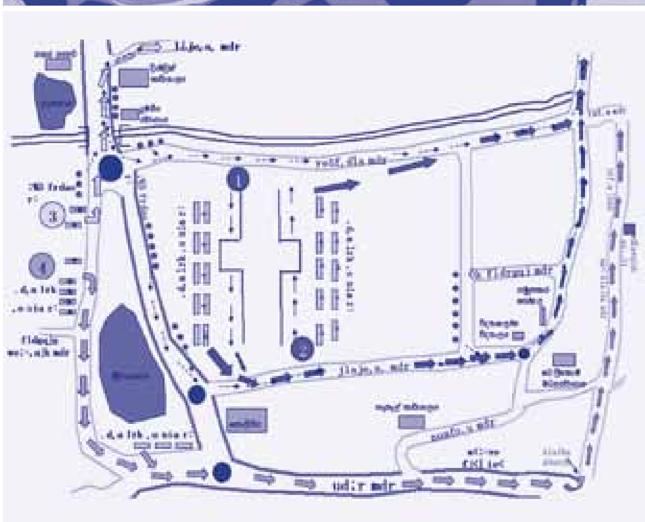

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# Tsunami Hazard Mapping in Developing Countries

## — An Effective Way of Raising Awareness for Tsunami Disaster Risk Reduction —

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The giant loss caused by the Indian Ocean Tsunami of 26 December 2004 (IOT 2004) is basically due to the lack of proper awareness and preparedness for tsunami disasters from national government level to local level.

Within five years after the IOT 2004, Indian Ocean countries have been developing and enhancing their national as well as regional disaster management system. However, the developed system will be useless if people do not aware about the disaster itself and perform incorrect responses if of an emergency. Since a massive tsunami occurs infrequently, for example once in 100 years, it is difficult but necessary to come up with ways to sustain public awareness towards tsunami disaster mitigation. In this regard, continual education and reminder to the communities about the danger of tsunami are very much significant to develop and maintain continuous awareness and preparedness.

This report intends to highlight the potential implementation of Tsunami Hazard Map (THM) as one of the most effective ways of raising awareness on tsunami disaster risk reduction in developing countries. Its main contents include the role of THM in achieving targets of key-issues of tsunami disaster risk reduction, driving factors for the urgency of THM development, practical uses of THM and indication on several ineffective practices in utilization of THM. A brief summary of the Japan Tsunami and Storm Surge Hazard Map Manual and the important notes on its adoption for developing countries is also given as an useful reference.

Keywords: tsunami hazard map, awareness, disaster risk reduction, developing countries

# Table of Contents

# 1. Introduction

## 1.1 Background

The Indian Ocean Tsunami of 26 December 2004 (hereafter called as IOT 2004) caused about 230,000 casualties and enormous property damage to Indian Ocean countries. This giant loss is basically due to the lack of proper awareness and preparedness for tsunami disasters from national government level to local level. Each country had a disaster management plan and established a related organization to look after the problems; however, such a plan generally does not include tsunami disasters. People living along the coast near the epicenter of the earthquake had little knowledge of moving to higher elevations when they felt a shock of an earthquake. Tsunami warning was not issued in countries those far away from the epicenter, such as Sri Lanka and India. Structural countermeasures were rarely in place except for some parts of the Maldives coast. Figure 1.1 shows number of death tolls in several countries due to IOT 2004.

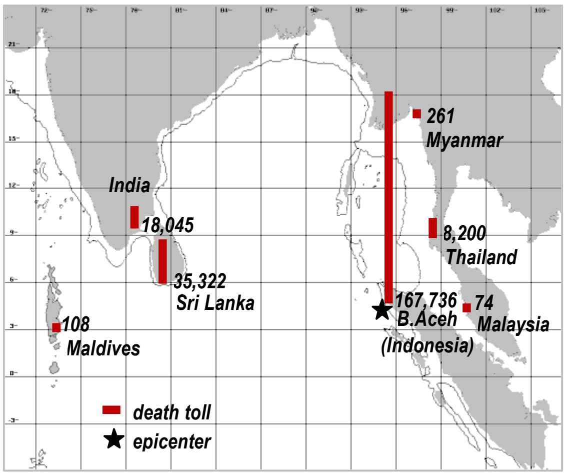



**Figure 1.1** Diagram of death-toll in most affected countries due to Indian Ocean Tsunami disaster 2004. (*data source: http://www.tsunamispecialenvoy.org/country/ humantoll.asp*)

Within five years after the IOT 2004 disaster, Indian Ocean countries have been developing and enhancing their national as well as regional disaster management system under the support of international communities. Several monumental progresses have been shown such as development of Indian Ocean Tsunami Warning System (IOTWS), development of national platform on disaster management, national action plan, and so on. However, the developed system will be useless if people do not aware about the disaster itself and perform incorrect responses if of an emergency. Therefore, awareness and preparedness at the community level are essentials. Since a massive tsunami occurs infrequently, for example once in 100 years, it is difficult but necessary to come up with ways to sustain public awareness towards tsunami disaster mitigation. In this regard, continual education and reminder to the communities about the danger of tsunami are very much significant to develop and maintain continuous awareness and preparedness.

## 1.2 Objectives and structure of this book

This book intends to highlight the potential implementation of Tsunami Hazard Map (THM) as one of the most effective ways of raising awareness on tsunami disaster risk reduction in developing countries.

Chapter-2 describes the characteristic of tsunami disaster in developing countries related to social condition and topographical condition and provides examples of potential countermeasure for the related conditions. These descriptions are provided based on the field investigations results of damage situation aftermath IOT 2004 in several areas over Indian Ocean countries, which were significantly damaged by tsunami.

In Chapter-3, issues and direction of tsunami countermeasures in developing countries will be addressed to give reasons for the urgency of tsunami disaster awareness in surrounding countries. This chapter includes description about potential tsunami hazard around the Indian Ocean, change of disaster countermeasure paradigm and issues concerning tsunami disaster risk reduction.

By taking the idea of Japan experiences, descriptions are given in Chapter-4 on the role of THM in achieving targets of key-issues of tsunami disaster risk reduction, driving factors for the urgency of THM development, practical uses of THM and indication on several ineffective practices in utilization of THM. In addition, since the potential application of coastal vegetation belt in many tropical developing countries are significant, this chapter also describes about the application of coastal vegetation belt in comprehensive tsunami disaster countermeasure.

Finally, the brief summary of the Japan Tsunami and Storm Surge Hazard Map Manual and the important notes on its adoption for developing countries is given in Chapter-5. In regard with detail methodology of tsunami hazard map development, the readers should refer to the Tsunami and Storm Surge Hazard Map Manual, which is published by Japan Cabinet Office (Disaster Management Section).

# 2. Characteristics of Tsunami Disaster in Developing Countries

The disaster of IOT 2004 has given once again valuable lessons for countries all over the world that preparedness and mitigation actions are indispensable measures to reduce the risks caused by disaster, especially those like tsunami disasters, which infrequently happened but generated high and extensive damages.

Developing countries are among the most vulnerable area subjected to tsunami disaster, especially due to unavailability of structural countermeasure and low awareness of the community on the danger of disaster.

Basing on the investigation data collected aftermath of IOT 2004, at the most damaged areas in the six countries surrounding Indian Ocean, the characteristics of tsunami disasters are classified related to the existing social conditions as well as topographical condition (Pacific Consultants, 2006). In reference to these disaster conditions and Japanese experience on tsunami disaster, the potential comprehensive tsunami disaster prevention measures are described for each case.

Within discourses of comprehensive tsunami disaster prevention measures, the roles of coastal vegetation belt in tsunami disaster mitigation have got a lot of attention especially after IOT 2004. In this regard, this chapter will also briefly describe about the role and limitation of coastal vegetation belt in tsunami disaster mitigation, its potential constraint of application and proposal of application idea by considering the constraint.

## 2.1 Tsunami disaster characteristics related to social condition

Disaster situation due to a certain hazard is specific for each location. Beside the hazard magnitude as the external forces, the existing social conditions as well as conditions of geophysics of the location affect the characteristics of possible generated disaster. Here, the social condition is classified into three groups according to its social environment in which all related social facilities, activities and behavior are intrinsically self-contented, *i.e.* urban area, tourism area, and fishery or agriculture area. Table 2.1 shows the description of tsunami disaster characteristics related to social conditions. Examples of area that fall into each classification are also given in the same Table.

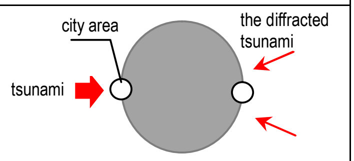
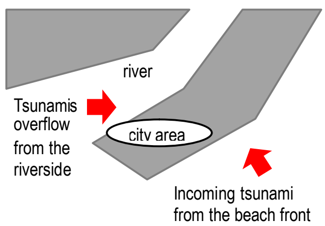
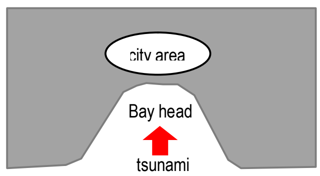
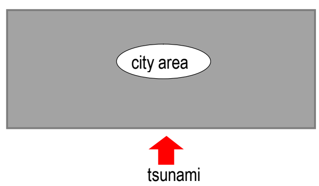
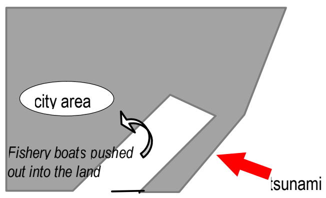
## 2.2 Tsunami disaster characteristics related to topographical condition

Topographical conditions affect tsunami propagation and possible amplification at the concern area. Thus, the disaster characteristics at certain location will be much affected by its topographical condition. The topographical condition is classified into five groups, *i.e.* Island, river flood plain, head of a bay, low and flat coastal area and harbor and fishery port. Table 2.2 shows the description of tsunami disaster characteristics related to topographical condition.

Table 2.1 Tsunami disaster characteristic related to social condition

| **Classification** | **Characteristics related to tsunami disaster** | **Examples** |
|---|---|---|
| Urban area | • Coastal area was developed as a populated city with various important infrastructures.<br>• High dense populated area that widely lay on the flood plain cause high vulnerability against tsunami disaster.<br>• Devastation of public facilities after the disaster (government office, lifeline facilities, hospital, *etc.*) will cause life difficulties for the survivors. | Sri Lanka: Galle;<br>Indonesia: Banda Aceh;<br>Maldives: Male Island;<br>India: Nagapattinam |
| Tourism area | • Coastal area is fully developed as a resort beach.<br>• Many hotels, restaurants, souvenir shops, rental shop, *etc.* on the plain beach as well as huge numbers of tourist who play in the seashore and around the beach as well are highly under vulnerable condition. | Thailand: Phiphi Island, Phuket;<br>Malaysia: Penang Island |
| Fishery and/or agricultural area | • Fishery or agricultural (industry) area is widely spread over the coastal area.<br>• Usually these areas are located over beach sand banks or around beach lagoon that make it highly vulnerable against tsunami overtopping flow. | Sri Lanka: Anpara;<br>India: Andaman Islands. |

Table 2.2 Tsunami disaster characteristic related to topographical condition

| **Classification** | **Characteristics related to tsunami disaster** | **Illustration** |
|---|---|---|
| Island | Small island with diameter about 2 to 3 kms; tsunamis can easily inundate inland from any parts of the island;<br>Example: Male Island (Maldives); Phiphi Island (Thailand) |   |
| River flood plain | The area lay on sand banks beside the river or nearby river mouth, which are easily inundated by flood from the river and the seashore as well; very vulnerable against flood disaster.<br>Example: Galle (Sri Lanka) |   |
| Head of a bay | U or V shapes bay causes tsunami flow's energy concentrated into the area around the bay head causes high tsunami runup and increases disaster vulnerability.<br>Example: Hanbantota (Sri Lanka); Phuket and Phaton beach (Thailand) |   |
| Low and flat coastal area | The low and flat land over wide area without disturbance may be damaged by high speed and dangerous flow of tsunami directly.<br>Example: Banda Aceh (Indonesia); MGR Titto Village (India) |   |
| Harbor and fishery port | Many ships, boats and other port equipments are possibly drifted inland by tsunami, destroyed buildings and may cause fires, *etc.*<br>Example: Galle and Hikkaduwa (Sri Lanka) |   |

## 2.3 Suggestion on comprehensive countermeasure for specific local cases

Combining classifications given in Table 2.1 and 2.2, we can make classification matrix of this combination as shown in Table 2.3. The examples of investigated case study are then written in its relevant matrix box. In the present presentation, not all combinations have an example of investigated case study.

For the combinations that have an example of investigated data, their respective potential countermeasures are summarized in Table 2.4. The ideas of countermeasures are provided based on the analysis on the available case study data. For each specific social condition (*i.e.* urban area, tourism area, and fisheries or agricultural area), the proposed measures include non-structural and structural countermeasures. Illustration of structural countermeasure allocation in each specific area is given in the same Table.

Table 2.3 Classification matrix of investigated area according to social condition and topographical characteristics

| Social / Topographical | **Urban area** | **Tourism area** | **Fishery or agricultural area** |
|---|---|---|---|
| **Island** | Case#1: Island–Urban area; *e.g.* Male Island of the Maldives | Case#2: Island–Tourism area; *e.g.* Phiphi Island of Thailand | |
| **River flood plain** | Case#3: River flood plain–Urban area; *e.g.* Galle of Sri Lanka | | |
| **Head of a bay** | Case#4: Head of bay–Urban area; *e.g.* Hanbantota of Sri Lanka | Case#5:Head of bay–Tourism area; *e.g.* Phuket and Phaton beach of Thailand | |
| **Low and flat area** | Case#6: Low and flate area–Urban area; *e.g.* Banda Aceh of Indonesia | | Case#7: Low and flate area–Urban area; *e.g.* MGR Titto Village of India |
| **Harbour and fishery port** | Case#8: Harbor and fishery–Urban area; *e.g.* Galle and Hikkaduwa of Sri Lanka | | |

Table 2.4 The potential comprehensive tsunami disaster prevention measures for the combination cases of social and topographical characteristics

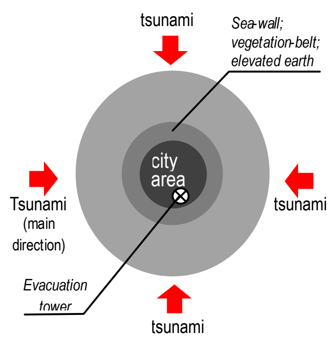
| Case | Cause of casualties and fatalities and potential countermeasures | Illustration of structural countermeasure allocation |
|---|---|---|
| Case#1: Island – urban area | *Cause of casualties and fatalities:*<br>• Very low level of island let tsunami penetrate inland easily<br>*Potential countermeasures:*<br>• Evacuation tower will help much to reduce the victim<br>• Coastal vegetations are potential (*e.g.* Pandanus odoratissimus) to reduce tsunami flow which eventually reducing tsunami force and damage<br>• Considering vulnerability distribution along the beach, building retrofitting and relocation as well as construction of escape building are necessary.<br>• Information, warning, and alert regarding the disaster situation as well as evacuation procedure<br>• Encourage the local community to lead the evacuation drill regularly |  |

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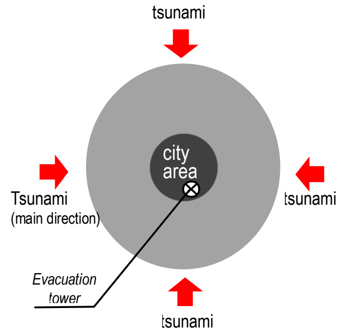
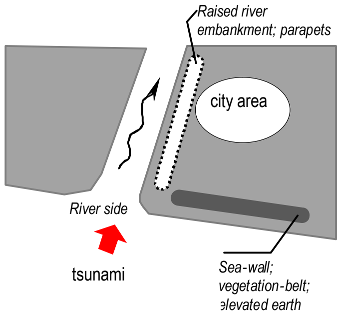
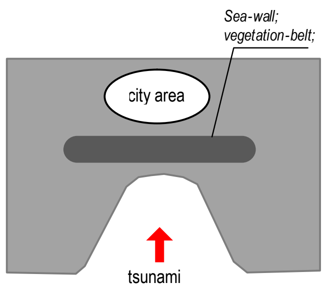
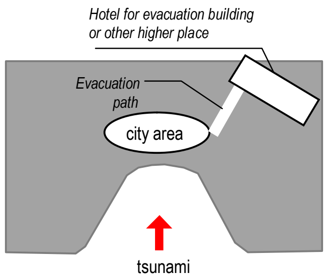
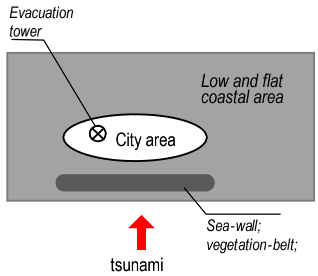
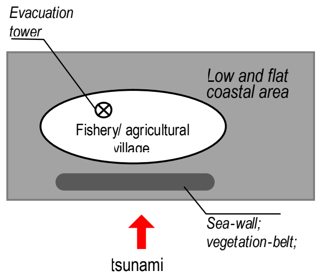
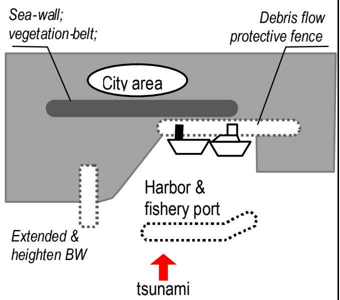
Table 2.4 The potential comprehensive tsunami disaster prevention measures for the combination cases of social and topographical characteristics (continuation)

| **Case** | **Cause of casualties and fatalities and potential countermeasures** | **Illustration of structural countermeasure allocation** |
|---|---|---|
| Case#2: Island – tourism area | *Cause of casualties and fatalities:*<br>• Sea water recede about 100m toward offshore; many tourist go to the offshore direction; 3 to5 minutes later the first wave came and captured tourist;<br>• Hotels on the beach shore were destroyed by high speed tsunami inundation onshore flow, caused big damages;<br>• Tsunami height were amplified at U-shape harbor;<br>*Potential countermeasures:*<br>• Rearrangement and replantation of hard trunk trees surrounding hotels nearby the beach to prevent damage<br>• Considering vulnerability distribution along the beach, building retrofitting and relocation as well as construction of escape building are necessary.<br>• Information, warning, and alert regarding the disaster situation as well as evacuation procedure<br>• Encourage the local community related to tourism industry lead the evacuation drill regularly |  |
| Case#3: River flood plain – urban area | *Cause of casualties and fatalities:*<br>• The central city area were trapped by wave collision coming from the beach and from the river mouth<br>• Tsunami runup through the river mouth reaches one km upstream and inundated flood plain area.<br>• Tsunami inland flow speed from the beach was very fast since no barrier along the flow.<br>*Potential countermeasures:*<br>• Enlarge the flood plain area of the river to reduce inundation level<br>• Combination of coastal vegetation belt to reduce flow speed and embankment to reduce inundation volume along the beach and river mouth.<br>• Buildings and factory along the river should be structurally strengthened against tsunami force. Coastal vegetation surrounding building will help to prevent direct crash<br>• Development of tsunami early warning and evacuation system as well as tsunami hazard mapping are very urgent. |  |
| Case#4: Head of a bay – urban area | *Cause of casualties and fatalities:*<br>• The city is located at the end of a U-shape bay, which is subjected to amplified wave attacks.<br>• The city is located in a low land between coastline and swampy wetland area<br>*Potential countermeasures:*<br>• A structural countermeasure like breakwater is necessary to reduce wave energy.<br>• To avoid human victim as many as possible, tsunami early warning and evacuation system should well implemented.<br>• To reduce tsunami flow, 50 to 200m thickness of coastal vegetation belt is suggested in combination with 1-2m height of embankment along the coastline. |  |

*(continued)*

Table 2.4 The potential comprehensive tsunami disaster prevention measures for the combination cases of social and topographical characteristics (continuation)

| Case | Cause of casualties and fatalities and potential countermeasures | Illustration of structural countermeasure allocation |
|---|---|---|
| Case#5: Head of a bay – tourism area | *Cause of casualties and fatalities:*<br>• The location is directly face to incoming wave direction from the Andaman Island.<br>• Waves directly attack the port and resort beach.<br>*Potential countermeasures:*<br>• A structural countermeasure like breakwater is necessary to reduce wave energy.<br>• To avoid human victim as many as possible, tsunami early warning and evacuation system should well implemented. |  |
| Case#6: Low and flat coastal area – urban area | *Cause of casualties and fatalities:*<br>• The city is located in a triangle shape low land flat area.<br>• Tsunami flew over pond and swampy area to attack the city<br>• Less knowledge about tsunami and limited time of evacuation after the earthquake (10-15minutes)<br>*Potential countermeasures:*<br>• Development of new land use management, including designation of evacuation building *etc.*<br>• Tsunami early warning and evacuation system<br>• Construction of evacuation tower, evacuation hill<br>• Tsunami breakwater to protect important ports.<br>• Coastal vegetation/mangrove plantation over swampy coastal area and along the river floodplain. |  |
| Case#7: Low and flat coastal area – fishery/agricultural village | *Cause of casualties and fatalities:*<br>• The land is located between port and water canal.<br>• With no any vegetation along coastline and canal, the wave propagates up to one km inland the village.<br>*Potential countermeasures:*<br>• To avoid direct attack of tsunami flow, all fishery facilities should be relocated to the safer area.<br>• Evacuation towers for temporary evacuation are important<br>• Plantation of mangrove along the water canal to reduce tsunami inundation flow.<br>• Tsunami EW and evacuation system should be developed |  |
| Case#8: Harbor and fishery port – urban area | *Cause of casualties and fatalities:*<br>• Wave energy were concentrated into the port , many ship and boat were drifted inland, causing damage to building and living thing<br>• The existence of road behind the harbor reduces tsunami inundation into the land behind.<br>*Potential countermeasures:*<br>• Since this port is very important, a tsunami structural countermeasure like breakwater is necessary to reduce direct attack of tsunami.<br>• On the coastline, combination of coastal vegetation belt and 1-2m height embankment will worth to reduce the hazard level.<br>• The available buildings, port and factory should be retrofitted against tsunami force.<br>• Development and implementation of tsunami early warning and evacuation system should be taken urgent. |  |

# 3. Issues and Direction of Tsunami Countermeasure in Developing Countries

## 3.1 Potential future tsunamis and urgency of non-structural countermeasure

Indian Ocean countries potentially face both local tsunamis as well as distant tsunamis. Within last two-decades tsunami happened once in two years over the Indonesian archipelago causing big or small calamities; the possible giant tsunami is predicted to be generated by tectonic earthquake anytime within 25-30 years along the West-coast of Sumatera (*e.g.* Sieh, 2006; Borrero *et al.*, 2006).

Potential giant tsunamigenic earthquake in northern Bay of Bengal with 200 years-recurrence interval after 1762 event will be very dangerous for its surrounding countries' coastal areas (Cummins, 2007). Historical tsunamigenic earthquake source at Arabian Sea (1945) is also being a potential hazard to the surrounding coastal areas (ITDB, 2006).

As illustrations, Figure 3.1 shows map of historical tsunami events around Indian Ocean (ITDB, 2006), whereas Figure 3.2 shows the bird-eye view of coastal area in several urban cities around Indian Ocean, *e.g.* Padang City (Indonesia), Chittagong (Bangladesh), Chennai (India) and Male (the Maldives). Evidently those tsunami-prone areas are densely occupied by residential houses and others.

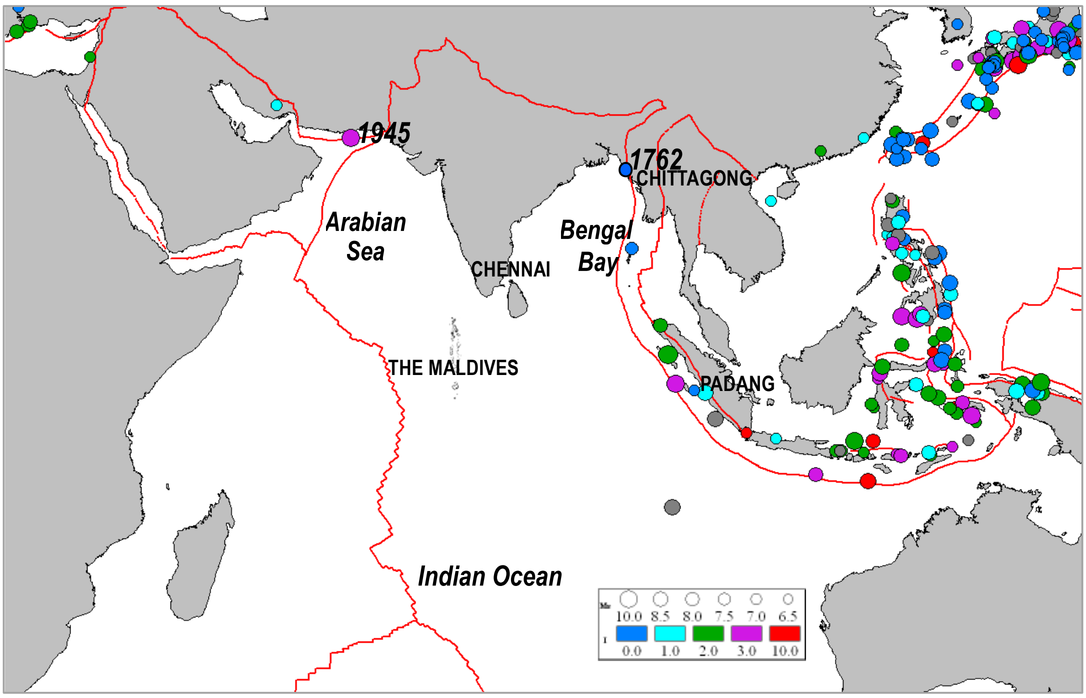



**Figure 3.1** Map of historical tsunami events around Indian Ocean; number beside circle indicates the year of event; the red-line indicates tectonic plates-boundary; legend: Ms=EQ magnitude; I=tsunami intensity (*Source: ITDB, 2006*)

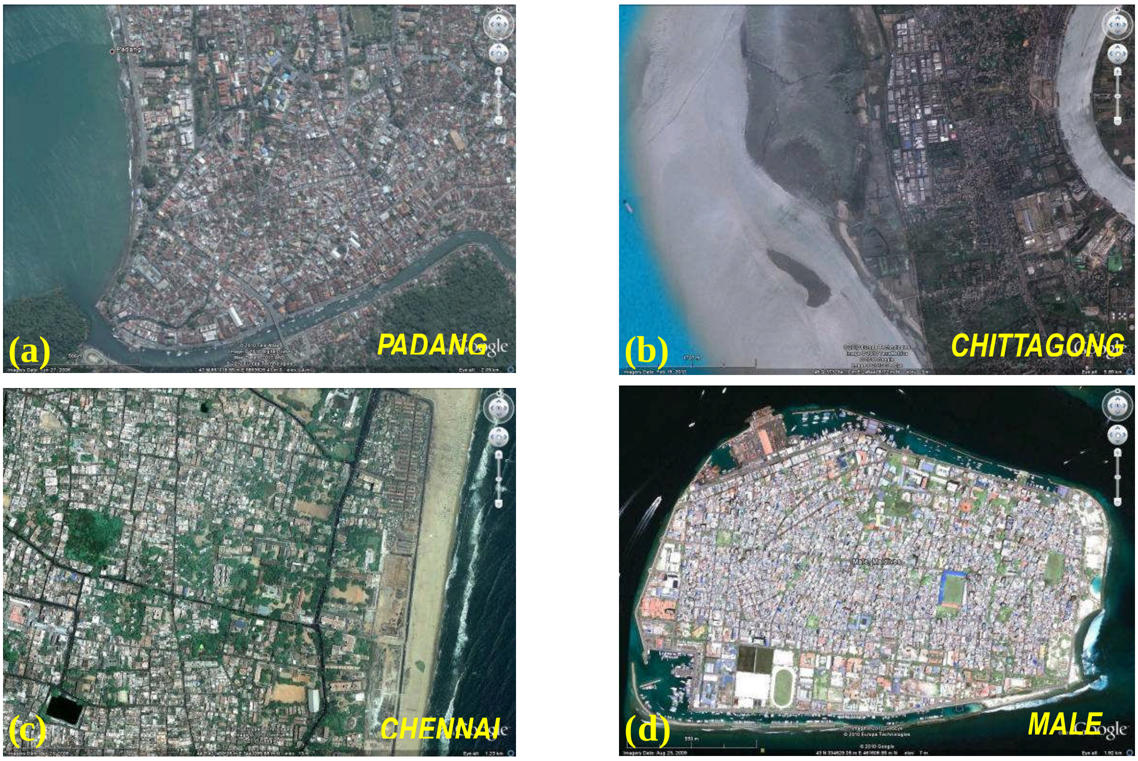



**Figure 3.2** Google Earth's bird-eye view of dense occupation of coastal area in several urban cities around tsunami prone area of Indian Ocean, *e.g.* (a) Padang, Indonesia; (b) Chittagong, Bangladesh; (c) Chennai, India; (d) Male, the Maldives

At the same time, in fact, coastal zone areas in many developing countries, including those along tsunami-prone areas, record the high population density within Low Elevation Coastal Zone (LECZ). LECZ is contiguous land area up to 100 kilometers from the coast that is ten meters or below in elevation (McGranahan *et al.*, 2006). Total numbers of people living in the LECZ for Bangladesh, India, Indonesia, Thailand, Philippines, Maldives and Bahamas are about 189,629,000 (McGranahan *et al.*, 2006). Furthermore, development of structural countermeasure such as tsunami breakwater or seawall is not a priority in most developing countries due to its high capital investment. This means that these coastal areas hold high potential of tsunami as well as storm surge disaster risk.

On the above consideration, therefore, comprehensive measures for reducing disaster risks and mitigating damage during tsunamis must be urgently and systematically established, especially due to the fact of hard availability of tsunami structural countermeasures and the poor quality of residential houses.

## 3.2 Change of disaster countermeasure paradigm and present safety against tsunami

Most of the Indian Ocean countries, except Indonesia, very rarely experienced giant tsunami before the IOT 2004. Furthermore, until before the IOT 2004, disaster countermeasures in all Indian Ocean countries were mostly response measures (relief, recovery and reconstruction). Experience of huge calamity due to the IOT 2004 have driven most of the countries in this area to develop and enhance their national as well as regional disaster management system under the support of international communities and organizations.

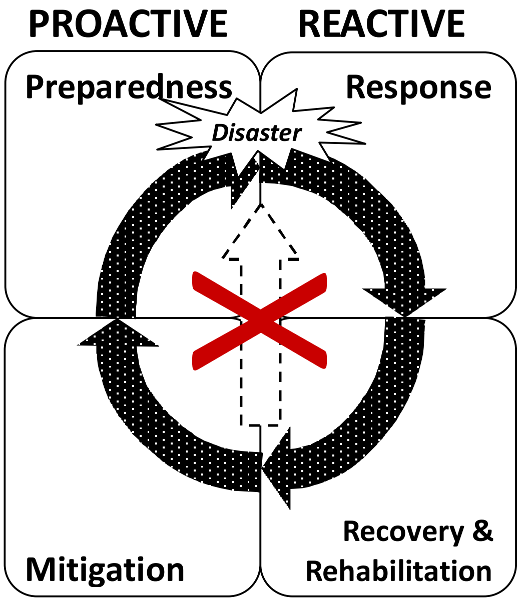



**Figure 3.3** Change of disaster countermeasure paradigm from merely response measures towards a complete disaster management cycle concept (*modified from ICHARM, 2006*)

In general, the disaster management system in these countries has now been developing toward the whole disaster management cycle including response, recovery, mitigation and preparedness. Activities before disaster, such as preparedness plan, emergency exercises/training and warning system are carried out under the frame of preparedness phase, while at the same time activities that reduce the effects of disaster, such as building codes and zoning, vulnerability analyses and public education are conducted within the frame of mitigation action. Figure 3.3 illustrates the change of disaster countermeasure paradigm from merely response measures (showed by red-crossed dotted line arrow) towards a complete disaster management cycle concept (modified from ICHARM, 2006).

However, despite this positive development, seems that very little numbers of structural tsunami countermeasures have been constructed. Even, this structural countermeasure is not a priority soon. This makes the tsunami disaster risks in the related area remain high. In this no-protection situation, public awareness on the danger of tsunami disaster should be intensively and extensively developed to educate people to perform correct response during disaster, *e.g.* immediate evacuation to reduce numbers of fatalities. In this regard, development of education methods as well as its related tools is urgent and indispensable.

On the other way, there are increasing trend of development of coastal vegetation belt along the coast prone to tsunami hazard. At present conditions, instead of an expensive tsunami structural countermeasure, development of coastal vegetation belt is among reasonable defense alternatives for the developing countries to lessen the level of damages. Nevertheless, for countries like Maldives, which are entirely laid on narrow atoll islands with very low land elevation, coastal vegetation belt development will be much impractical and tsunami disaster risk remains high. In this last case, other suitable countermeasure actions are required.

## 3.3 Issues concerning tsunami disaster risk reduction in developing countries

Despite the above mentioned encouraging development, there are typical issues that need urgent attention as follow:

- Low preparedness of community, especially on self-help and mutual support; [*note: description about “self-help” and “mutual support” is given in Chapter 3, Section 3.1, pp.10*]
- Low awareness of community on disaster, such as problems of law enforcement regarding settlement area along dangerous coastal zone
- Unavailability of structural countermeasure against tsunami and poor quality of residential houses
- Land use planning coordination among governmental institution and municipalities
- Some atoll countries, *e.g.* Maldives, require specific consideration related to structural countermeasure, for example regarding the land carrying capacity, flood drainage after tsunami, *etc.*


**Figure 3.4** New houses were reconstructed at one of the most destructed location by IOT 2004 at Uleuleu, Banda Aceh of Indonesia; red-arrow pointed out the location; the upper-right inzet shows the view of dykes protecting the area from coastal erosion.

Figure 3.4 shows a picture of many houses that were reconstructed at Uleuleu, Banda Aceh of Indonesia, one of most destructed areas by IOT 2004. Only about one meter height of rubble mound dykes protects the area from open-sea waves. Despite complex consideration underlying the decision of giving permission for reconstruction at this site, this may be an example of low awareness of community in the high potential danger of tsunami.

## 3.4 Direction of tsunami disaster countermeasure in developing countries

Based on the previously mentioned typical issues that need urgent attention, the direction of action development in the near future shall include the following activities.

(i) Education on tsunami disaster awareness ought to take emphasis on self-help and mutual support. These are including awareness on maintaining the existing structural countermeasure facilities and encouraging community efforts for the development of mitigation structures. THM will be very useful to provide information on the proneness of respective location as well as being an informative map to locate the required structural countermeasure.

Figure 3.5 shows several elementary and junior-high-school students put soil on the existing tsunami-embankment that was developed more than a hundred years ago at Hirokawa Town of Japan. This is an annual ceremony that is conducted to maintain people awareness on the tsunami danger as well as on the maintenance of existing structural countermeasure.

(ii) Government needs to adopt disaster-risk-reductive structures in the planning and design of infrastructure construction. Besides considering disaster mitigation functionality of new developed infrastructures (road, public service buildings, *etc.*), efforts should also be made to maintain historical sign related to tsunami disaster, such as development of tsunami pole (sign of tsunami inundation depth at certain locations), maintained signs of inundation depth on structures (mosque, temple, *etc.*), tsunami-drifted boat, ship or car, *etc.*

Figure 3.6 shows some examples of structures that are maintained to develop people awareness on the danger of tsunami.

(iii) Tsunamis must be counteracted by taking structural countermeasures up to certain external force levels (the design protection level). Forces exceeding the level are difficult to deal with only by structures, since they require a huge quantity of expense, and thus non-structural measures should be developed as well. Non-structural measures are effective even when external force levels are within the designed range.

**Figure 3.5** Several elementary and junior-high-school students put soil on the existing tsunami-embankment that was developed more than a hundred year ago at Hirokawa Town of Japan. This is an annual ceremony that is conducted to maintain people awareness on the tsunami danger as well as on the maintenance of existing structural countermeasure (*Source: Tanaka, 2008)*

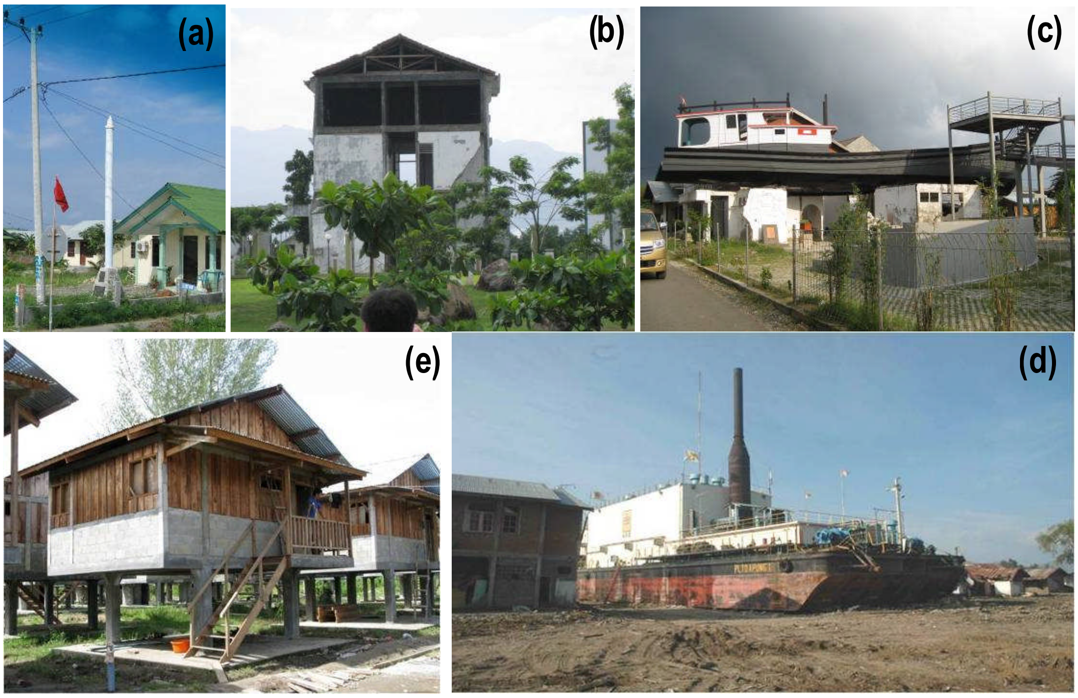



**Figure 3.6** Some examples of structures that are maintained to develop people awareness on the danger of tsunami; (a) tsunami pole as a sign of tsunami inundation depth; (b) hospital destroyed by tsunami, which is now functioned as a museum; (c) a monument of tsunami danger, an inland drifted boat by tsunami; (d) a 2km inland drifted electric-generator ship by tsunami; (e) elevated houses to mitigate tsunami flow.

(iv) The structural and non-structural measures for reducing disaster risks need to be coordinated to minimize the damage, improve the protection standards by constructing appropriate structures, enhance the self-defense capability of residents through non-structural measures (for example, sharing disaster prevention information), and, as a result, mitigate damage.

Figure 3.7 shows the schematic diagram of coordination between structural and non-structural measures for preventing disasters.

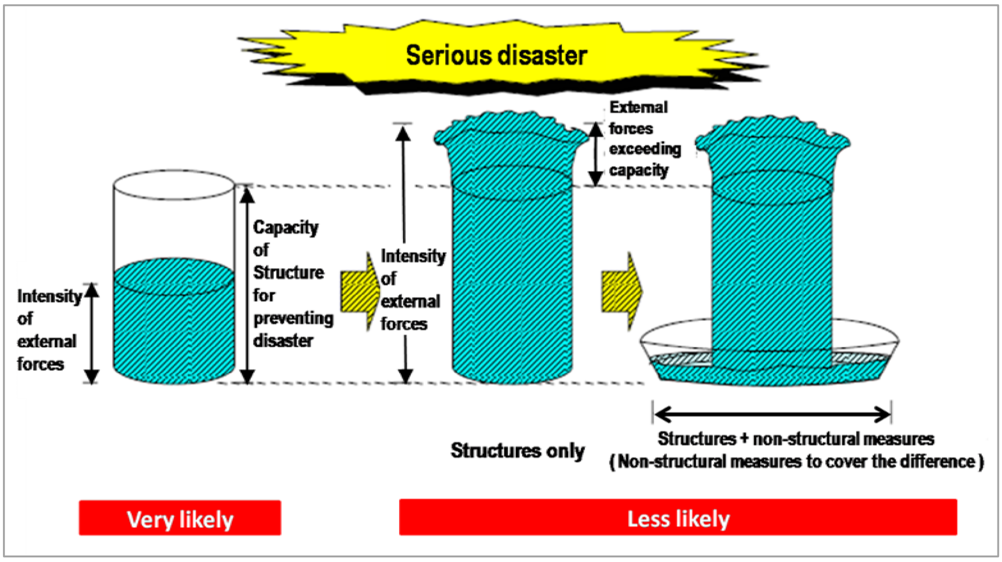



**Figure 3.7** Schematic diagram of coordination between structural and non-structural measures for preventing disasters (*Source: Japan Cabinet Office, 2004*)

## 3.5 Applications of coastal vegetation belts in comprehensive tsunami disaster countermeasure

### 3.5.1 The role and limitation of coastal vegetation belt in tsunami disaster countermeasure

Depending on the tsunami scale and vegetation belt characteristics, Shuto [1987] and Tanaka, *et al.* [2007] identified that the roles of coastal vegetation belt in tsunami disaster mitigation may include (i) trapping effect, *i.e.* stop driftwood (fallen trees, *etc.*), debris (destroyed houses, *etc.*) and other floatages (*e.g.* boat); (ii) energy dissipation effect, *i.e.* reduces water flow velocity, flow pressures and inundation water depth; (iii) soft-landing effect, *i.e.* provide a life-saving means by catching persons carried-off by tsunamis and enable them landed on tree branches; and (iv) escaping effect, *i.e.* provide "a way" of escape by climbing trees. Additionally, in coastal area with high supply of sandy sediment materials, the existence of coastal vegetation belt may collect wind-blown sands and raise dunes, which eventually act as a natural barrier against tsunami. These benefits have attracted many communities to develop such a tsunami-mitigative vegetation belt in their relevant area.

However, it should be kept in mind that all post tsunami disaster investigation results have also shown that coastal vegetation belt posed none mitigation effects for tsunami inundation greater than 5m, *e.g.* [Shuto, 1987], [Tanaka, *et al.*, 2006,2007]. Thus, for area with tsunami hazard potential of inundation depth greater than 5m, coastal vegetation belt would provide no protection at all. In such cases coastal vegetation belt may be used as a supplement to the main protection structure such as seawall *etc.* It should be emphasized too that even for tsunami inundation less than 5m coastal vegetation belt never provide a hundred percent protection. Therefore, depends on the necessity, combination with other type of mitigation measures is very important to ensure higher level of disaster risk reduction.

### 3.5.2 Applications of coastal vegetation belts under the constraints of land space, coastal morphology and vegetation type

The present knowledge on the significant factors involved in tsunami and coastal vegetation belt interaction enable systematic planning and design procedure. However, in practice, the space availability for coastal vegetation belt as well as local social conditions may hamper its successful application. Apart from these, coastal morphology (*e.g.* sandy beach, wetland, delta, *etc.*) should be considered too as it restricts the types of vegetation at the location.

Space availability is usually limited by the existing dense residential houses nearby the coastline or by narrow beach topography. Most coastal areas in the countries around Indian Ocean are plain with mild slope in average, *e.g.* [Bird, E.C.F. and Ongkosongo, S.R., 1980]. More than half of Asian people live in the coastal zone [Yu, 2007]. Most of the tsunami vulnerable coastal areas are occupied for the settlements and have been developing for various purposes (industry, urban and residential development, tourism and recreation, transport, fisheries and agriculture) which left only limited space remained between the land and the sea.

Local social conditions include livelihood, poverty, socio-natural interaction, *etc.* These social conditions highly affect the residents' awareness on the coastal forest sustainability. Sustainability of coastal forest is very important to ensure its continuous mitigation function against tsunami disaster. Forest maintenance is a challenging matter, especially in many developing countries where coastal forest resources are highly demanded to support the daily life of local people [Sukardjo (2002)].

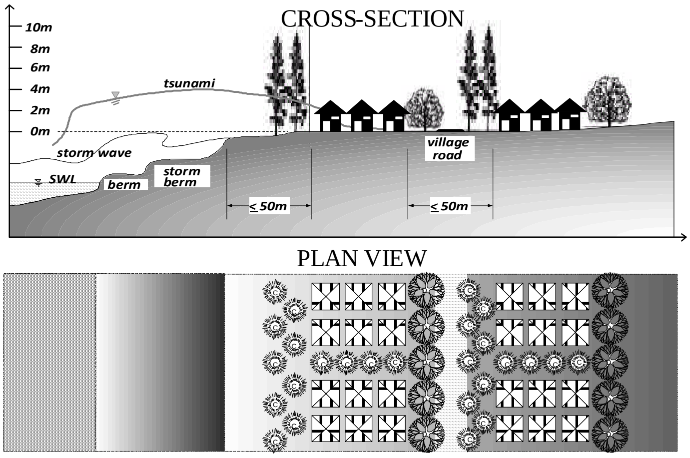
Type of vegetation in the concerned area or its nearby coast is important datum to identify the site suitability of coastal vegetation belt implementation. This datum would also give initial picture on the possible level of mitigation given by the belt. Type of vegetation is usually specific to local coastal morphology. Mangroves-type vegetations are specifically dominant in wetland areas, whereas in sandy beach area various hard trunk type of vegetations exist and grown in combination.

On the above consideration, the availability of wide-land space along the coastline for coastal vegetation plantation should be clearly confirmed. However, merely to trap small debris floatages (small boats, cars, wooden bars, *etc.*), 20m-width of coastal forests with total summed-diameter (basal area) of 30nr.cm have been empirically proven to provide the least protection against tsunami [Shuto, 1987]. Base on this knowledge, several ideas on the potential application of coastal forest in combination with other structures may be done. One of possibility is by including tsunami protection design in the coastal area infrastructure development plan. Functioning coastal rural road as tsunami flow reduction in combination with coastal forest is a possible alternative. The combination between coastal forest and coastal rural road or community based developed levee is expected to reduce tsunami propagation time to provide relative longer time for evacuation to the higher ground behind.

In coastal area where economically reliable for aqua farming, coastal vegetation belt design that accommodates both functions of short term economic benefit and long term tsunami disaster mitigation is highly demanded. Smart combination of coastal vegetation belt and aqua farm should be considered. Coastal vegetation belt-line and aqua farming-line may be arranged in parallel like mangrove forest area with several lines of creeks inside. Tanaka *et al.* [2007] reported field investigation facts that broken branches and trees accumulated in the creek behind the forest after tsunami aftermath. However, further scientific investigation is necessary to examine the effectiveness of such a coastal forest design.

Table 3.1 shows the illustrations of each application idea (Istiyanto *et al.*, 2008).

Table 3.1 Ideas on the potential application of coastal forest in combination with other structures (Istiyanto *et al.*, 2008)




**Constraint**

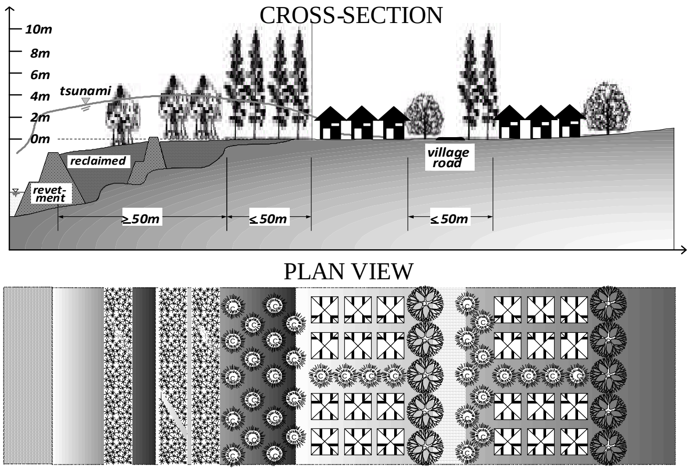
- Residential housing occupy most of land nearby coastline;
- very limited space for vegetation;

**Function and vegetation-type**

- The least function;
- Floatage trapping and escaping means;
- Hard-trunk vegetations

**Position and dimension**

- Coastline; surrounding houses; between blocks;
- 20m-width; *dn*=30;




**Constraint**

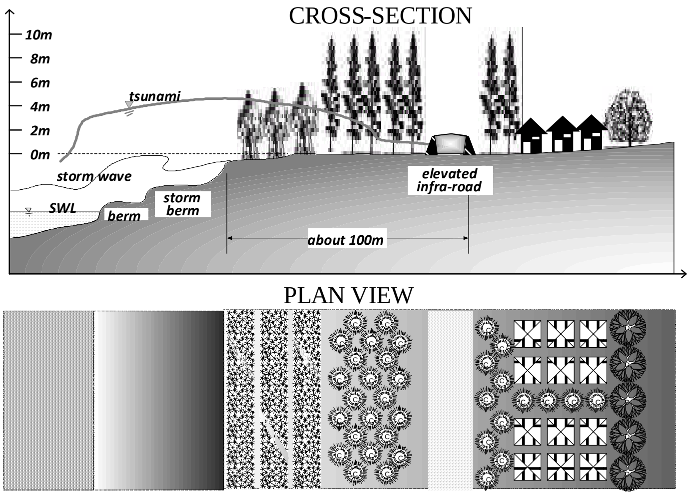
- Residential housing occupy most of land nearby coastline;
- very limited space for vegetation;

**Function and vegetation-type**

- Floatage trapping and flow reduction;
- Combination of hard-trunk and flexible vegetation (Pandanus, *etc.*)

**Position and dimension**

- Beach reclamation;
- width ≥50m; *dn* >200;




**Constraint**

- Limited space are available (100m)
- partially are used for infra-road

**Function and vegetation-type**

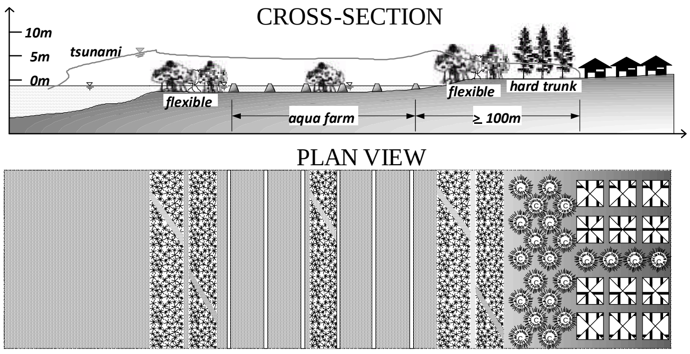
- Floatage trapping and small flow reduction;
- Combination of hard-trunk and flexible vegetation (Pandanus, *etc.*);
- road is functioned as flow breaker

**Position and dimension**

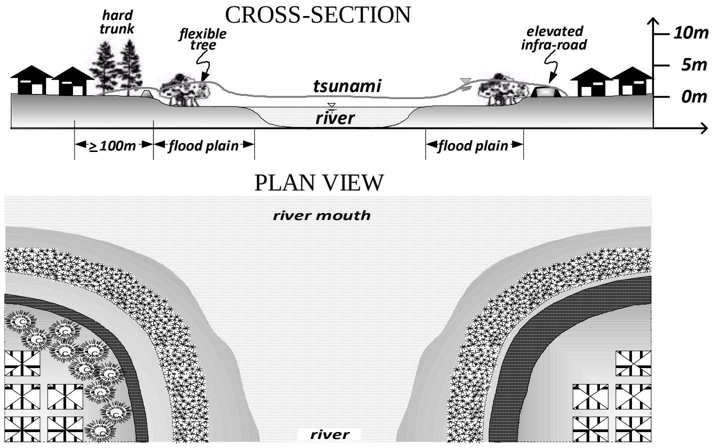
- Between coastline and the road
- width ≤50m; *dn* >200;

*(continued)*

Table 3.1 Ideas on the potential application of coastal forest in combination with other structures (Istiyanto *et al.*, 2008) (continuation)




| | |
|---|---|
| **Constraint** | ▪ The land is occupied by aqua farming |
| **Function and vegetation-type** | ▪ Floatage trapping and flow reduction;<br>▪ Two layers of forest, mangrove at the front and Pandanus at the inland |
| **Position and dimension** | ▪ Marsh and tidal area and inland beach;<br>▪ width ≤50m; *dn* >400; |




| | |
|---|---|
| **Constraint** | ▪ River mouth and flood plain along river; |
| **Function and vegetation-type** | ▪ Floatage trapping and flow reduction;<br>▪ Mangrove |
| **Position and dimension** | ▪ Marsh and tidal area; flood plain area<br>▪ width ≤50m; *dn* >200; |

### 3.5.3 Tsunami hazard map and awareness development in the implementation of coastal vegetation belt

Implementation time of coastal vegetation belt for tsunami disaster mitigation needs at least 5 to 10 years to get the vegetation grown up well to reach its expected dimension. Further, maintenance of vegetation belt for its function sustainability needs continuous and consistent management. Without awareness of all stakeholders, this implementation will not be successfully effective.

The awareness would never be developed without consciousness on the importance of the matter. The consciousness would never be developed without correct understanding on the danger of tsunami. Thus, awareness development should be started since the beginning process of tsunami disaster management planning by educating stakeholders in charge. In this relation, utilization of THM can be further explored.

The awareness of the community can be developed if all stakeholders are involved in the planning process to express and discuss their opinions toward conclusion. It is started when stakeholders meet to identify potential tsunami hazard in their locality by referring to the available THM. The meeting will identify locations and points which are potentially have high disaster and discuss the possible countermeasure to reduce the risk. Once the requirement of coastal vegetation belt is agreed, suitable type of vegetation will be determined after hearing an expert suggestion. During this meeting, management of vegetation belt should also be discussed and the roles of each stakeholder must be clearly understood and agreed.

Several experiences show that sustainability of coastal vegetation belt will be better if the local community in the vegetation belt area is the main implementing actor with strengthen organization and resource-use rights under regulation endorsed by all stakeholders, *e.g.* Smith and Berkes (1993).

# 4. Role of Tsunami Hazard Map in Sustainable Tsunami Disaster Risk Reduction

Sustainable tsunami disaster risk reduction measures are necessary since tsunami is usually a low frequency but highly hazardous for the prone area. Its long recurrence period of a hundred to several hundred years make it naturally to be unawared by the next generations who never experience it.

To develop sustainable tsunami disaster risk reduction, sustainable awareness and preparedness are very important since disaster always come when we forgot about it.

Developing continual risk communication among stakeholders is an important action to maintain sustainable awareness and preparedness to construct strong society against disaster. In this regard, tsunami hazard map (THM) shall be considered as one of effective medium for communicating tsunami risk.

The development of THM became one of indispensable measure along with the development of tsunami disaster mitigation in most of tsunami hazard prone areas. It is a basic requirement for the development of measurable tsunami disaster mitigation planning.

## 4.1 The role of THM in achieving targets of key-issues of tsunami disaster risk reduction

Five issues that shall be considered as key issues in tsunami disaster risk reduction include conducting mitigation efforts before the society forget or become not serious; precise knowledge on the danger of tsunami hazard; immediate evacuation as priority response; assets protection as important as life protection; and society participatory and awareness. These key-issues and their related target will be described in the following paragraphs, including description about possible role of THM in achieving the target. Figure 4.1 shows the diagram of key-issues, their respective target and the role of THM in achieving targets of key-issues of tsunami disaster risk reduction.

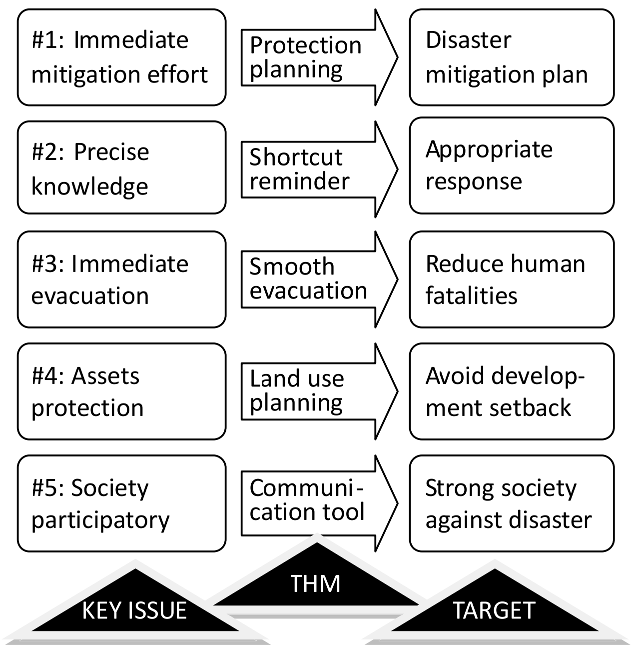



**Figure 4.1** The role of THM in achieving target of key-issues of tsunami disaster risk reduction.

**Issue#1**: Maintaining awareness and enhancing preparedness for those who never experience the disaster are challenging things. Palm (1990) and Palm (1995) (in Kuhnreuther, 2006) showed (from their survey related to earthquake insurance) that insurance purchase is unrelated to any measure of seismic risk that is likely to be familiar to homeowners. Rather experience plays a key role in insurance purchase decisions. Learn from this research conclusion, we may set strategy of conducting intensive and extensive tsunami mitigation efforts immediately before the society (government, community, and individuals) forgot or became not serious about the disaster. This is the prime period to develop effective preparedness within the society. Working with those who experienced tsunami disaster, for example in convincing people about the danger of tsunami and listing necessary countermeasure will be very effective.

**Issue#2**: Precise knowledge and understanding on the danger of tsunami hazard is very important to increase people awareness on tsunami disaster and taking appropriate preparedness. Without accurate understanding on the tsunami danger, proper response will never be actually implemented. In fact, only those who experienced tsunami disaster can really understand the danger of tsunami. Videos, pictures, or any facts about disaster that can well illustrate the tsunami danger must be systematically disseminated to the society. Brief information about various tsunami dangers on part of THM shall play as a shortcut reminder and possible to encourage people to learn more about the matter.

**Issue#3**: Despite availability of structural countermeasure, immediate evacuation action is a priority response in tsunami disaster risk reduction. It should be borne in mind that tsunami hazard always has possibility to be much stronger than the designed condition of structural countermeasure. In this relation, THM can be used by the society to develop familiarity with their disaster related environment towards smooth evacuation action.

**Issue#4**: Further, it should be emphasized that life protection only is not enough. We should think assets protection during disaster is as important as life protection. Huge assets damage has significant economical impact especially for the developing countries. It may setback the development progress. Serious efforts have to be done to reduce assets destruction by tsunami hazard. Solution may be different for each locality. It is not necessarily to be tsunami seawall or breakwater. Land use management is also a good way of reducing economic loss due to disaster. In this regard, stakeholders may use THM in communicating land use planning under the frame of tsunami disaster mitigation. Setting structural countermeasures can be communicated as well by using THM.

**Issue#5**: Society participatory and awareness is another important issue in tsunami disaster risk reduction. It means that mitigation initiative and awareness should come from all components of the society. Society component's contributions and responsibilities in disaster mitigation must be formulated well in the disaster mitigation strategy. Japan, for example, uses concepts of self-help, mutual support and public assistance as key concepts in disaster mitigation strategy. These key concepts represent different perspectives in terms of disaster mitigation strategies. “Self-help” is related to the public, whereby each individual protects him/herself. “Mutual support” is related to friends, neighbors, voluntary disaster management organizations and communities, whereby such groups of people protect their own communities among themselves. Finally, “public assistance” is related to administrative bodies at the national to local levels, whereby administrative organizations conduct disaster mitigation strategies, including the construction of disaster mitigation structures and the organization of disaster mitigation systems (Tanaka, 2008). Figure 4.2 shows the conceptual image of correlation among self-help, mutual support and public assistance (Tanaka, 2008).

The Japan government encourages and eases the development of community based THM by each locality. At the same time, they use THM as one of tsunami disaster risk communication tool. For this purpose the government published manual.

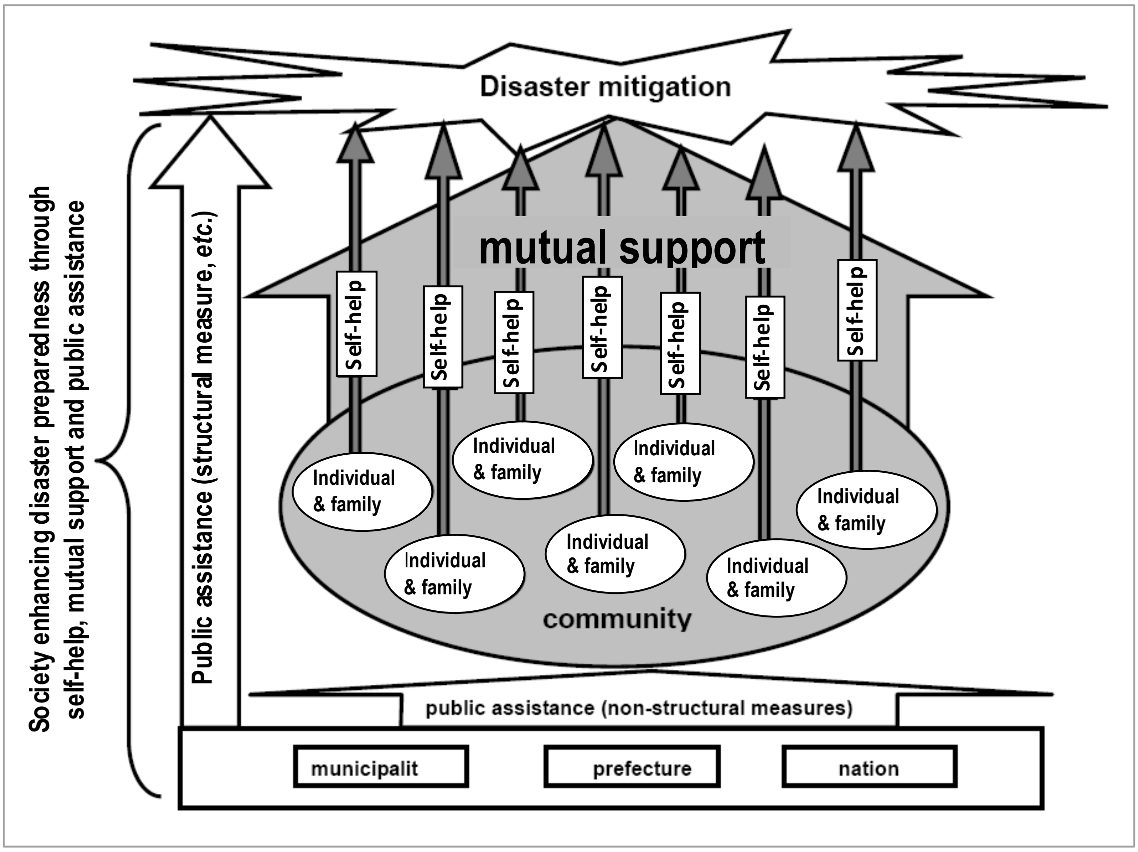



**Figure 4.2** Conceptual image of correlation among self-help, mutual support and public assistance (*Tanaka, 2008*)

## 4.2 Practical use of THM

### 4.2.1 The form and usage of THM in general

Japan Tsunami and Storm Surge Hazard Maps Manual describes that THM shows areas on which inundation is expected, the degree of inundation and, when necessary, disaster prevention information, such as evacuation sites and routes (Japan Cabinet Office, 2004).

Among presently available THM, they can be identified in three ways, *i.e.* according to its spatial coverage, according to its contents, and according to its utilization purposes.

According to its spatial coverage, there are national and local THM. A national THM, which shows spatial distribution of tsunami hazard level over the country, is found *e.g.* for Indonesian case. See Figure 4.3. For a very wide archipelago country with high potential of tsunami hazard over the area such a map is very useful especially for set up of spatial-prioritization of disaster countermeasure action and set up of local-region disaster response center, *etc.* Among various available versions of such a map, the central government should determine a single reference map on which any related disaster management decision must be based on.

A local THM, which shows tsunami inundation both in horizontal and vertical directions, is a basic requirement for the development of local tsunami disaster mitigation planning. According to its contents, there are two types of local THM. The first is that contains only inundation information and the second is the first type plus evacuation routes and evacuation locations. In Japan, both types are

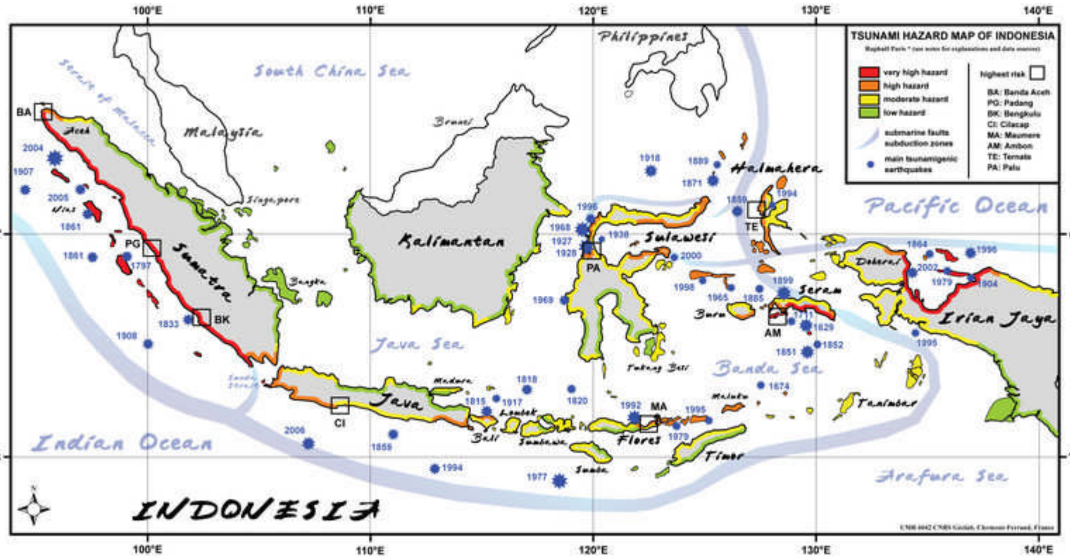



**Figure 4.3** Indonesian THM, an example of a national tsunami hazard map (*Paris, 2007*)

named as tsunami hazard map, while in the USA the first type is named as tsunami hazard map, while in the USA the first type is named as tsunami hazard map and the second type is tsunami evacuation map.

According to its utilization purposes, two different types of THM are available. "Hazard map for residents" should be used by residents for evacuation planning (before disaster), while "hazard map for administrators" should be used by administrative bodies to investigate disaster prevention measures. Typical difference between these two types of THM can be learned from Table 4.1, which shows the summary of users and utilization purpose of tsunami and storm surge hazard map in Japan (Japan Cabinet Office, 2004).

Table 4.1 Users of tsunami and storm surge maps and utilization purpose at each stage of disaster (Source: Tsunami and Storm Surge Hazard Map Manual, Japan Cabinet Office, 2004)

| Stage of disaster | Users | Utilization purpose |
|---|---|---|
| Before disaster | Residents | Collect information for evacuation activities, and learn about disasters and the region (land use, *etc.*) |
| | Administrators | Draw up and execute preventive measures (by constructing evacuation sites and disaster prevention facilities) |
| Immediately before disaster | Residents | Collect information about tsunami or storm surge (such as the height of high tides) and evacuation sites |
| | Administrators | Draw up and execute emergency measures (evacuation plans, rescue plans, *etc.*) |
| After disaster | Residents | Collect information after evacuation (orders from municipal governments, *etc.*) |
| | Administrators | Draw up and execute emergency measures (evacuation and rescue plans) |

Figure 4.4 shows an example of local tsunami hazard map in Japan, the case of Kesennuma City of Miyagi Prefecture. This map contains information on predicted (pre-calculated) tsunami inundation depth as well as predicted arrival time based on a certain tsunami design scenario, evacuation location and evacuation direction. Since this map seems to be prepared for the residents, important educative

information are added including the characteristics of tsunami disaster, correct response to tsunami disaster, flow disaster alert.

In Japan, THM developments follow the manual provided by the government (refer to Chapter 5). THM is prepared by municipality offices such as city and town, printed usually on an A3, A2 or A1 size of papers and distributed freely to all residents in the related area. Several municipalities have made THM to be easily gained and free downloaded by the citizens through internet. For smaller local level like town or village, the community developed their own THM on the map provided by municipality. After several consultations, THM is printed by municipality and distributed to all households in the area. Figure 4.5 shows an example of a THM made by local residents at a part of Tanohata village in Sanriku Area, Japan.

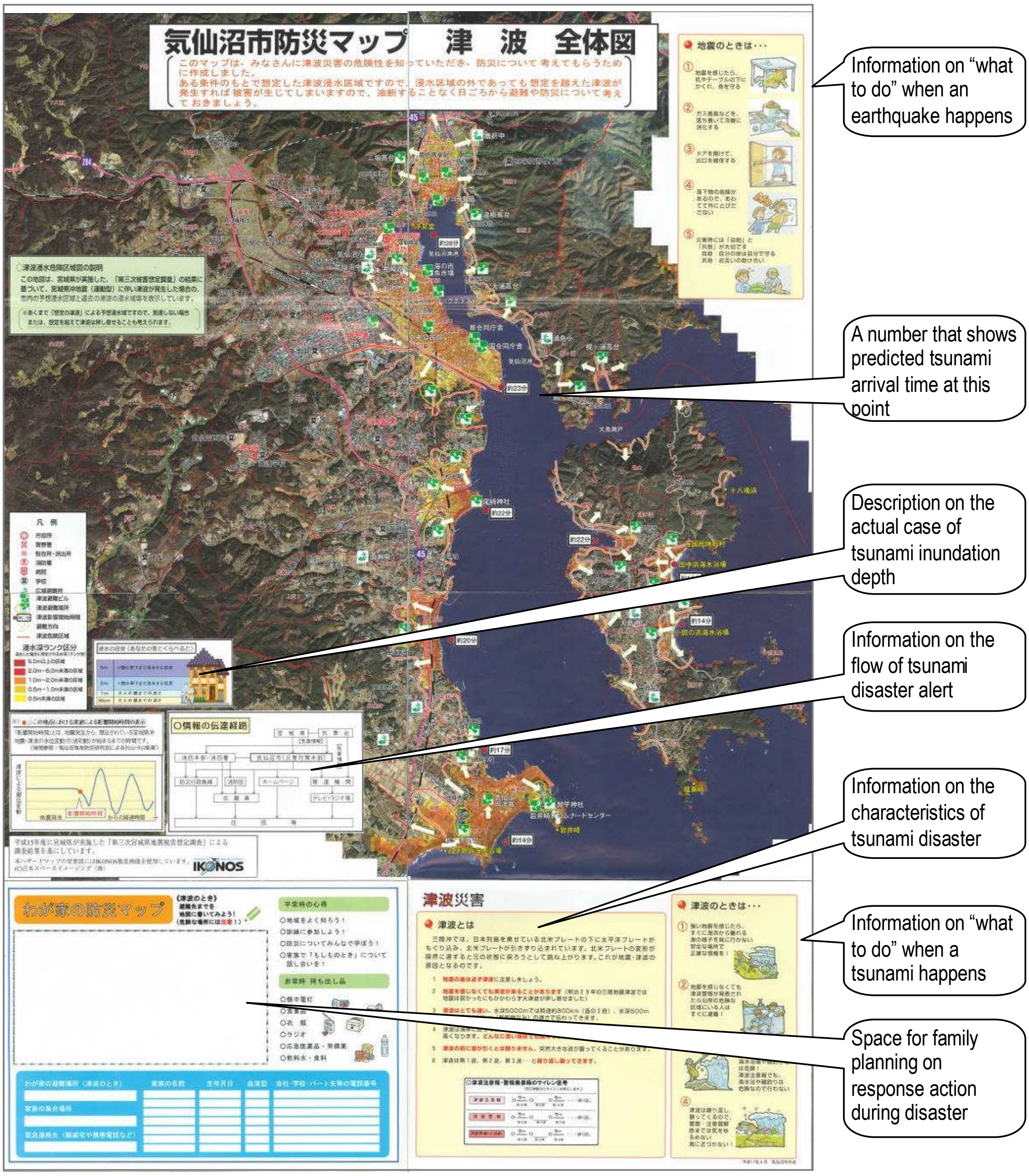



**Figure 4.4** An example of local tsunami hazard map in Japan, the case of Kesennuma City, Miyagi Prefecture (*Kesennuma City, 2005*)

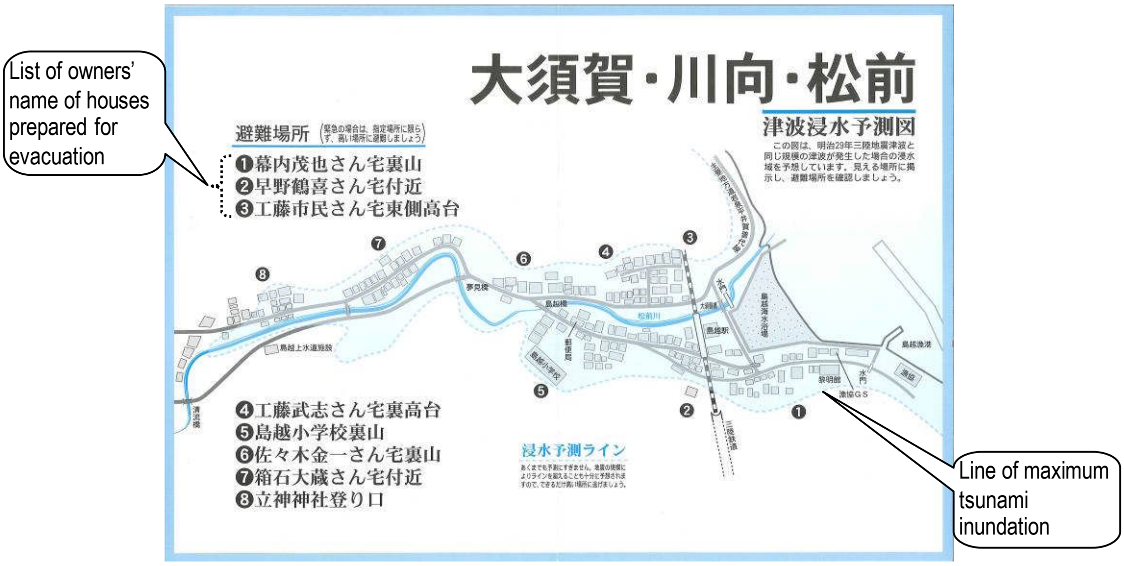



**Figure 4.5** An example of a THM made by local residents of Tanohata village (Oosaku, Kawamukai and Matsumae area) in Sanriku Area of Japan (*Iwate-ken, 2007*)

THM in Figure 4.5 contains only three contents of information, *i.e.* tsunami inundation line, location of residents' houses and location of houses for evacuation during tsunami. The houses for evacuation are numbered and the house owner names are listed respectively. No evacuation route directions are necessary since the residents are fully familiar with their local environment. This map is very simple but very much significant in developing tsunami disaster awareness.

In the USA, tsunami inundation map is prepared locally by each state government in cooperation with NOAA-FEMA-USGS. Base on the available inundation map, municipalities developed their local tsunami evacuation map. These maps are also easily seen through the internet, but not always freely downloadable.

After IOT 2004, development of THM is going on in several countries surrounding Indian Ocean. In Indonesia, the national government produces an Indonesian Tsunami Hazard Map to show the tsunami prone level of any areas entire the country. At the same time, local municipalities (city or regency) prepare tsunami inundation map as well as tsunami evacuation map of their area. Tsunami evacuation map, which shows inundated areas, the degree of inundation and evacuation sites and routes is printed in limited numbers and put up in the community publication boards. In Sri Lanka, THM contains information of tsunami inundation over City level (Wijetunge, 2007), while maps of tsunami evacuation plan is made separately in more detail scale of smaller area, which show the evacuation route only (Bandara *et al.*, 2008). Similar types of THM are under development in many other tsunami-prone countries. Figure 4.6 shows examples of local THM as well as tsunami evacuation map in Indonesia and Sri Lanka.

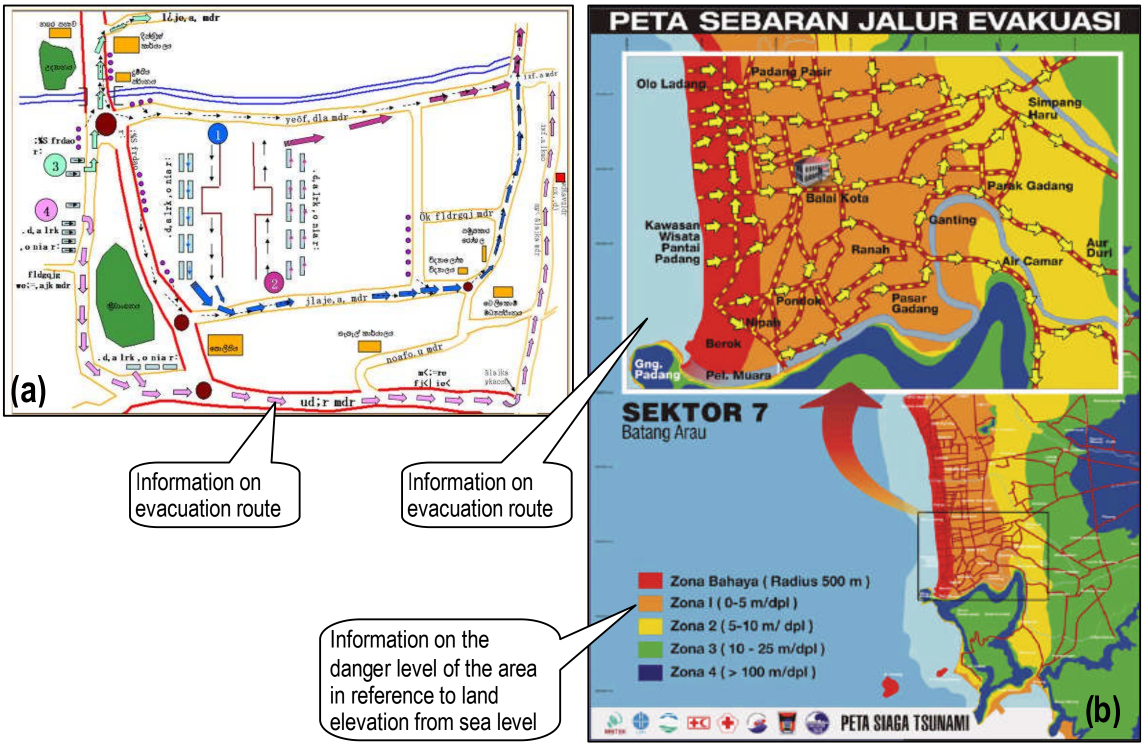



**Figure 4.6** (a) An example of tsunami evacuation map developed by local community at Sri Lanka; (b) an example of tsunami hazard and evacuation map in Indonesia, the case of Padang City.
(*Source: Trainee's Country Reports, Comprehensive Tsunami Training, ICHARM, 2008)*

### 4.2.2 THM as a reference tool and connecting people in tsunami disaster mitigation actions

It is previously mentioned that THM is a tool to ease tsunami disaster mitigation. It is part of proactive measures in disaster mitigation cycle that enable the society be well prepared before the disaster.

In the formulation of mitigation measures, participation and coordination among the government, communities, and individuals are indispensable. In this relation, THM shall be an useful medium to draw the attention and communicate the hazard potential by which all stakeholders have conformity on it and share the idea on action of minimizing the potential disasters.

Since tsunami hazard is a long term recurrence hazard whose occurrence tends to be misawared along with the passing of time, the availability of THM could also be used as a tool to recall people awareness on tsunami hazard and its disaster potential in their area. For example, in regular period, the municipality should publish progress report on tsunami disaster countermeasure planning and activities along with the distribution of recent stage of land use map in correlation with tsunami disaster prevention.

Again, if we look at Table 4.1, THM utilizations are actually necessary in all disaster stages (before, during, as well as after disaster). Even, several more functions can be added into Table 4.1. For example, in the stage of before disaster, the administrator shall also use THM for increasing people awareness on the importance of making immediate evacuation at the first chance. Also, after disaster stage, THM can be by the residents to confirm the recovery and rehabilitation measures with the government or to collect information on the future land use planning. On the opposite, the administrator can use THM at this stage to draw up recovery and rehabilitation planning and measures according to the situation after disaster as well as to draw up future land use planning.

In reference to Table 2.4 in Chapter 2, the potential countermeasures are various but unique for each case. They include non-structural and structural countermeasures as well. In practice, planning of comprehensive countermeasures need intensive and extensive communication and coordination among stakeholders.

In the above relation, there is a demand on a medium or a reference tool by which stakeholders can cooperatively discuss the most appropriate countermeasures for their localities based on accurate information of potential hazard. By using THM, the following topics can be communicated among stakeholders:

(1) Identification of potential tsunami inundation (water depth as well as inland penetration reach)
(2) Planning of necessary structural countermeasure (where, what and how)
(3) Disaster safer land use planning and management (residential relocation, buffer zone)
(4) Emergency plan in a tsunami disaster event
(5) Public education on the danger of tsunami
(6) Coordinating measures related to other potential disaster in the respective area (development of multi-hazard map)

Figure 4.7 shows the illustration of THM role as a medium or reference tool for stakeholders to communicate and plan comprehensive tsunami disaster countermeasure.

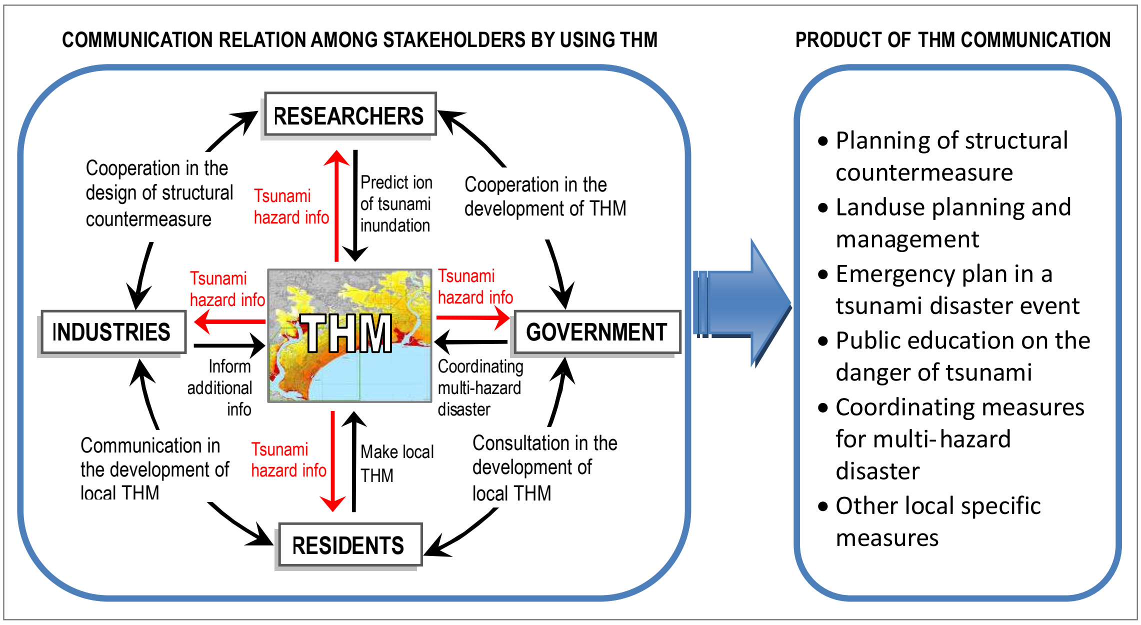



**Figure 4.7** Illustration of THM role as a medium or reference tool for stakeholders to communicate and plan a comprehensive tsunami disaster countermeasure; (*the THM picture is courtesy to Cilacap municipality, 2009*)

### 4.2.3 Effective dissemination of THM

In conclusion, THM plays an important role in all stages of tsunami disaster mitigation. However, THM will have no great influence if it is just treated as an end product, especially if it is produced in one way direction, from the government to the citizens. The important thing is how to make people are connected one another by THM and feel necessary to use the information available in the map. People here are not only the residents but include all society members, including private sectors as well as government. In this regard, thematic THM based on the stakeholders' requirement will be necessary rather than uniform single THM.

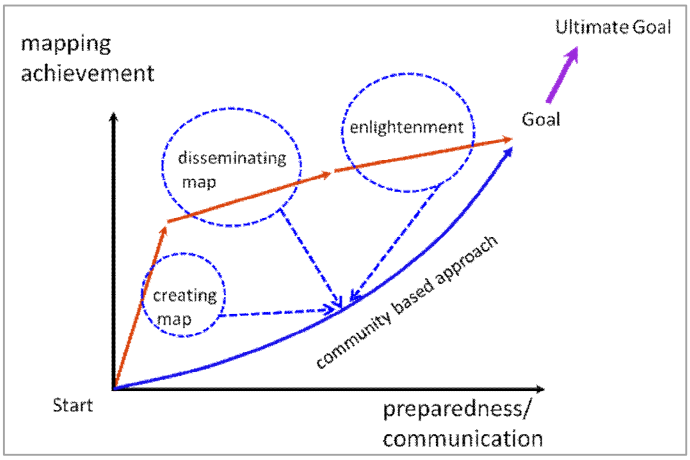



**Figure 4.8** Diagram of tsunami hazard map development paths; the red-arrow path is THM development without active involvement of communities, whereas the blue arrow is THM development with the involvement of community since the initial stage (*Tanaka, 2008*)

At this point, it shall be considered that the best way of getting the goal of THM is by involving the communities since the initial stage of THM development. Figure 4.8 shows diagram illustrating two paths of THM development. The red-arrow path is THM development without active involvement of communities, whereas the blue arrow is THM development with the involvement of community from the initial stage.

By following the red-arrow path, the government or municipality shall develop THM fast and efficiently in time. However, processes of dissemination and enlightenment need longer time and open possibility of low awareness since people passively receive an end-product. On the contrary, involvement of community from the initial stage of THM development will do all aspects of map creation, dissemination and people enlightenment in one inclusive process, which eventually develop self-belonging and better achievement in developing sustainable preparedness and awareness of the community.

By such a way, THM is a reference tool for mitigating tsunami disaster mainly in a self supportive and mutually supportive manner, and to help administrative bodies to draw up evacuation plans, provide education on disaster prevention, increase public awareness of disaster prevention, construct strong communities against disasters, and enhance communication with residents regarding disaster risks (Japan Cabinet Office, 2004).

4.2.4 Town watching: an effective way of developing community awareness by using THM

During the development of local THM, local specific information is necessarily added to the basic inundation risk area map. Because “necessary information” depends on area and the size of tsunami hazard maps is limited, the information should be selected to meet effectively local residents' needs. To select such information, it is essential to collect many types of information concerning the target area: for example, residents' awareness levels of tsunami disasters, the status of the area's infrastructures, potentially dangerous sites that cannot be identified using inundation risk area maps, opposition to the public release of detailed tsunami-related information, *etc.* Producing tsunami hazard maps based on such information will be considered useful by local residents and will definitely promote their wide use.

On the above relation, “Town Watching” is considered a good way to involve the community in the process of THM development while at the same time developing their knowledge capacity and awareness. During town watching participants will be given the basic inundation risk area map and conduct on-site surveys in groups, walking around the target areas and checking places thoroughly. The collected information includes the appropriate locations for evacuation sites (easy accessibility, potentially dangerous places to the evacuation sites, reasonable environments for refugees, *etc.*), required facilities to communicate disaster-related information to residents (signs of directions to evacuation sites, night light, speakers and bulletin boards to inform residents on tsunami information, other communication tools to help residents' easy access to necessary information, *etc.*), type and location of structural countermeasure (levees, gates, evacuation buildings, *etc.*). Base on the survey findings, the participants will discuss to get conclusion about what and which information is necessary. The necessary information is then added to the basic inundation risk map and accordingly a local unique THM that meets local residents' need can be produced by municipality to be distributed back to the residents.

Figure 4.9 shows an illustration of town watching activities.

**Figure 4.9** Illustration of "town watching" activities, conducted by a group of tsunami training course participants. (Left) in reference to the inundation risk area map, the participants watching around the area situation and identifying specific information. (Mid) the collected information is plotted on the map. (Right) the results of identification are presented and discussed. The final conclusion was conveyed to the disaster management office of the municipality.

## 4.3 Ineffective utilization of THM

THM will be less useful if:

THM is distributed only once forever. Actually, THM must be regularly "updated" and distributed to the society as a reminder. Even if only very small updates are conducted, distribution of new "updated" THM is very valuable to refresh the community awareness on tsunami hazard potential in their area.

The THM users tend to think that inundation information is fixed and exactly as it is shown in the map. This will mislead the users by thinking of do nothing if they note their housing area is outside the inundation limit. This way of thinking is very dangerous, especially those who are living very near the inundation limit. It should be clearly communicated to the society members that inundation map is determined based on several approximations due to the present stage of lack understanding on the complete tsunami generation as well as its coastal inundation. It means hundreds meter distance from the shown inundation limit never guarantee the exact safety level. People in this area should put in their mind that, at the present stage, the inundation information should be considered as lower bound and immediate evacuation is still the best way to safe life from unpredictable disaster.

THM is not well communicated (or merely distributed) to the whole community. Even if THM is distributed extensively to the community, but without appropriate communication about its function and utilization, THM will be put aside at each home of residents with no meaning.

THM is not integrated into tsunami disaster management and development planning as a whole. The residents will get positive impression on THM if they know that tsunami hazard information were well considered and adopted in the development planning of their city, such as in the policy of land use planning, *etc.* This will motivate them to consider the importance of THM in their community life.

# 5. Introduction of Japan Tsunami Hazard Map Manual and Important Points Regarding Its Adoption for Developing Countries

Contents of this chapter are mainly summary of Japan Tsunami and Storm Surge Hazard Map Manual (Japan Cabinet Office, 2004). The objective of providing this chapter is to give a brief outline about development of THM in Japan, structure of Japan THM manual and to discuss potential adoption of this Manual and important notes for its adoption in developing countries.

## 5.1 Background of THM manual development in Japan

In Japan, conventional disaster prevention measures, which mainly rely on structural countermeasure, such as tsunami breakwater, dyke, *etc.* have sharply reduced damage by tsunamis. However, the level of coastal safety is still insufficient. Even districts where facilities to counter tsunamis are completed may still suffer damage when the levels of tsunamis exceed the assumed levels, and may not be always safe. Recent technology has improved prediction accuracy and has revealed that external forces exceeding the present protection level can possibly occur, and may thus cause tsunami damage.

While the urgency and importance of disaster prevention during tsunamis are recognized, there are three issues to be resolved in disaster prevention during tsunamis in coastal areas: 1) reduced self-defensive capability of residents due to lack of awareness, 2) coastal characteristics prone to disasters, and 3) difficulty of identifying areas that need evacuation.

Considering the above mentioned situations, the Japan Government determined that disaster prevention measures against tsunamis should include education for residents, providing and sharing information, and enhancing cooperation and measures for mitigating damage. Or, in other word, tsunamis must be counteracted by taking structural measures up to certain external force levels (the design protection level). Forces exceeding the level are difficult to deal with only by structures, since they require a huge quantity of expense, and thus non-structural measures should be developed as well. Non-structural measures are effective even when external force levels are within the designed range.

The structural and non-structural measures for preventing disasters need to be coordinated to minimize the damage, improve the protection standards by constructing appropriate structures, enhance the self-defense capability of residents through non-structural measures (for example, sharing disaster prevention information),and, as a result, mitigate damage.

Tsunami hazard map is a tool for mitigating damage during tsunamis, mainly in a self supportive and mutually supportive manner, and to help administrative bodies to draw up evacuation plans, provide education on disaster prevention, increase public awareness of disaster prevention, construct strong communities against disasters, and enhance communication with residents regarding risks.

In tsunami disaster prevention, tsunami hazard map functions as a non-structural measure for enhancing the self defensive capability and evacuation activities of residents, and as structural measures for supporting the investigation of what facilities to construct to improve protection levels.

Despite availability of evidences that tsunami hazard map is an effective evacuation measure and various attempts have been made to prepare hazard maps for tsunamis, preparation of hazard maps that cover the entire country is at a standstill. This is probably because of:

(1) the staffs of municipal governments in charge of disaster prevention and preparing hazard maps have no clear concept of tsunami hazard maps,
(2) the staffs have no understanding of for whom tsunami hazard maps are to be prepared, nor how to use such maps, and
(3) preparation of tsunami and storm surge hazard maps is technically difficult and expensive.

In this relation the Japan Government developed a manual to promote preparation of tsunami hazard maps and to help people in charge of preparation by providing information on:

(1) basic concepts of tsunami hazard maps, such as the purposes of preparation, role allotment (support from national and prefectural governments), and utilization policies, and
(2) standard methods for preparing tsunami hazard maps, such as methods for identifying inundation risk areas, determining details to be stated on the maps, expressing those details, and using the maps.

The manual helps in preparing and using tsunami hazard maps and shows essential points of technological systems and utilization methods.

## 5.2 Outline of Japan THM Manual contents

The Japan THM Manual is in one package with storm surge hazard map manual. It consists of the main chapters (1-5) and references. The main chapters summarize the basic concepts of significance and methods for preparing and using tsunami and storm surge hazard maps. The references describe recommended methods for predicting inundation to prepare tsunami and storm surge hazard maps and examples of using such hazard maps. As an illustration, Figure 5.1 shows the organization of the Manual, whereas Table 5.1 shows the Manual table of contents.

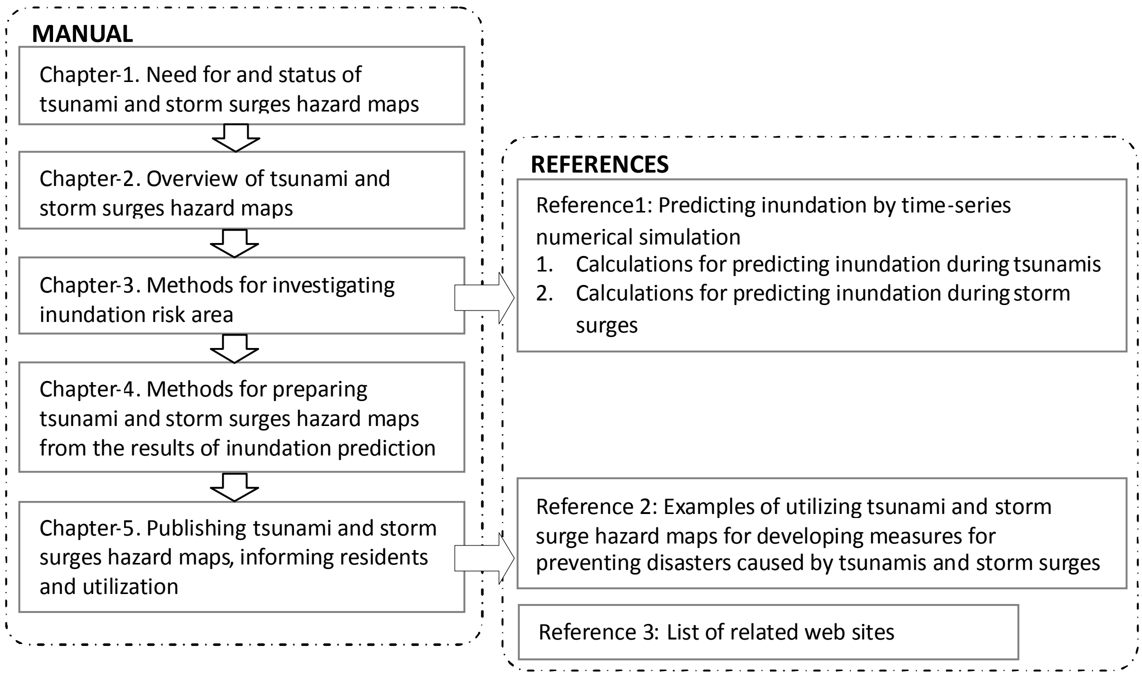



**Figure 5.1** Organizations of the Japan Tsunami and Storm Surge Hazard Maps Manual (*Japan Cabinet Office, 2004*)

Table 5.1 Japan Tsunami and Storm Surge Hazard Maps Manual - Table of Contents (*JCO, 2004*)

- **Introduction**
- **Chapter 1** Need for and roles of tsunami and storm surge hazard maps
  - 1.1 Present state of measures for preventing disasters caused by tsunamis and storm surges
  - 1.2 Issues concerning disaster prevention measures against tsunamis and storm surges
  - 1.3 Direction of development of measures to prevent disasters caused by tsunamis and storm surges
  - 1.4 Roles of hazard maps as a measure for preventing disasters by tsunamis and storm surges
- **Chapter 2** Overview of tsunami and storm surge hazard maps
  - 2.1 Purposes of preparing tsunami and storm surge hazard maps
  - 2.2 Target disasters and range of tsunami and storm surge hazard maps
  - 2.3 Bodies in charge of preparing tsunami and storm surge hazard maps and their roles
  - 2.4 Forms and expressions of hazard maps
  - 2.5 Procedure for preparing tsunami and storm surge hazard maps
  - 2.6 Utilization of hazard maps during evacuation
- **Chapter 3** Methods for identifying inundation risk areas
  - 3.1 Characteristics of tsunamis and storm surges
  - 3.2 Conditions for identifying inundation risk areas
  - 3.3 Choosing a method for predicting inundation
- **Chapter 4** Methods for preparing tsunami and storm surge hazard maps from the results of inundation prediction
  - 4.1 Considerations for preparing hazard maps for specific purposes
  - 4.2 Information to be included in hazard maps for residents
  - 4.3 Information to be included in hazard maps for administrators
  - 4.4 Methods for displaying predicted inundation risk areas and evacuation zones
- **Chapter 5** Use of tsunami and storm surge hazard maps
  - 5.1 Disseminating tsunami and storm surge hazard maps
  - 5.2 Ways to promote the understanding of residents about hazard maps
  - 5.3 Utilization of tsunami and storm surge hazard maps for developing measures against tsunamis and storm surges
  - 5.4 Review and revision of tsunami and storm surge hazard maps
  - 5.5 Measures for encouraging preparation

- **Reference 1**: Predicting inundation by time-series numerical simulation
  - Chapter 1 Calculations for predicting inundation during tsunamis
    - 1.1 Flow of calculations for predicting inundation
    - 1.2 Earthquake fault model
    - 1.3 Initial water level simulated by the earthquake fault model
    - 1.4 Grid intervals
    - 1.5 Elevation
    - 1.6 Conditions of river topography
    - 1.7 Tide (astronomical tide)
    - 1.8 Conditions of structures
    - 1.9 Damage to structures during earthquakes
    - 1.10 Method of numerical analysis for tsunami
  - Chapter 2 Calculations for predicting inundation during storm surge
    - *(……this part is not detailed since it has relation only with storm surge……)*

- **Reference 2**: Examples of utilizing tsunami and storm surge hazard maps for developing measures for preventing disasters
  1. Methods for enhancing residents' self defense capabilities by utilizing tsunami and storm surge hazard maps
  2. Drawing up evacuation plans by using tsunami and storm surge hazard maps (for administrative bodies)
  3. Investigating emergency measures and restoration plans using real-time information

- **Reference 3**: List of related web sites

## 5.3 Important points regarding adoption of the Japan THM Manual

The Japan THM Manual was developed based on specific situations and conditions of coastal geophysics as well as social structure and relation of Japan. The advance of technology and the accuracy of available data also affect the Manual content. These conditions and situations might be significantly different from the case of developing countries based on which some adjustment are needed to do in adopting the Manual.

5.3.1 High requirement of ground elevation detail data and the importance of recording past tsunami inundation.

In the Japan THM Manual, four alternative inundation area prediction methods are described: 1) numerical simulation, 2) level filling method, 3) estimation based on ground elevation, and 4) prediction based on past inundation. Detail description about each method is out of scope of this book, but it will be briefly introduced to discuss their significant difference and implementation requirement.

(1) Numerical simulation method is a prediction of tsunami inundation by using the most advance numerical model. Depends on the input data accuracy, various information related to tsunami hazard mapping shall be precisely estimated by this method, such as time-series inundation zone and point depth as well as protection scenario-based inundation. The prediction of inundation flow speed and directions are also made possible. However this method needs skills and costs.

(2) Level filling method is prediction of tsunami inundation area based on the volume of water overtopping the structural countermeasure or passing through the breached points. The volume of water is calculated based on the assumed external forces. The inundated area and level of inundation are estimated by if inundation starts from the lowest elevation zones. By this method, only the ultimate inundation zones can be estimated. Also, it may result in unrealistic estimation depending on the area topography, such as showing an enclave in the inundation area since the flow of water is ignored. This method needs skills on certain calculation basis for determining the quantity of flooding water and inundation zones from the level of external force.

(3) Estimation based on ground elevation method. This method assumes the areas whose elevation is lower than the assumed height of tsunami are determined as inundation zone. The inundation depths are estimated by subtracting ground elevation from the predicted height of tsunami level. The effect of maximum tide elevation is also included. This method estimates only the ultimate inundation zones. Although this method is more simple and inexpensive, it may underestimate the inundation area since the momentum of water flow (flow speed and direction) is ignored.

All the above mentioned prediction methods need accurate data of ground elevation (topography and bathymetry data). Without accurate data input, sophisticated method never produces sophisticated result. Therefore, availability of detail scale map is very important. Unfortunately this is usually the challenge in many developing countries because detail scale map are hardly available while huge amount of fund is necessary to fulfill such a requirement. Considering this situation, the following fourth method will be the best alternative for the area where detail scale map are not available.

(4) Prediction based on past inundation. A time series, zones and depth of inundation are predicted based on historical data of tsunami events. The required data include recorded data on runup height, runup distance from coastline, inundation depth and time series of event. This method is in fact the simplest and inexpensive one. This is also more realistic since it is based on the record of actual event. However, it will not work for the areas have not suffered inundation, or no records on the past events are available. Another point of attention is if the recorded past inundation is not the worst one, thus there will be possibility of underestimate prediction.

In the future, a record system of tsunami event should be developed to provide long term actual data of tsunami inundation for better prediction of tsunami inundation zone.

5.3.2 Tsunami flood properties information is dependent on the characteristics of coastal geophysics

Japan is surrounded by sea and has coastal characteristics prone to damage from tsunamis. Many coastal areas have V or U-shape of bay, which enable high amplification of tsunami height at the end reach of the bay. Figure 5.2 shows examples of many V or U-shape bays along Kii Peninsula and Sanriku coastal areas in Japan. In districts where the mountains are close to the sea, the villages are scattered along a narrow strip of lowland and protection of these villages from tsunamis is difficult. However, the steep slopes bring the advantage of possible immediate evacuation towards higher safer places. In lowlands, where the elevation is almost zero, tsunamis are known to cause inundation even until sites far from the coast. Thus, disaster prevention measures must be developed based on thorough understanding of the flood properties of each area.

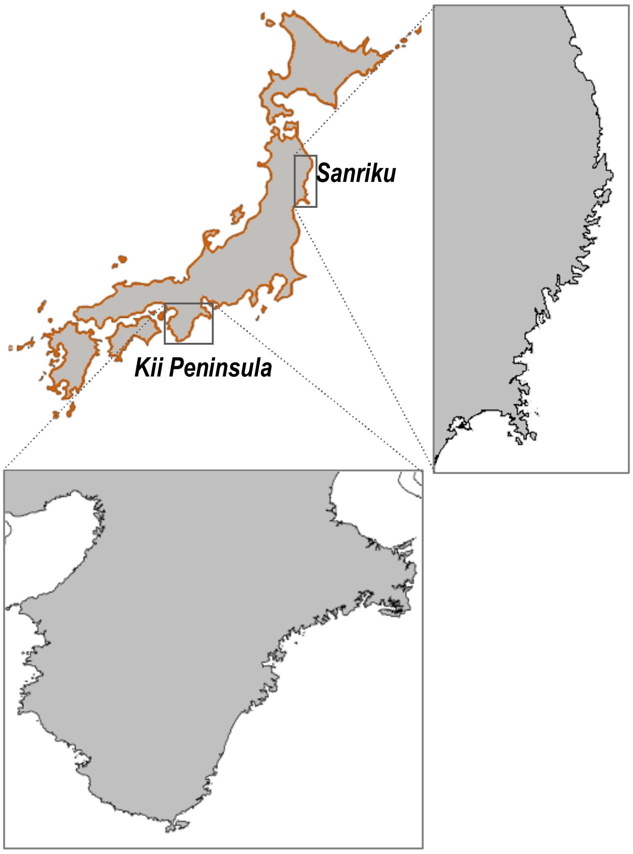



**Figure 5.2** Examples of many V or U-shape bays along Sanriku and Kii Peninsula coastal areas of Japan

Many coastal areas surrounding Indian Ocean and Pacific Ocean have different situation with Japan coasts. In tsunami prone area of Bangladesh, India, Sri Lanka and Indonesia, many coastal areas have elevation less than 10m until five kilometers inland, whereas many small island countries such as the Maldives, Marshall Islands, *etc.* have potential to be completely swept by tsunami. In both types of LECZ, tsunami hazard map is very much necessary to show and emphasize the danger of living in the inundation area and support the decision maker to make disaster resilient coastal zone development plan.

Therefore, tsunami flood properties information provided in the THM depends on the characteristics of local coastal geophysics. This difference should be clearly emphasized to educate local people about specific actual tsunami danger and characteristics in their area, *e.g.* whether receding sea water level before first tsunami necessarily happen for their area, what like of sound are usually perceived when tsunami is coming, *etc.*

5.3.3 Local understandable signs and symbols are very important

Publication and communication by using printed material is common thing all over the world. However, depending on the illiteracy percentage of population, attention should be given on the way of representing the information. Sentences explanation may be easily understood by several communities, but in opposite, pictures and symbols may be more effective and efficient to convey the messages in other communities. International standard signs maybe important to some extent but optionally shall be adjusted if other signs are more easily understandable by local people. Figure 5.3 shows an international and Japan (Takatoyo Beach) symbols for informing "tsunami hazard zone" including a command to flee to higher ground in earthquake events. Both pictures convey similar situation and command, but the symbol at Takatoyo Beach is expressed in local understandable and familiar way.


**Figure 5.3** Symbol for informing "tsunami hazard zone"; international version (left); Takatoyo Beach of Japan (right); both contain same message but expressed in different version

Further, in wider meaning, tsunami hazard mapping is not merely a picture of map printed and distributed to the community members, but it should be considered also, especially for the community with high illiteracy level, extensive utilization of "eye-catching" sign of possible inundation level (based on numerical estimation or past inundation record) in many points inside the tsunami prone area. It may be new constructed artificial structures or signs or ruins of past disaster. This is expected to increase awareness and always remind people (the residents as well as visitors) about the danger level of their area and encourage them to look for information about safety. Examples of these signs are shown in Figure 5.4.

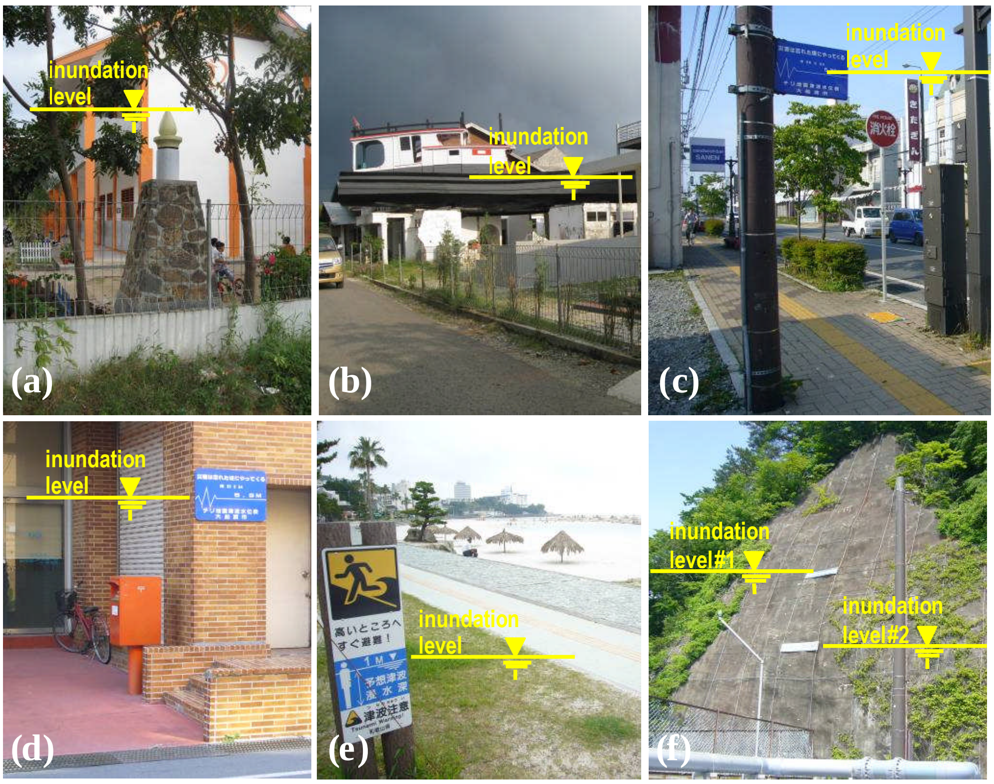



**Figure 5.4** Examples of "eye-catching" sign of possible inundation level in many points inside tsunami prone area to increase awareness and remind people about the danger level of their area: (a) tsunami-pole, B.Aceh; (b) inland drifted boat, B.Aceh; (c), (d), (e) and (f) are historical tsunami inundation mark in Japan cities, wrote on an electric pole (Ofunato), house-wall (Ofunato), beach (Shirahama) and hill slope (Taro), respectively.

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