

7. Recommendations for Future Tsunami Disaster Reduction

7.1 Introduction

On 2 April 2007, an earthquake and its induced tsunami caused severe damage to many of the Solomon Islands. The tsunami, in particular, caused damage even on islands far from the earthquake epicenter.

The Solomon Islands are along the plate boundary between the Pacific Plate and the Australia Plate, in which many earthquakes have occurred. However, big earthquakes have not been generated near the Solomon Islands since 1900, as shown in Fig. 7.1.1.1, which shows epicenters of earthquakes of $M \geq 7.5$ around the Solomon Islands since 1900, based on the USGS Earthquake Catalogue. History suggests that a big earthquake will probably occur near the Solomon Islands in the future, and islands of the country will again suffer tsunami disasters. For tsunami disaster prevention and reduction in the future, therefore, it is recommended that holistic measures which integrate evacuation support measures to save human lives and structural measures to reduce tsunami should be established based on expected disasters from possible tsunamis.

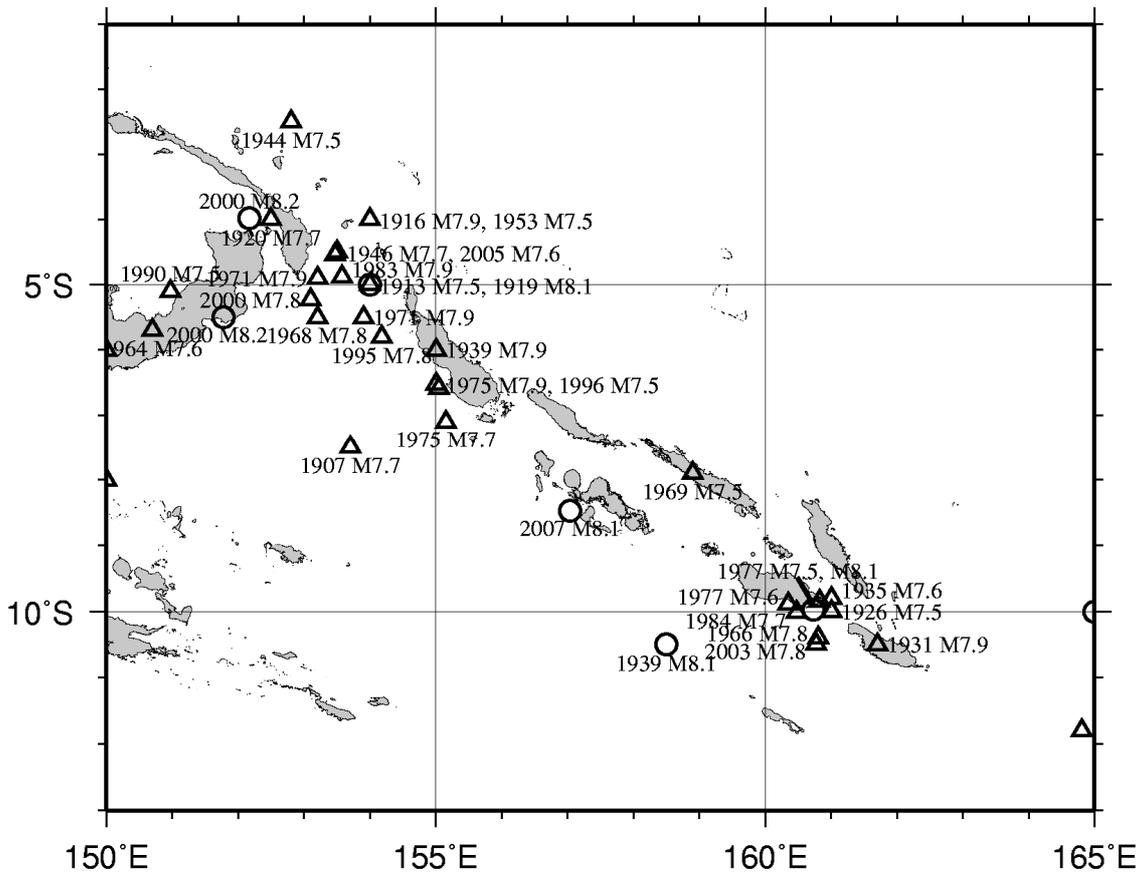


Figure 7.1.1.1 Earthquakes of M ≥ 7.5 and more around the Solomon Islands (Circle: earthquakes of M8.0 and more, Triangle: earthquakes in the range between M7.5 and M8.0)

7.2 Measures to save human lives

7.2.1 Significance of evacuation

Evacuation is a crucial measure for saving human lives. Many of those saved from the tsunami did so by running to nearby hills or high houses soon after the earthquake occurred or as soon as they saw the tsunami approaching. Because tsunamis will strike this area again, it is important to improve measures to support evacuation of residents, tourists and others. Supporting measures include, increasing local awareness of tsunami disasters, providing a national tsunami warning system which reaches local communities to trigger evacuation of the residents and tourists, and constructing tsunami shelters.

7.2.2 Lesson from previous disasters reduced victims

(1) Villagers knew past experiences such as Indian Ocean Tsunami

During our visit to affected villages, we felt that the loss of life was much less than the damage to property would suggest, although there were some exceptions such as Titiana.

One possibility was that many villagers in the affected islands already knew about tsunamis from newspaper accounts of the Indian Ocean Tsunami (IOT) (TV and radio are not available except in Gizo), and through watching IOT-related videos at some villages, where DVD players are available. In 2006, a local NGO brought IOT videos to some villages in the affected islands to raise tsunami awareness. Because they had learned from IOT experiences, villagers knew that tsunamis often follow a big earthquake, and the rapid reduction of sea level is a warning sign of a tsunami attack. Such knowledge was already transferred to the villagers before the IOT through their ancestors who knew similar lessons from the earthquakes and tsunamis in 1934 that the magnitude of both earthquakes was 8.1 and occurred around 166° in longitude, and others.

Moreover, some persons escaped to nearby hills because of a tradition to run inland if the sea surface retreats suddenly. It may be based on an ancient tsunami disaster.

Based on knowledge of tsunamis, family heads and community leaders, just after the earthquake, told their family and community members to evacuate to higher safety places nearby.

On the other hand, some family heads went to the coast to monitor whether a tsunami is coming or not. At Tapurai Village at the north end of Simbo Island, some casualties occurred when the tsunami attacked from different direction than the villagers expected.

(2) Disaster risk reduction culture from past experiences

From their experiences with tsunamis and more frequent abnormally high tides, Solomon Islanders often build coastal houses elevated above ground level on a wooden frame. Construction materials, including the roof, are light wood and leaves. This elevated floor on a wooden frame helps protect houses from being washed away during abnormally high tides and tsunamis; the light housing structure is earthquake resistant. We could confirm only one case where a man was directly killed by collapse of his house, despite the severe shaking from the earthquake.

Additionally, some villages have plantations along the coast, which worked effectively to reduce tsunami power and protected the houses built behind the trees. Such indigenous housing construction method apparently reduced the damage and

victims.

(3) Lucky factors which reduced victims

In addition to indigenous house construction practices, fatalities were low by good fortune, including:

- The earthquake epicenter was close to the affected area, so they felt strong earthquake shaking, which was enough to give them forewarning of the tsunami based on their knowledge as detailed above.
- The earthquake and tsunami occurred at 7:40 am. At that time it was already after sunrise and the weather was fine, which enabled villagers to evacuate promptly and safely to higher ground.
- Many villagers were living on flat coastal areas. Just behind the living areas, they had hilly places which are good and safe to evacuate from tsunami.

(4) Consideration of worse scenario for future disasters

As mentioned above, some lucky factors worked in this case. However, worse scenarios should be considered where these factors do not help to reduce damage and fatalities. For example,

- Earthquake and tsunami occur at midnight without moonlight or at rainy midnight.
- Faraway large earthquake which causes less shaking, however a big tsunami is generated and attacks the villages several hours later. The situation will be much worse than this case.

Decision makers, disaster management offices, community leaders and residents should be prepared for the worst case.

(5) Challenges for disaster risk reduction

From the experiences detailed here, some challenges were found for future disaster risk reduction

i) Evacuation places / routes

Many residents were able to safely evacuate from the 2007 tsunami because hills for evacuation places were close to their residential areas. Some people also escaped to high-floored houses on stilts, which are the traditional style of house in the Solomon Islands. For successful evacuation, therefore, higher evacuation places than the expected tsunami inundation depth should be set in and/or near residential areas. High rigid houses are, in particular, important tsunami shelters in low-lying and urbanized coastal areas.

The experience of the 2007 event showed that some high-floored houses with stilts, as shown in Photo 7.2.2.1, remained after the tsunami if the tsunami inundation depth was lower than their floor level. This means that the high-floored house were available for an emergency tsunami shelter. On the other hand, the tsunami washed out some high-floored houses whose wall parts underwent tsunami wave pressure. Comparison between two examples on high-floored houses indicates that a high-floored house built on a place as high as possible is safer against future tsunamis. Houses on high ground suffered less damage from the tsunami, of course. Photo 7.2.2.2 shows a church on a hill side in Tapurai where almost all houses were completely destroyed by the tsunami. From these instances, it is recommended that floor-level of house should be designed in consideration of the ground height so as to be higher than the expected maximum inundation depth due to possible tsunamis. The high-floored house on higher ground is safer against tsunamis.



Photo 7.2.2.1 High-floored house remaining after the tsunami, Titiana, Ghizo Island



Photo 7.2.2.2 Remaining architectural structure (Church) on a hill side, Tapurai, Simbo Island

ii) Another safe evacuation

For evacuation from the tsunami which comes soon after earthquake motion, it is necessary for residents to reach high and safe places as soon as possible. To climb steep hillslopes for quick evacuation, stairs set on the slopes may be effective. Photo 7.2.2.3 shows an example of an additional stair set on steep hillslope in Okushiri Island, Japan. Besides, in case of tsunami at midnight, it will be much more dangerous for the villagers to evacuate, because of the complete darkness without electricity. So, some indications to let them know the evacuation route should be considered. Making effective use of solar generation panels and battery and small lighting indicating the route are one example.



Photo 7.2.2.3 Additional stairs to help people run up a hillslope, Okushiri, Hokkaido, Japan

An emergency evacuation place on the way to a hill top is also effective for saving lives of community members. The height of the place should be higher than the expected tsunami inundation depth. It is better to climb a higher place from there in preparation for unexpected tsunamis. Photo 7.2.2.4 indicates an example of the emergency evacuation place on the way to a hill top in Wakayama Prefecture, Japan.



Photo 7.2.2.4 Emergency evacuation place on the way to a hill top

An artificial height is also an effective tsunami shelter. Some artificial heights have been constructed in Japan. Photo 7.2.2.5 shows the artificial height in a fishery harbor of Okushiri Island, which suffered devastating disaster from the 1993 Hokkaido Nansei-oki Earthquake Tsunami (the Okushiri Tsunami in another name). The height has been constructed as an emergency tsunami shelter for workers in the harbor and been connected to a nearby hill with a road. In normal time, it has been used for fishery activities: for example, drying marine products. Photo 7.2.2.6 shows also other artificial heights in Wakayama Prefecture, which are designed as a tsunami shelter against possible tsunamis striking there.

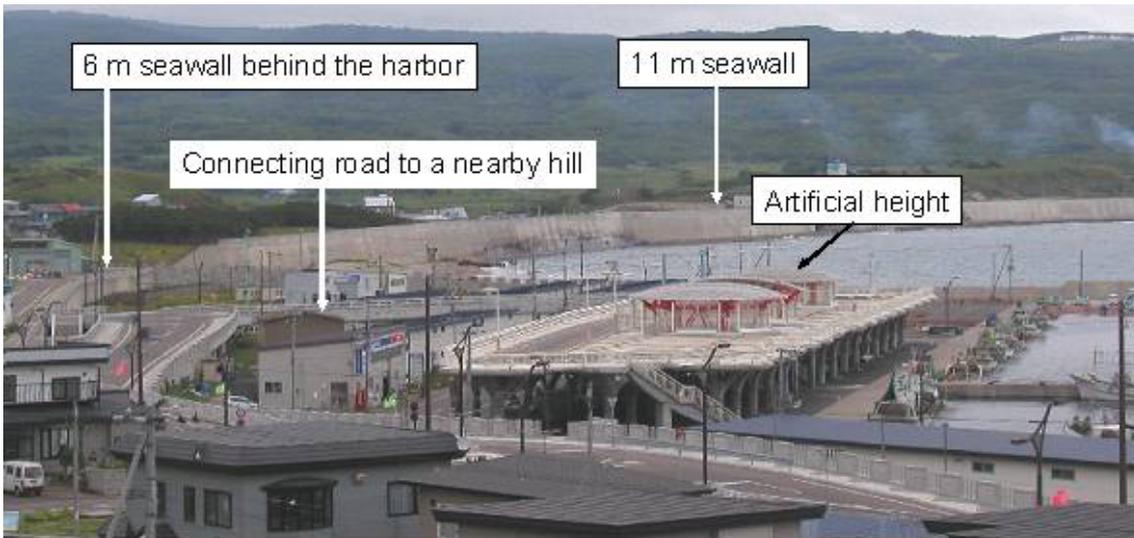


Photo 7.2.2.5 Artificial height in the Aonae fishery harbor, Okushiri, Hokkaido, Japan



Photo 7.2.2.6 Artificial heights in residential areas, Wakayama, Japan

Other reasonable evacuation places include tsunami shelters, which may be similar to 2-3 floored cyclone shelters made of reinforced concrete with roofs, which are found in the coastal area of Bangladesh (around 2,000 are built), as shown in Photo 7.2.2.7. The ground floor has only columns to support the upper floors, which is high enough to protect the above floors from normal tidal wave or moderate tsunami and the wave power will not affect the upper floors. Most of such shelters are used as schools or community centers most of the time, so moderate maintenance is continuously done through daily use.



Photo 7.2.2.7 Typical cyclone shelter in Bangladesh (Capacity 500 people, including roof)

7.2.3 Tsunami warning system

At the event on 2 April 2007, the Pacific Tsunami Warning Center issued a Tsunami Warning for the Solomon Islands and Papua New Guinea at 07:55 in local time which was approximately 15 minute after earthquake occurrence. The Japan Meteorological Agency also issued Tsunami Information at 09:02. However, the tsunami arrived some islands near the epicenter before these warnings and bulletins. In the case of a local tsunami which is generated near the Solomon Islands and which arrives at the coasts soon after the occurrence of an earthquake, a national tsunami warning system is necessary for immediate issuance of a tsunami warning.

Also important is transmission of tsunami information to disaster managers in local islands, who are in charge of disseminating the information into all residents in the islands. Therefore, it is important to establish an End-to-End dissemination system of tsunami information which consists of the National Tsunami Warning System, Transmission System to local islands and Dissemination System to residents, tourists and others. Cooperation with radio broadcasters is also effective for dissemination of the information to residents and others. Establishment of an information transmission system among islands also plays a significant role after a disaster. It can send damage reports of an affected island to the capital and nearby islands, resulting in immediate rescue and support activities. Of course, residents should have continuing consciousness

that they should escape to safe palaces soon after they feel the ground motion of earthquake, not relying on the transmission of tsunami information.

7.3 Measures to reduce tsunamis

7.3.1 Structural measures to reduce tsunami disasters

Measures other than evacuation support measures are available for construction of 'Safer Islands' against future tsunamis. In particular, structural measures may be necessary for protection of the capital which suffered less damage from the 2007 event, because the capital has a crucial function as a center to manage rescue and recovery activities soon after disasters, as conducted for the 2007 event. Ports, harbors and airports in local islands should also be protected from tsunamis, because they are bases for activities of rescue, rehabilitation and reconstruction.

Based on lessons from disasters from the 2004 Indian Ocean Tsunami, structures such as port and harbor facilities, rigid buildings along a coast, coastal dunes, and dense coastal plantations can reduce the tsunami, resulting in reduction of tsunami disasters behind them. Photo 7.3.1.1 shows an example of tsunami reduction by harbor facilities in the Beruwara fishery harbor, Sri Lanka. The numbers in the left picture indicate the tsunami trace height above the sea surface at the time of tsunami arrival. The harbor facilities such as breakwaters reduced tsunami height to 2.35 m above the sea surface, although the height was 4.84 m outside of the harbor. The reduced tsunami height produced low inundation depth on the ground resulting in less destruction in a village behind the harbor.

The structural measures have another function of disaster reduction. It is the retarding effect. Tsunami inundation does not start until the tsunami overflows the structures such as seawalls and a line of structures can reduce the inundation height behind them. These effects results in extension of time available for evacuation.



Photo 7.3.1.1 Example of tsunami disaster reduction due to port and harbor facilities

7.3.2 Sand dune and coastal plantation

More effective measures in local islands of the Solomon Islands may be coastal dunes and plantings, which are lower in cost than construction of massive structures and are eco-friendly measures.

7.3.3 Earthquake and tsunami resistant houses

As mentioned at 7.2.2 (2), the local indigenous housing building method with a floor elevated by a wood frame is quite effective for high waves by tsunamis and storm surges. However, the higher the frame becomes, the more vulnerable the house becomes to earthquakes. So, earthquake resistant design of the wood frames should be considered.

There are some methods to increase both height and strength.

i) Using pre-cast reinforced concrete frames

Pre-cast RC concrete frame should be strong enough for both earthquake and tsunami; however, it will be very heavy, which is not suitable for villages without heavy machinery and with no port to bring such equipment to the village.

So, PC-RC parts for some typical standard design of frames with connection metal bars or plates, which enables the villagers to assemble the frame easily using bolts and nuts using simple construction materials (such as chain lifter, wrench) may provide multi-hazard resistant housing frame.

ii) Reinforcement of connection corners of upper part of wood frames

From our observation, most of corners of wooden frames were simply connected by nails with partial cutting of wood parts so that two woods parts would be more firmly connected.

At only a few villages, we could see diagonal braces to reinforce the square-shaped wood frame. However such diagonal braces sometimes work to inhibit the tidal waves' smooth passage over the frame, which may cause damage to the frames, although this will greatly contribute to stabilize the frame against earthquake. Indeed we could see most of the braces had debris and grasses in tsunami flowing.

So, rather than using the diagonal braces (connecting upper part to ground level part), introducing some suitable reinforcement connection metal parts (ex. T shape or right angle stainless/ coated steel metal plates) will be more effective for both earthquake and to streamline the frames, as shown in Fig. 7.3.3.1.

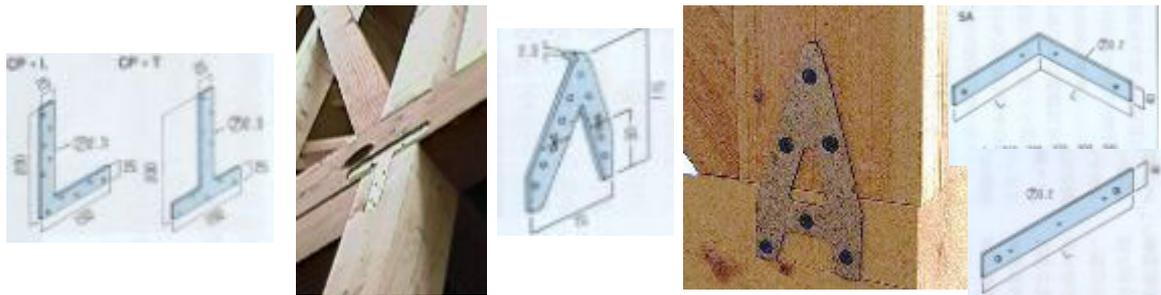


Figure 7.3.3.1 Examples of reinforcement metal parts

In case such special metal parts can't be obtained, partial reinforcement of each upper connection corners by attaching triangular wood plates or short and thick diagonal braces by nails may also work effectively for this purpose.

7.4 Prediction and understanding of tsunami disasters by hazard mapping

The earthquake and tsunami in April 2007 caused serious disasters in the western islands on the Solomon Islands. However, the other islands including the capital had less damage by the tsunami, which may suffer the disaster due to the next tsunami. To establish the integrated measures to prevent and reduce disasters especially from possible tsunamis, the disasters should be predicted and understood and necessary and adequate measures combined according to each situation to create a protective area

against the tsunamis.

Tsunami hazard mapping is major way to understand and prepare for upcoming tsunamis. One popular method of tsunami hazard mapping is to indicate graphically tsunami inundation risk areas as shown in Fig. 7.4.1, resulting in easy understanding of upcoming tsunami hazards. The estimation of inundation area can be determined by records of historical tsunami disasters and numerical simulation of possible tsunamis. These numerical simulations can, in particular, provide inundation depth and starting time of inundation as well as inundation areas, which lead to easy and good understanding of the degree of risk from tsunamis. Even on the planned topography after future urbanization and in the area protected by new structures, numerical simulation can also estimate the tsunami hazards.

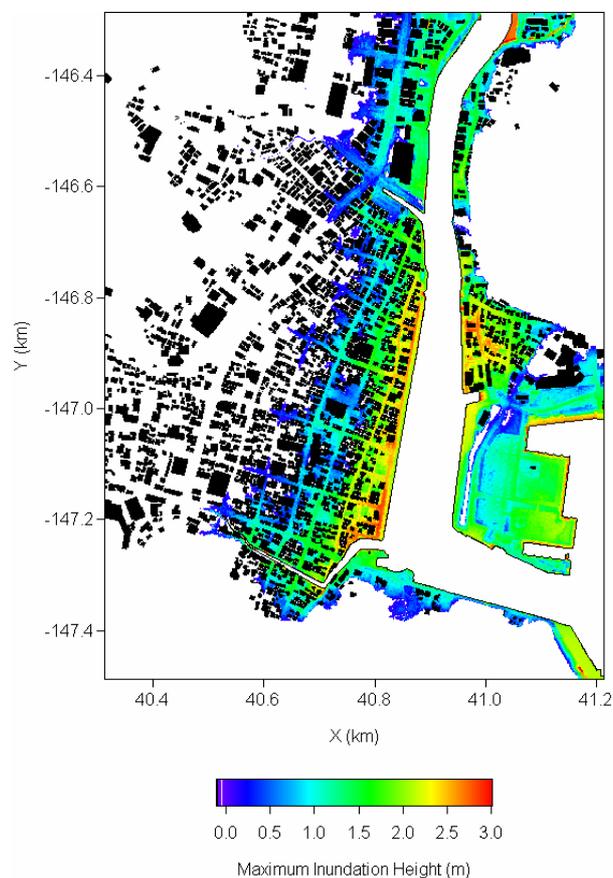


Figure 7.4.1 Example of tsunami hazard map

The numerical simulation of tsunami needs bathymetry and topography data, as shown in Fig. 7.4.2. Even if only bathymetric data and configuration data of coastlines are available, the tsunami height and arrival time along coasts can be calculated. Possessing available topography data on the ground, furthermore, provides estimation

of inundation features. Data on the location of structures, including houses and buildings, which may be prepared by aerial survey, can also provide evaluation of their tsunami reduction effects and their destruction status by tsunami action. Since the accuracy of numerical simulation results depends on the spatial resolution and accuracy of the data of bathymetry and topography, it is recommended to prepare bathymetry and topography data as fine and accurate as possible for accurate estimation of tsunami hazards. Recently, more accurate tsunami numerical simulations, which estimate tsunami fluid velocity and wave force, are also available using a three-dimensional model and fine topography and structure data.

According to the development phase of tsunami numerical models and the availability of detailed data on bathymetry, topography and structures, the prediction of tsunami hazards will become more sophisticated and can be utilized to formulate measures against tsunamis as shown in Fig. 7.4.3.

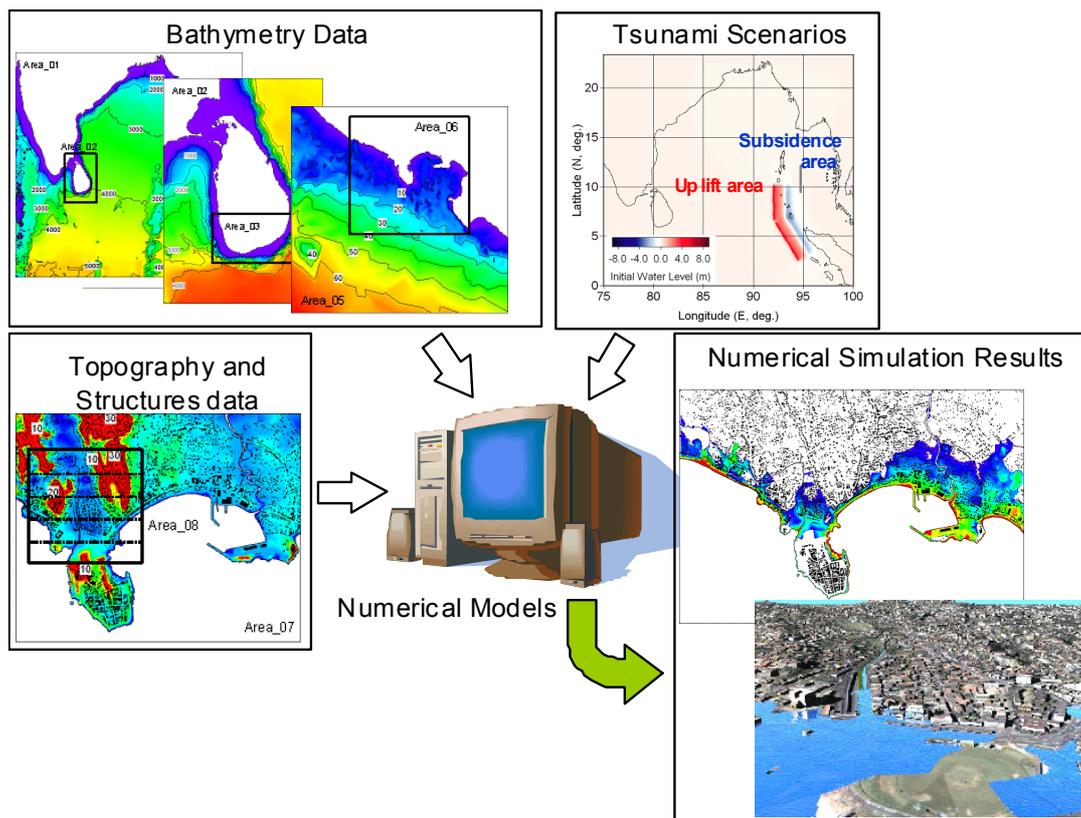


Figure 7.4.2 Image of tsunami hazard mapping using the numerical simulation

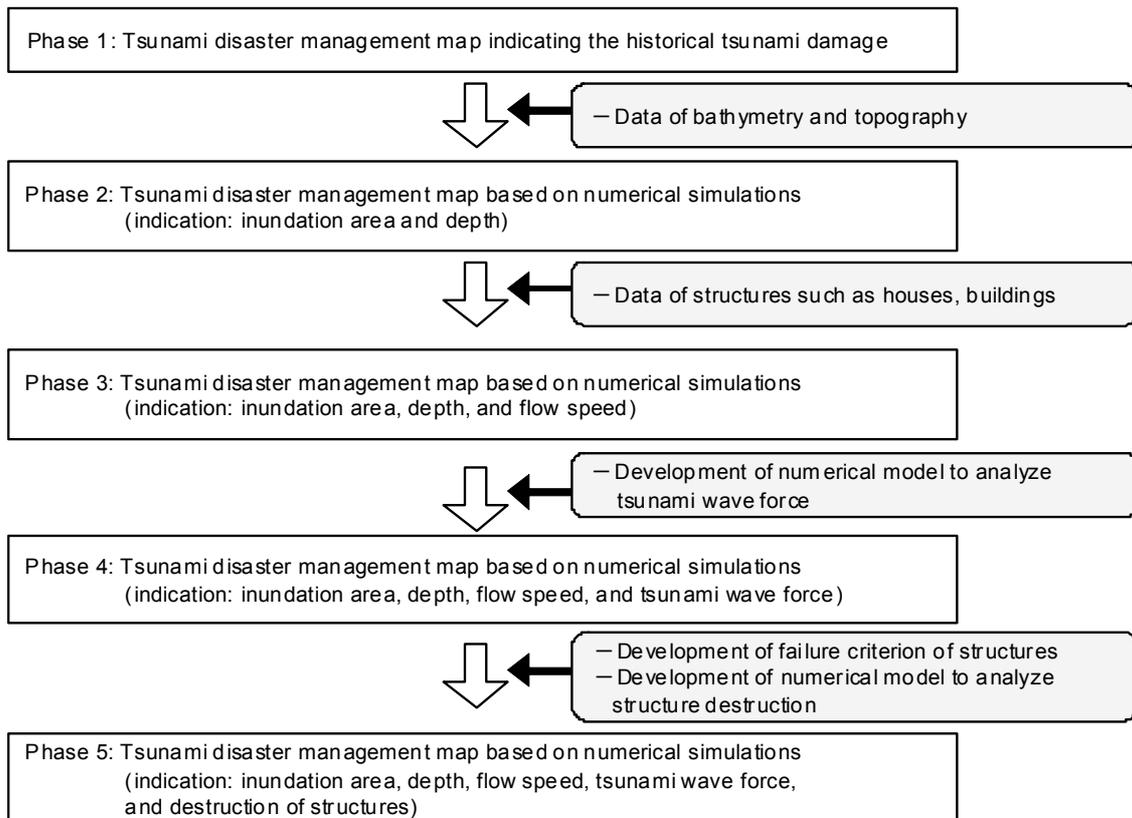


Figure 7.4.3 Example of step-by-step progress of tsunami disaster management map

Other necessary data to produce tsunami numerical simulations is a tsunami scenario which determines original condition of tsunami. It is, therefore, recommended that possible earthquakes that could trigger tsunamis should be determined through analysis of historical earthquakes and seismological aspects. Numerical simulations of distant tsunamis generated far from the Solomon Islands are also a good way to prepare for integrated tsunami disaster management.

How to make a tsunami disaster management map, which is necessary data for tsunami disaster mitigation in the tsunami hazard map, and how to utilize the tsunami disaster management map are described in “Guideline for Development and Utilization of Tsunami Disaster Management Map for ASEAN and Indian Ocean Tsunami Affected Countries.” This guideline aims to assist developing countries, particularly ASEAN countries, to develop and utilize tsunami disaster management maps by using Japan’s Tsunami and Storm Surge Hazard Map Manual. It clarifies the basic concepts such as the purpose, role, preparation methods and utilization of such maps. It is freely downloaded in the following web site:

<http://www.pari.go.jp/bsh/ky-skb/trc/project/p1.html>

7.5 Summary

The recommendations for future tsunami disaster prevention and reduction are summarized as follows:

i) Holistic measures

- Since tsunami disasters depend on regional characteristics of bathymetry, geometry, topography, social, economical and cultural, measures to support residents' evacuation and measures to control the tsunami should be integrated to mitigate possible tsunami disasters. The measures supporting evacuation, for example, include increasing people's awareness and preparedness, and establishment of an early tsunami warning system, tsunami shelters and evacuation routes. The measures to control tsunamis include protection works such as sand dunes, coastal vegetation, breakwaters, seawalls, and lines of rigid houses.

ii) Estimation of hazards

- Numerical simulations are an effective way to estimate tsunami hazards from upcoming tsunamis.
- Through investigation and analysis of historical earthquakes and tsunamis, determination of possible earthquakes generating tsunamis is necessary for estimation of hazards from the upcoming tsunamis and establishment of countermeasures against them.
- The tsunami numerical simulation requires bathymetry and topography data. Data with finer resolution provides more accurate estimation of tsunami disaster. If structural data is included, detailed tsunami features in a coastal city or town can be resolved using the data together with accurate numerical models such as a three-dimensional model.

iii) Tsunami warning

- The national tsunami warning system is required to provide warning for local tsunamis generated near the Solomon Islands.
- An End-to-End information transmission system is crucial for sending the tsunami warning to disaster managers in local islands. It is also effective to transmit disaster reports in the affected island to the capital and nearby islands, resulting in immediate rescue and support activities.
- Dissemination of the information to residents, tourists and others is important for saving human lives. Cooperation with radio broadcasters is effective way to disseminate warning messages to people.

iv) Measures to support evacuation

- For successful evacuation, higher evacuation places (tsunami shelters) than the expected tsunami inundation depth should be set in and/or near residential areas.
- The high-floored house set on a seismically resistant frame may be an emergency evacuation site if the floor level of house is designed in consideration of ground height so as to be higher than the expected maximum inundation depth due to possible tsunamis. The high-floored house on higher ground is safer against tsunamis.
- Stairs and lights set on nearby hillslopes help quick evacuation even in the dark or bad weather.
- An emergency evacuation place on the way to a hill top is also effective for saving lives of community members. It is better to climb a higher place from these in preparation for unexpected tsunamis.
- Artificial hills are also an effective tsunami shelter in low-lying coastal areas.

v) Measures to control tsunamis

- Structural measures to reduce tsunamis are effective for construction of 'Safer Island'.
- Protecting structures against tsunamis extend available time for people's evacuation as well as reduce inundation and destruction.

vi) Others

- For quick search and rescue and continuous assessment of relief and recovery needs, basic statistic social data such as population, family, housing, occupation data etc. should be prepared periodically. A system to collect damage information should be also prepared.
- Raising public awareness and education for multi hazard disaster management periodically will also contribute to reducing the damage and to an early recovery.