CONCERT-Japan
Research and Innovation Joint Call

Efficient Energy Storage and Distribution
Resilience against Disasters

RAPSODI Project

Risk **A**ssessment and design of **P**revention **S**tructures f**O**r enhanced tsunami **DI**saster resilience

Deliverable D4 – Comparison of mitigation strategies in Europe and Japan

1st year of funding

20120768-04-R
1 June 2014
Revision: 1 / February 2015

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CONCERT JAPAN
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www.concertjapan.eu

This work was supported by funding received from the
CONCERT–Japan Joint Call on Efficient Energy Storage
and Distribution/Resilience against Disasters

Project information

Name of the project:	RAPSODI
Start of the project:	01 July 2013
Duration (no. of months):	24
End of the project	01 July 2015
Name and country/region of each partner	NGI, Norway; PARI, Japan; TU-BS, Germany; METU, Turkey
Overall budget	383 k€

Client

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Contract reference:	NGI 229578/H20; METU 113M556; TUBS 01DR13016;
Settlement numbers	PARI 2013 H25国際第1-33号 and for 2014 H26国際第1-17号

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Publishable summary

One of the objectives of the consortium of Risk Assessment and design of Prevention Structures fOr enhanced tsunami DIsaster resilience (RAPSODI) project is to propose tsunami mitigation strategies which include both hard measures such as structures as well as soft measures such as early warning systems or evacuation planning to improve resilience against tsunami impacts. Within the project period it is planned to bring together the different expertise, data, and backgrounds of Europe and Japan and to a) explore potential synergies between them end b) develop further ideas and perform further research to improve the existing state of the art. In this regard, Deliverable 4 - Comparison of mitigation strategies in Europe and Japan is prepared within the first work package of RAPSODI project. The report describes the existing measures against tsunami attack in Europe and Japan. It discusses the hard and soft measures in both areas and evaluates the use of each described methods. The key objective of this report is to obtain a profound and state-of-the-art overview of existing mitigation measures and providing a comparative evaluation based on this knowledge.

Tsunami mitigation strategies are discussed in two categories as the structural (hard) measures and non-structural (soft) techniques in Japan and Europe. First, an overview of those measures are introduced and described. Then, the existing structural mitigation strategies, current design approaches and some examples of coastal protection structures from different prefectures in Japan are provided based on an extensive literature survey. Major structural measures against tsunamis can be categorized as coastal dikes, tsunami seawalls or walls (barriers), water gates, breakwaters and greenbelts in Japan. After that, the structural mitigation in Europe is presented although the existing information is limited and coastal protection structures against tsunami are very rare.

Non-structural mitigation is a multi-element system consisting of several different approaches which requires integration. Tsunami early warning system, community preparedness and education, land-use and evacuation root planning and use of coastal vegetation are the main soft techniques that can be implemented for an effective tsunami mitigation. There is a variety of those soft measures applied in Japan whereas few of them are encountered in Europe. In Japan, there exists a tsunami and earthquake early warning system working effectively and operated by Japan Meteorological Agency (JMA). Nevertheless, the system had some gaps on information dissemination to the public and had some critical problems on estimation of tsunami height in the 2011 Great East Japan Earthquake event. Community-based disaster risk management in Japan is also one of the issues that focused on together with land-use and evacuation planning. However, community preparedness and education should be continuous whereas evacuation root and land-use planning need to be updated according to the changes and developments. Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and Connected Seas (NEAMTWS), evacuation planning in some regions such as Portugal and Italy and some monitoring and community preparedness actions taken

in Norway on the European side. It is important that those measures also need to be enhanced and applied as common measures around the Europe.

Both systems rely on different mitigation measures rather than just one. Large systems in Europe act as natural defences like beaches and dunes which are maintained. Therefore, very often the ‘mitigation’ in Europe means to keep natural systems in their original condition. In Japan, due to the high loadings of defences induced by tsunamis and storm surges, this would in most cases be insufficient to defend the coastal areas so that hard measures (e.g. concrete seawalls) are utilized.

To conclude, tsunami mitigation measures in terms of structural and non-structural cases differ greatly in Japan and Europe due to the difference in perception of the tsunami risk. There is a great variety of measures in Japan extending from constructing coastal dikes of an advanced design to community preparedness and coastal vegetation although there exist some gaps and deficiencies whereas measures in the European side are limited to few types of actions. Practice of evacuation planning in a few regions such as Portugal and Italy and some activities in Norway such as monitoring of the tsunami and capacity building activities for the population are some of them. This could be attributed to the fact that the occurrence of most tsunamis in the Pacific region has led to a thought that tsunami hazard in Europe is insignificant, but the hazard is real according to the European records of tsunami both from documentary evidence and the geological records. Therefore, it can be suggested that more actions on tsunami mitigation should be taken in the European side considering new research on sources, risk and performance of existing structures under tsunami loading whereas the mitigation strategies in the Japanese side should be enhanced for a more resilient system against tsunamis.

Contents

1 Introduction

Preparedness, evacuation, and mitigation are representative countermeasures to protect humans and infrastructure facilities from natural hazards besides the hard solutions such as defence structures. Tsunami mitigation techniques are therefore broadly categorized in two ways:

1) Hard solutions such as constructing seawalls, tsunami gates or breakwaters (for more information; Deliverable 3 - Comparison of coastal structures in Europe and Japan http://www.ngi.no/en/Project-pages/RAPSODI/Reports-and-Publications/); and
2) Soft solutions referring to nonstructural mitigation strategies such as an effective tsunami early warning system, utilizing a natural buffer zone of coastal vegetation, evacuation route planning and community based disaster management.

Artificial coastal barriers such as seawalls and breakwaters have been constructed along the Japanese coast and have played an important role in protecting the coastal area from natural hazards, tsunamis. However, the countermeasures against tsunamis by only using the artificial coastal barriers are not recommended for all coastal areas and in future coastal management plans. For more appropriate management of natural disaster reduction that also considers the environment, a new countermeasure method which integrates artificial and natural functions is needed.

The consortium of Risk Assessment and design of Prevention Structures fOr enhanced tsunami DIsaster resilience (RAPSODI) project aims to propose tsunami mitigation strategies which include both hard measures such as structures as well as other measures such as early warning systems or evacuation planning to improve resilience against tsunami impacts. Within the period of the project, it is planned to bring together the different expertise, data, and backgrounds in the Europe and Japan and to a) explore potential synergies between them and b) develop further ideas and perform further research to improve the existing state of the art.

This report, Deliverable 4 - *Comparison of mitigation strategies in Europe and Japan* describes the existing measures against tsunami attack in Europe and Japan whereas the previous Deliverable 3 - *Comparison of coastal structures in Europe and Japan* (http://www.ngi.no/en/Project-pages/RAPSODI/Reports-and-Publications/), describes coastal protection structures against related hazards in Europe and Japan. It will distinguish between hard and soft measures in both areas and will evaluate the use of each described method. The key objective of this report is therefore to obtain a profound and state-of-the-art overview of existing mitigation measures. Furthermore, a comparative evaluation of these approaches is provided based on this knowledge.

In Chapter 2 of the report, structural mitigation measures in Japan and Europe are introduced and described. Chapter 3 continues with a description of the non-structural measures, again both in Japan and Europe. Chapter 4 summarises the results and provides some concluding remarks.

2 Structural Mitigation

2.1 Japan

Coastal protection measures in Japan against storm surges and tsunamis have undergone a change in a way as described below (Kawata et al., 2004).

1- Japan suffered serious damage from storm surges and tsunamis after World War II and the measures for coastal protection consisted of mainly restoration activities at those days.
2- The construction of structures such as revetments, banks, groins and parapets started for coastal protection within the concept of “the linear protection method” in 1956 with enacting of the Coast Law.
3- Projects based on constructing two or more structures such as detached breakwaters, submerged breakwaters, artificial reefs, and sandy beaches to gradually reduce external forces (wave forces) started after 1975 within the concept of “the area protection method”.
4- More advanced structural measures were also taken subsequently by applying earthquake resistant structures and anti-liquefaction structures.

Japan has constructed dikes against tsunamis for nearly 2,000 years. When the 2011 tsunami hit eastern Japan, 300 km of coastal dikes, some about 15 meters high, had been built along the Pacific Coasts of Japan (Ishiwatari and Sagara, World Bank KN 1-1, 2012). These dikes were designed to resist the largest predicted tsunami heights and storm surge heights (*Fig.* 2.1).

Fig. 2.1 600 m long and 5 m high dike in Hiro, Japan. The paintings remind of the 1854 tsunami which led to the building of the dike. Hiro was hit by another tsunami in 1946, but the almost 100 years old dike protected the community behind (modified from Ohta et al. 2005).

The dike design heights in Japan (cf. *Fig.* 2.2) were determined according to historical records in some regions such as Iwate and northern Miyagi, whereas they were based on the storm surge predictions in southern Miyagi and Fukushima. Dikes and breakwaters constructed before the 2011 event were designed to protect against relatively frequent tsunamis. However, in the Great East Japan Earthquake (GEJE) event the height of the tsunami was far more than the predictions and building much higher structures would not be feasible in terms of financial and socio-ecological issues.

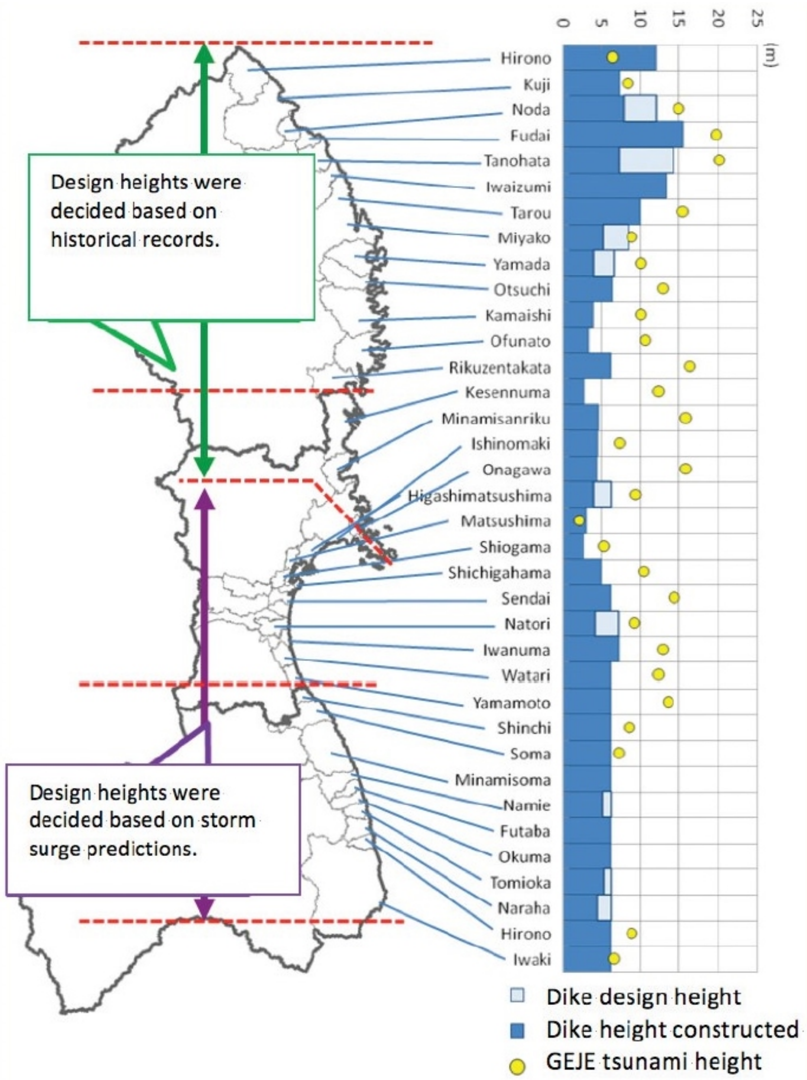


Fig. 2.2 Determining Dike Design Heights along the Pacific Coasts of Japan. (Source: Ishiwatari and Sagara, World Bank KN 1-1, 2012. Retrieved from MLIT)

Following the GEJE, the Japanese government has followed a two-level approach for the design parameters of structures after the event. According to the methodology, Level 1 events are the tsunamis that occur once in 100 years and cause serious damage, whereas level 2 includes the largest possible tsunami, which has a probability of occurrence once in every 1,000 years but results in devastating destruction. The situation is illustrated in *Fig.* 2.3.

	Tsunami to be considered	*Required performance*
Level 1 tsunami	Largest in recent history (return period of approx. 100 yrs.)	Disaster prevention • Protect human lives • Protect properties/economic activities
Level 2 tsunami	Maximum level (return period of approx. 1000 yrs)	Disaster reduction • Protect human lives • Mitigate economic loss • Prevent major secondary disasters • Enable early recovery

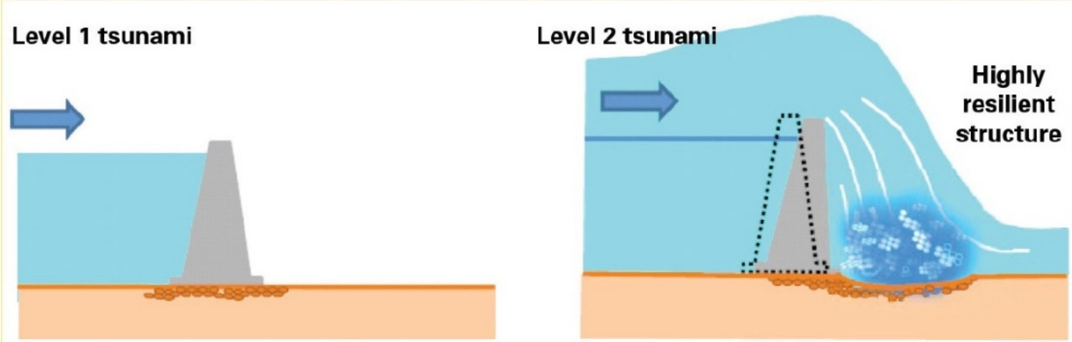


Fig. 2.3 Countermeasures against level 1 and level 2 tsunamis (Source: Ishiwatari and Sagara, World Bank KN 1-1, 2012. Retrieved from: MLIT)

Tsunami breakwaters are constructed to control the tsunami height and seawalls are constructed and reinforced to control the overflow effects. On the other hand, water gates are constructed and reinforced to control the run up along the rivers. Maintaining and controlling the facilities is also an essential point to prevent destruction of the measures.

The ASCE/COPRI Coastal Structures Team took a survey trip to investigate the effects of 2011 Japan earthquake and tsunami particularly on engineered coastal structures, coastal landforms, and coastal processes in Japan. The team’s field survey of coastal structures started in the north— at the Momoishi Fishing Port, located approximately 12 kilometres southeast of the Misawa Airport in Aomori Prefecture, and extended southward to Natori Beach, located immediately adjacent to the Sendai Airport in the Miyagi Prefecture. The main five categories of coastal protection structures which the team observed in their field survey can be listed as coastal dikes, tsunami seawalls, floodwater gates, breakwaters, and vegetated greenbelts. The design parameters of these structures are based on is a once in 100-year or once in 500-year event consideration. However after the event, it is understood that more extreme conditions are possible.

For the design parameters of structures possible to tsunami exposure, the team suggests that hydrodynamic loads like vertical uplift, fluid and debris impacts, hydrostatic loads, and the drag force should be taken into account. Internal and foundation connections, tie-ins, end attachments, and abutments must all be designed against these loads as well. Another point is that, current design practice does not include the scour patterns that were observed inland of coastal dikes. Both shore and scour protection in Japan is mostly based on concrete armour units. The availability of quarry stone in Japan is limited and that is why they rely on concrete. Therefore, it is suggested to analyse each unit's stability coefficient and performance under conditions in a wave tank or monitored field conditions before considering the use of these units in applications.

PIANC Report N° 122 (2014) also discusses tsunami protection facilities specific to the Sanriku Coast in Japan. The first coastal dyke in Taro Region completed in 1958 was extended and reinforced twice after the 1960 Chilean tsunami hit a wide region of the Pacific coast of Japan. It finally became a huge coastal dyke with a total length of 2,433 m.

Fig. 2.4 Coastal dyke in Taro District. (Source: PIANC Report N° 122, 2014)

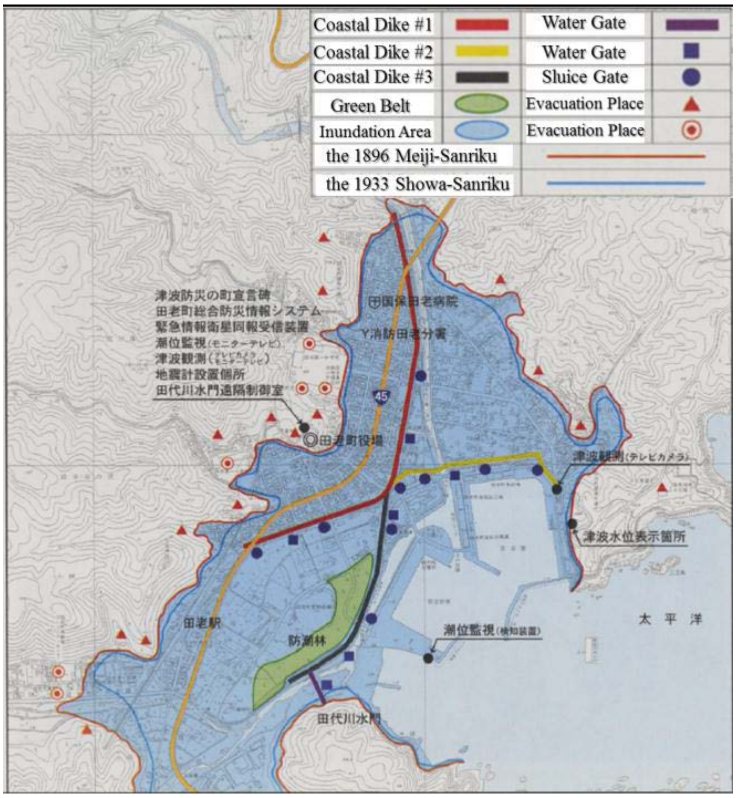


Fig. 2.5 Coastal dyke, water gates, green belt and previous tsunami inundation areas in Taro District. (Source: PIANC Report N° 122, 2014)

The breakwaters at the mouth of Kamaishi Bay include three parts as the North Breakwater having a length of 990 m, the South Breakwater with a length of 670 m and the Bay entrance section with a length of 330 m. The maximum depth at the breakwaters is given as 63 m in PIANC Report N° 122 (2014).

Fig. 2.6 Breakwaters at the entrance to Kamaishi Bay. (Source: PIANC Report N° 122, 2014)

At the North Breakwater, the deep section consists almost totally of trapezoidal caissons. Its foundation mound ranges from -60 m to -27 m and above it, caissons weighing about 36,000 tons are installed. In the shallow parts, the caissons are rectangular with a height of 10-15 m. At the South Breakwater, three caissons are trapezoidal caissons, and the rest are approximately 32,000 ton rectangular caissons. Their crest height is +6.0 m and their foundation mound extends from a depth of 55 m to a depth of 22 m. The bay entrance section is built as a submerged breakwater so that it allows for ship traffic. The depth at the mouth is 19.0 m and reinforcement blocks are inserted around the opening.

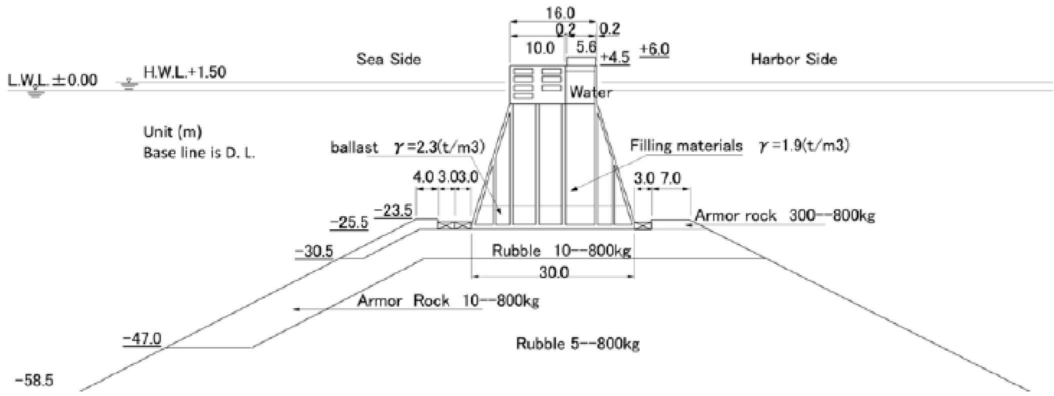


Fig. 2.7 Standard cross section at deep area of North Breakwater in Kamaishi Bay. (Source: PIANC Report N° 122, 2014)

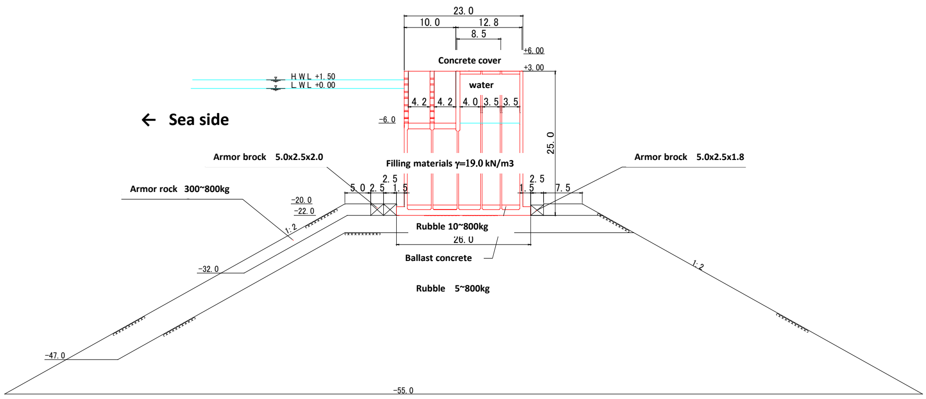


Fig. 2.8 Standard cross section at deep area of South Breakwater in Kamaishi Bay. (Source: PIANC Report N° 122, 2014)

Despite the fact that the breakwater at the mouth of Kamaishi Bay was the world's deepest breakwater, it was severely damaged by the GEJE tsunami. It shows that structural measures do not always provide full protection although it reduced the tsunami force, and therefore its height, by about 40 percent and delayed its arrival by some six minutes, allowing more time for people to evacuate to higher ground. However, in some towns like Iwate's Fudai Village, the 15.5-meter floodgate, protected the village and its inhabitants because the village was severely damaged by the Meiji Sanriku Tsunami of 1896 (height 15.2 meters), the Showa Sanriku Tsunami of 1933 (11.5 meters), and the Chilean Earthquake Tsunami of 1960 (11.5 meters) and the mayor of the village was convinced that a 15-meter tsunami would hit the village again at some point, and built the 200 meter-wide floodgate about 300 meters inland from the mouth of the Fudaigawa River, which runs through the village. Although the 20-meter-high GEJE tsunami did top the floodgate, the gate kept the water from reaching the town center (Ishiwatari and Sagara, World Bank KN 1-1, 2012).

2.2 Europe

Structural coastal protection in European countries is mainly based on defending the hinterland against storm surges and protecting the beaches and dunes against coastal erosion. Information on European actions against tsunamis is very limited although Europe was hit by large tsunamis in the past and similar, or possibly larger, events may happen again. For instance, several studies (Louat and Baldassari, 1989; Soloviev, 1990, 2000; Tinti et al., 1996, 2004; Pelinovski et al., 2002; Lander et al., 2002; O'Loughlin and Lander, 2003; Sahal et al., 2010) have shown that the coasts of France and its overseas territories have been hit by tsunamis in the past (*Fig.* 2.9).

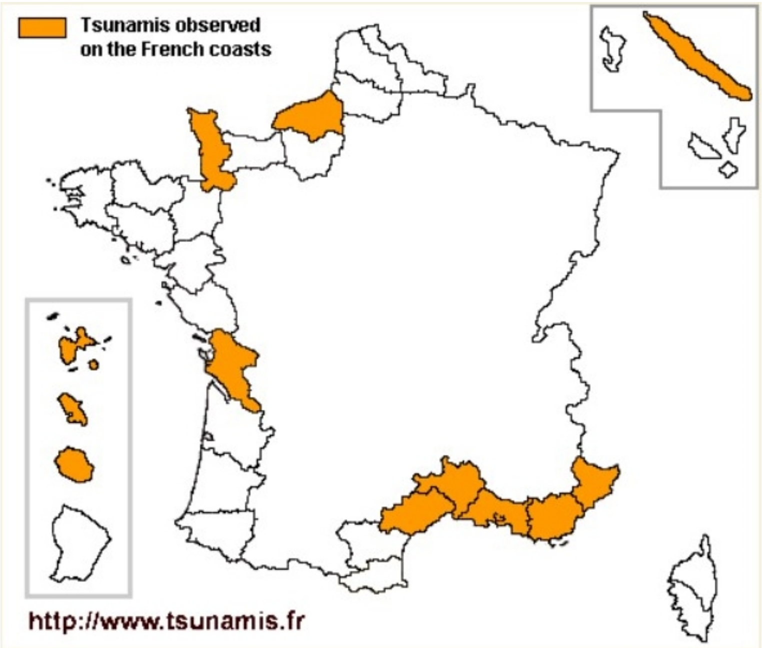


Fig. 2.9 Tsunamis observed on the French Coasts. (Source: www.tsunamis.fr)

Also, the Spanish coasts have suffered from the effects of large tsunamis on several events. Historically, the areas most affected are the southwestern Atlantic basin (especially the Gulf of Cadiz) and the Mediterranean coasts of Spain. There are studies on that issue (Álvarez-Gómez, 2011, Cardineau, 2011). In the Netherlands, some studies on tsunami risk (Dababneh, 2012) exist. Cardineau's (2011) study also includes Portugal on tsunami risk issue. Italy is another European country that studies developed by the Istituto Nazionale di Geofisica e Vulcanologia have recorded over seventy more or less destructive tsunamis along its coasts in the past two thousand years. Moreover, tsunamis in the eastern Mediterranean have had a slight impact on the southern-most coasts of the Italian peninsula. A study of the catalogue of Italian tsunamis shows that southern Calabria, the Messina Strait, and eastern Sicily have been the areas along Italian coasts mostly affected by tsunamis in the past. Some are the result of strong submarine or nearshore earthquakes whereas the others have been caused by volcanic activity and submarine landslides. In Norway also, tsunamis may arise from submarine landslides in the NE Atlantic, as well as submarine landslides and rockslides in the fjords.

In spite of the occurrence of tsunamis and those risk assessment studies, it is stated in the **T**sunami **R**isk **An**d **S**trategies **F**or the **E**uropean **R**egion (TRANSFER) Project that no protection is currently in place and therefore possible tsunamis may cause much larger destruction due to the increased occupation of the coasts (TRANSFER, 2009).

Only in Norway, structural measures against tsunamis are encountered. The country has different strategies to reduce and manage tsunami risk and in terms of structural measures, constructing dikes is one of the options (*Fig.* 2.10). The dikes to protect low-lying areas should be designed with caution to avoid possibly increased run-up heights due to reflection, refraction, interference or amplification. Further, the dikes should not lead to an increased risk in the surrounding areas (e.g. by increased currents through gaps or escape routes). Moreover, dike constructions go along with some problems such as changes in local currents, sediment transport, or environmental impacts, which again cause problems for the local communities.

Fig. 2.10 Dike to protect from tsunamis in Årdalsvatn, Norway (Source: Årdal kommune)

In the Baltic Sea Countries (Estonia, Latvia and Lithuanie), Denmark, the Netherlands, Belgium, France, Spain, Portugal, Italy, Greece, Ireland and the Great Britain tsunami is not considered in the design of coastal structures. Moreover, no information on structural measures against tsunamis could be accessed for those countries. In Germany, tsunami is also not considered in the design of coastal structures and therefore, no structural measure exists against it. In Turkey, although tsunami phenomenon is not taken into consideration in the design of coastal structures, tsunami risk assessment studies (Balas and Ergin, 2003) are carried out for major coastal projects such as Haydarpaşa Port Project.

3 Non-Structural Mitigation

3.1 Introduction

Tsunamis, like most natural disasters, are beyond human control. There are, however, a number of methodologies that can minimize the impacts of tsunamis to the physical environment and to individuals and coastal communities. Associated with an effective warning system, proper design and community preparedness can reduce the damage and prevent loss of human life. Coastal communities can gain resilience against the tsunamis through appropriate programs of preparedness and education. Therefore, to summarize, proper guidelines leading the local communities in terms of mitigation and adaptation measures and sustained public awareness in the long term are essential components of an end-to-end tsunami warning and mitigation system. However, several countermeasures such as evacuations to higher ground or the stopping of trains, depend on getting the right information and disseminating it in a timely manner. *Fig.* 3.1 shows that the system must be aligned with community response for an effective and proper warning.

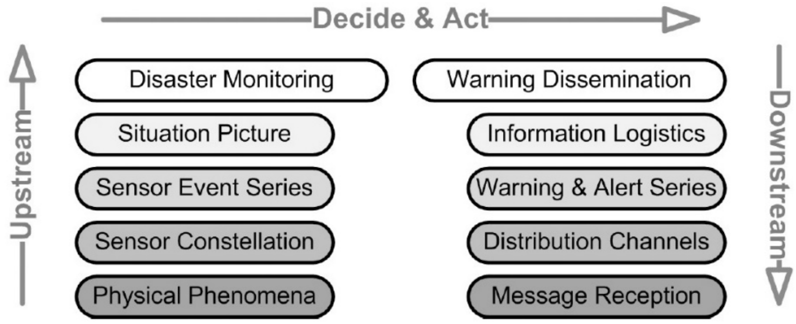


Fig. 3.1 Upstream and downstream flow of events and information in early warning systems (<u>Source:</u> Wächter et al., Development of tsunami early warning systems and future challenges, 2012. Retrieved from: Wächter et al., 2009; Lendholt and Hammitzsch, 2011).

In this regard, community-based disaster management teams become a key element in disaster mitigation. Volunteering is very important because the local people have a good knowledge of what needs to be done and needs to be involved in case of a disaster. Working together on building mitigation structures, such as seawalls and evacuation centers, creates a sense of control over the environment after a disaster and builds a sense of community among workers. Volunteers working on disaster preparedness are also able to make connections between local villages and the larger disaster agencies. In addition to that, many coastal areas have specified tsunami inundation zones and marked evacuation routes to assist people to higher ground. Local emergency management groups also provide tsunami education information, organise meetings and workshops, and many more community preparedness activities.

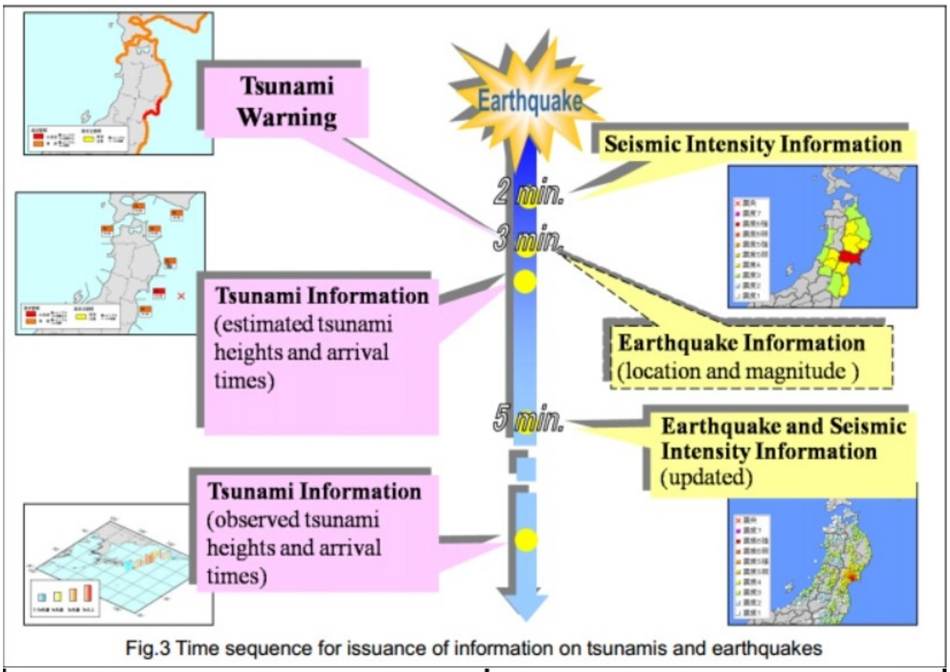
Coastal vegetation also has a significant potential to mitigate damage in constructed areas and save human lives by acting as buffer zones during extreme natural events such as tsunamis. Even for the 2011 event, the coastal forests and dunes worked relatively well in areas of lower tsunami heights, such as Ibaraki and Aomori. However, the tsunami impact was too strong in the Sanriku region, and the coastal forests did not significantly reduce the tsunami damage (Hoshino, 2012). Additionally, the effectiveness of vegetation changes with the age and structure of the forest (Harada and Imamura, 2005 and Tanaka, 2009).

All in all, tsunami mitigation strategies such as early warning systems, community based disaster management or evacuation and land use planning are essential in addition to the structural measures. Therefore, identifying the existing measures throughout different coastal areas may be the first step and starting from these, more effective strategies can be developed resulting in more resilience. In this respect, an overview of the present non-structural mitigation strategies in Japan and Europe is provided in sections 3.2 and 3.3 to analyse their approaches and make a comparison between them.

3.2 Japan

3.2.1 Tsunami and Earthquake Warning Systems in Japan

Japan Meteorological Agency (JMA) has established the Tsunami and Earthquake Warning System which issues warning information quickly after an earthquake occurred. In order to prevent tsunami disaster, a tsunami warning is provided before the tsunami reaches the coast. The system includes satellite communications and hundreds of real-time monitoring stations. The warning tells the estimated height and expected arrival time of tsunami. This information is based on the result of numerical simulations. In the case of a major earthquake occurring at the seafloor, JMA estimates the height of the tsunami by referring to the database of simulation results. If the tsunami is expected to exceed the threshold, warning is issued to the area. This sequence will be completed within approximately three minutes after the earthquake occurred (*Fig.* 3.2).



Tsunami Forecast		Tsunami Height
Tsunami Warning	Major Tsunami	"3m", "4m", "6m", "8m", "over 10m"
	Tsunami	"1m", "2m"
Tsunami Advisory		"0.5m"

Fig. 3.2 Tsunami Warning System in Japan - Time sequence for issuance of information on tsunamis and earthquakes (Source: Yamada, 2010).

The Government of Japan (2009) noted that “All of Japan’s national territory is covered by early warning systems for storms, torrential rains, heavy snow, sediment disasters, tsunamis, tidal waves, high surf, inundation and floods, the Ministry of Land, Infrastructure and Transport, the Japan Meteorological Agency and local government bodies being the main institutions involved. The organizations use 24-hour systems to carefully monitor various natural phenomena and weather conditions” (Government of Japan, 2009). It can be stated that the country has been well informed on the level of tsunami and in terms of earthquake preparedness since the Cabinet Office has carried out Disaster Preparedness Surveys regularly during 1991, 1995, 1997, 1999 and 2002.

However, while Japan had already developed the most sophisticated tsunami-warning system in the world before March 11, 2011, the system underestimated the tsunami height and may have increased loss of lives. This has been discussed in detail in Shaw et al. (2012), Worldbank KN 2-1, Nonstructural Measures. JMA issued the first tsunami warning at 14:49, three minutes after the earthquake. People started evacuating and organizations started preparing for the tsunami. Critical problems were found in estimating the tsunami's height and information dissemination to the public. Underestimation of the tsunami's height likely contributed to the delay in people's evacuation.

3.2.2 Community-Based Disaster Risk Management in Japan

Local communities are the first responders to disasters and therefore they have a key role in mitigation against tsunamis such as the Great East Japan Earthquake. On March 11, 2011, community-based organizations (CBOs) were active in the disaster response and saved countless human lives (Shaw et al., 2012). The importance of the local people in mitigation should be identified and government support should be provided to maintain and strengthen the community-based disaster management system. Community-based organizations (CBOs) have existed for centuries and they carried out activities against disasters as volunteers before the Japan's formal state system was established. They include: Suibo-dan for flood risk, Syobo-dan for firefighting, and Jisyubo for earthquake disasters (Shaw et al., 2012).

The volunteer fire organizations are also critical elements of the disaster risk management system for several reasons. First of all, volunteers have knowledge of the local people since they are from the community and therefore they are familiar with those residents who may need help to evacuate, such as the disabled or bedridden. Second, the total number of volunteers is nearly six times that of the professional firefighting staff. That condition provides a cost-effective way of large-scale emergency response. Finally, the members receive regular training and their reaction is generally faster since they are locally based.

Fig. 3.3 Training of volunteers for supplying food in Yawatahama City, Ehime Prefecture

In addition, various nongovernmental organizations (NGOs) and non-profit organizations (NPOs) are involved in disaster risk management (DRM) activities at the community level (*Fig.* 3.4). Many of them collaborate with jichikai (neighbourhood associations) and local governments, and sometimes with local academic institutions (Shaw et al., 2012).

Organization	*Hazard*	*Legal act*	*Supervising government organization*	*Date established*	*Number of staff or groups*
Suibo-dan	Flood	Flood Fighting Act	Ministry of Land, Infrastructure, and Transport	17th century	900,000 staff in two organizations
Syobo-dan	Fire	Fire Defense Organization Act	Fire and Disaster Management Authority (FDMA)	18th century	
Jisyubo	Earthquake	Basic Act on Disaster Reduction	Cabinet Office, FDMA	1970s	140,000 staff
NPO	All	Act to Promote Specified Nonprofit Activities	Cabinet Office	After the Kobe earthquake in 1995	> 2,000 groups

Fig. 3.4 Structure of community-based organizations (<u>Source:</u> Shaw et al., 2012, Worldbank KN 2-1, Nonstructural Measures. Retrieved from: Forest Agency, 2011)

3.2.3 *Practice of evacuation planning in Japan*

Evacuation planning may have a stronger influence in disaster risk management since it is deeply related with other mitigation strategies; i.e. the overall aim of most of other measures is the successful evacuation. The relationship between evacuation and other DRM measures is given in Shaw et al., 2012 (Fig. 3.5).

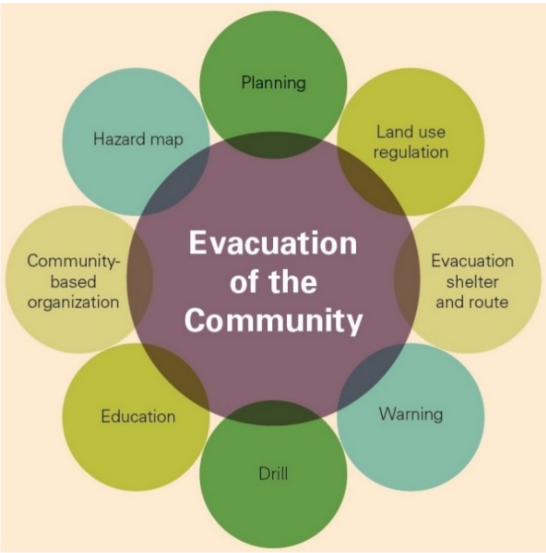


Fig. 3.5 The relationship between evacuation and other DRM measures (<u>Source:</u> Shaw et al., 2012, Worldbank KN 2-1, Nonstructural Measures. Retrieved from: Forest Agency, 2011)

As the occurrences of tsunamis have been integrated into the Japanese life, evacuation planning is an old tradition in the country. Many community-based preparedness measures exist along all coasts of Japan which face the tsunami threat. In recent history, the Hokkaido coast earthquake-induced tsunami from 1993 allowed an evacuation time of 3–5 minutes (Nagao, 2005). For these reasons, in Japan, there exists a trend towards the use of existing shelter buildings and the construction of new buildings of this type (*Fig. 3.6* and *Fig. 3.7*).

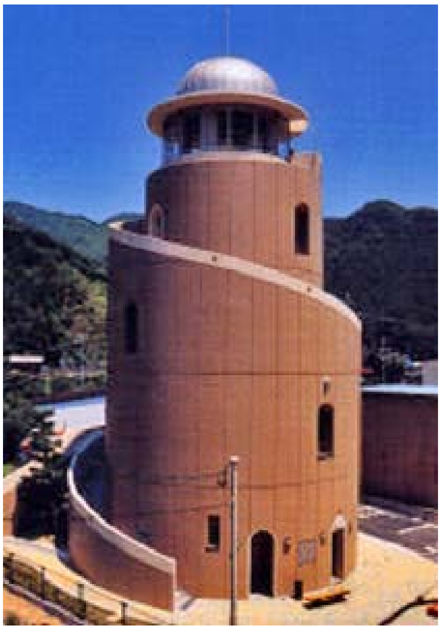


Fig. 3.6 Emergency shelter building, Mie prefecture, Japan (Source: Scheer et al., Handbook of Tsunami Evacuation Planning, 2011. Retrieved from: http://www.webmie.or.jp)

After the devastating tsunami in 1993, artificial vertical shelters have been built along the beaches in Okushiri Island. Seaside places seem to be have negative conditions in terms of the evacuation of a high number of temporarily residing people; however construction of those vertical shelters is a convenient option to compensate that disadvantage which could also be used as panorama platforms.

Fig. 3.7 Elevated platform used on Okushiri Island (Source: Scheer et al., Handbook of Tsunami Evacuation Planning, 2011. Retrieved from: http://ioc3.unesco.org/itic/printer.php?id=20)

Japanese signboards provide the direction to escape, the distance to the next shelter, and the name of the shelter; in Japanese and in English (*Fig.* 3.8). Previous tsunami water levels are posted somewhere on the roadside.

Fig. 3.8 Tsunami Evacuation Map (Source: Shaw et al., 2012, Worldbank KN 2-1, Nonstructural Measures. Retrieved from: Forest Agency, 2011)

In Japan, tsunami evacuation route signs, pictograms on tsunamis as well as the information signs showing the features of past tsunamis are provided in the evacuation zones (Fig. 3.9).

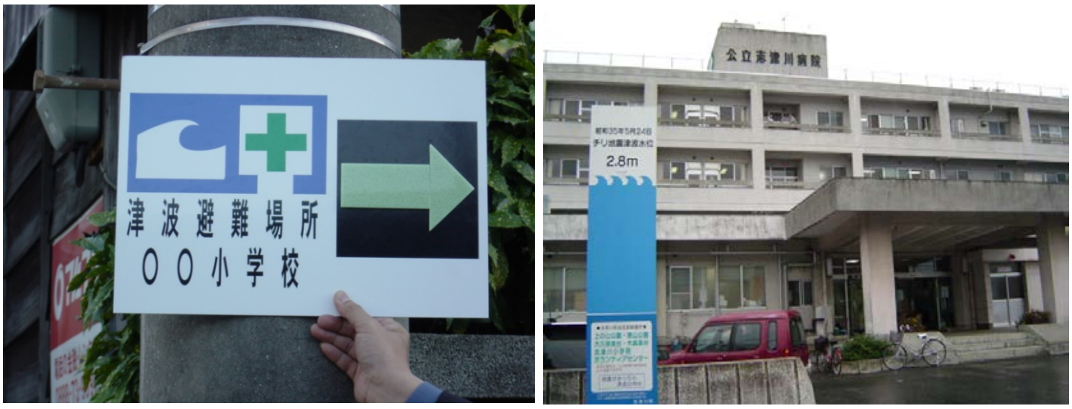


Fig. 3.9 a) Tsunami evacuation route sign b) Sign showing the inundated level of previous Tsunami

Tsunami hazard maps including the locations of evacuation shelters are displayed on sign boards in town and distributed to every household. The purposes of these maps are mainly identifying and showing the vulnerable areas and enhancing public awareness. The National Government prepared a guideline to help the local authorities to make and use tsunami hazard maps. Government of Japan (2009) reported that 493 municipalities throughout Japan have so far published and distributed their hazard maps as of July 2007 (Lassa, 2011).

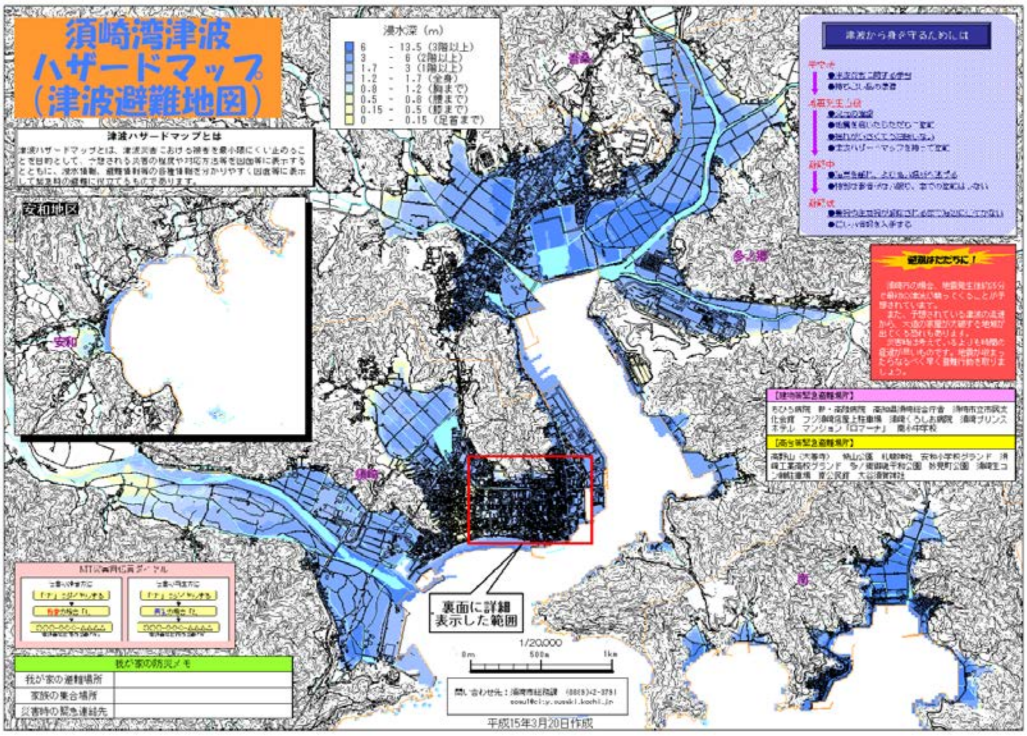


Fig. 3.10 Tsunami Hazard Map for Susaki City, Kochi Prefecture

Most of the evacuation preparedness is also incorporated with the work of voluntary disaster management organisations; over 28 million people are organised in such a way (Scheer et al., 2012). Also, local governments organize tsunami evacuation drills every year on days commemorating past large-scale tsunamis, and people learn how to evacuate safely and quickly from their houses to the shelters.

Fig. 3.11 a) Evacuation Drill on Tsunami in Taro Town, Iwate Prefecture b) Group Session on Evacuation Plan, Urado-District, Kochi Prefecture

3.2.4 Land Use Planning in Japan

Local authorities in Japan have not regulated land use in the tsunami affected areas from a perspective of disaster risk management (DRM). Lowlands had been developed for residential, commercial, and industrial purposes. But economic development and urbanization have increased vulnerability to tsunami disaster in coastal areas. Therefore, the Japanese government is strengthening disaster risk management systems by involving land use regulations based on lessons learned from the GEJE. The Act on Building Communities Resilient to Tsunami was legislated in December 2011 to mitigate against low-probability, high-impact tsunamis with a goal of protection of human lives at all costs.

The Ministry of Land, Infrastructure, Transport, and Tourism has developed some guidelines on tsunami mitigation strategies for prefectures and municipal governments. The guidelines point out that prefectural authorities should classify the risk areas as the yellow zone, the orange zone and the red zone. Yellow zones are the areas where residents are likely to lose their lives. Therefore, evacuation measures, such as evacuation shelters, drills and hazard maps, are required in these zones. In the orange zone, where residents are highly likely to lose their lives, hospitals and other critical structures must be built as tsunami resilient structures. In the red zone where residents have no way to escape from the tsunami, all buildings must also be tsunami resilient, such as having multiple stories that rise high enough to avoid the tsunami water.

3.2.5 Use of Coastal Vegetation in Japan

Utilization of coastal forests along the coasts is one of the traditional countermeasures against tsunamis in Japan. According to the literature on the mitigation effects of coastal forests in Japan, four main functions as the reduction effects are stated (Harada and Imamura, 2005).

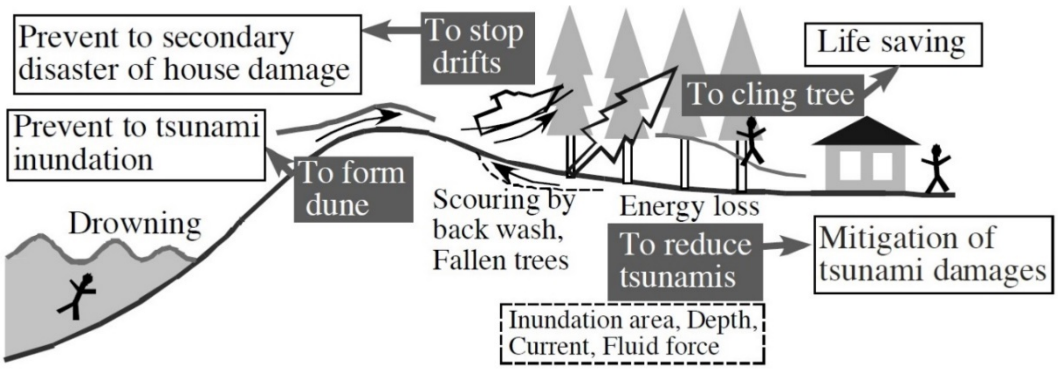


Fig. 3.12 Functions and effects of coastal forest to prevent tsunami disaster. (Source: Harada and Imamura, Effects of Coastal Forest on Tsunami Hazard Mitigation – A Preliminary Investigation, 2005)

These functions can be summarized as:

- to prevent the attack of drifting boats and ships and woods that would be the secondary disaster as destructing the houses more severely (*Fig.* 3.13),
- to reduce the tsunami energy, inundation depth, inundation area, current and the hydraulic force behind the forest,
- to provide lifesaving by holding people who carried away by tsunamis and,
- to form a natural barrier by the function of making dunes and preventing inflow of tsunami because coastal forest prevents also sea wind and wind-blown sand and blown sand accumulation blocked by the forest make dunes higher along the seaside. An example is provided as the case of the Nihonkai-Chubu earthquake tsunami in 1983. The tsunami was reduced by the sand dunes of 10 meter over ground along the coasts of Aomori and Akita Prefectures (Ishikawa, 1988; Murai, 1983).

Fig. 3.13 A floating ship captured by the forest in Hachinohe City, Aomori Prefecture (Source: Shaw et al., 2012, Wordlbank KN 2-1, Nonstructural Measures. Retrieved from: Forest Agency, 2011)

However, in spite of the important role of coastal vegetation in tsunami mitigation, it should be noted that unless the structure of the vegetation is planned properly and their tsunami reduction capacity and limitations are specified, there are possibilities of resulting in secondary damage due to the negative effects of coastal forests such as driftwood damage or gap features as roads or rivers behaving like a channel to the inundation.

3.3 Europe

3.3.1 Overview

Important differences in tsunami source mechanisms within different areas of Europe arise from geological differences between the eastern North Atlantic and the Mediterranean regions (Dawson and Lockett, 2004). The most common sources of tsunami in the eastern North Atlantic are the underwater sediment slides and slumps. Although the occurrence of most tsunamis in the Pacific region has led to a thought that tsunami hazard in Europe is insignificant, the hazard is real according to the European records of tsunami from documentary evidence, together with the identification of tsunami in the geological records. The active tectonics of the Mediterranean has also resulted in numerous tsunami generated by offshore earthquakes.

In Norway, tsunamis may arise from submarine landslides in the NE Atlantic, as well as submarine landslides and rockslides in the fjords. Norway has different strategies to reduce and manage tsunami risk. These include monitoring systems, well organized early warning systems, and capacity building activities for the population, evacuation planning and land use planning. It may be safe to build houses on higher ground outside the tsunami hazard zone, but problems exist due to industrial sites and other buildings that have to be located close to the shore at low altitudes. For the rockslide tsunamis, monitoring of the tsunami combined with early warning is not sufficient due to the short warning time between tsunami generation and a possible impact. For this reason, the landslide areas themselves are monitored and risk and vulnerability analyses are conducted in order to inform and prepare the affected communities and thus reduce the risk to an acceptable level. The warnings can be improved by installing seabed pressure sensors for direct measurements of the waves. Such sensors at the bottom of fjords or lakes are capable to distinguish between tsunamis and other kinds of waves, from boats, tides, storm surges, swells, or wind-waves. Another advantage is that the seabed sensors – as opposed to the on-land monitoring of the rockslides - will record tsunamis not only from one single rockslide area.

Since tsunamis in most places are rare, it is important to keep risk awareness and preparedness alive. This may be done e.g. by commemoration days and memorials from former events or by including this topic in the school curriculum, which is also already applied in some schools in Norway can be found in Norway.

A case study has been conducted in Norway exemplifying a multidisciplinary assessment of rockslide tsunami hazard and risk in a complex fjord system (Harbitz et al. 2014). The approach includes five steps: 1) geological and geotechnical fieldwork as well as numerical analyses to assess the stability of the rock slopes; 2) statistical analysis for probability of release and for run-out distance of the rockslides; 3) numerical simulations and laboratory experiments of rockslide dynamics, and of tsunami generation, propagation, and inundation; 4) hazard and risk analyses; and finally 5) risk assessment and management including the establishment of a preparedness centre for rock-slope monitoring, early-warning systems, public awareness, evacuation plans, and land-use planning.

Results of the study were strategies for risk management including hazard maps (*Fig. 3.14*) and land-use planning. Evacuation zones and routes were designed for the larger scenarios, while smaller and more probable scenarios were applied for location and design of less critical facilities accepted in the corresponding inundation zone. Also an operational tsunami early-warning system was designed (Harbitz et al. 2014).

Fig. 3.14: Example of hazard map for tsunamis from a potential rockslide at Åkerneset impacting Stranda, Sunnylvsfjorden. (Hazard zone up to 10 m.a.s.l., produced by the Åknes/Tafjord project) (Source: Harbitz et al., Rockslide tsunamis in complex fjords: From an unstable rock slope at Åkerneset to tsunami risk in western Norway. 2014)

For the Vaiont dam in Italy, there was concern about the stability, when experts recognized a threat of a landslide and a subsequent tsunami when filling the reservoir completely. Despite monitoring of displacements while filling the reservoir and attempts to control the joint water thrust within the rock mass by means of drainage tunnels, the project failed and a landslide was triggered generating a wave which crested 140 meters above the top of the dam and that still had a height of about 70 m downstream, at the confluence of the Vaiont with the Piave Valley. No evacuation or warning activities are known. The event pointed out the importance of modelling and monitoring as well as appropriate mitigation measures (Harbitz et al. 2014). Further detailed information is provided in Semenza (2005) and Ghirotti (2012).

In Switzerland hydropower reservoirs may be at risk to different kinds of mass movements generating tsunamis. Therefore, slope stability is assessed every five years, potentially unstable slopes are monitored, and larger reservoirs are even equipped with an alarm warning the people affected (Harbitz et al. 2014).

In the Netherlands, for the analysis of flood risk management measures Slomp (2012) suggests to use the “Multilayer safety concept”. In this concept, flood risk management can be separated into three layers (Fig. 3.6):

- (3) Flood alerts, evacuation, response and recovery (civil protection issues) most of these issues are organizational, some issues like identifying, checking, repairing/restoring and signaling evacuation routes are physical measures.
- (2) Spatial planning issues, reducing the impact of flooding through spatial planning measures, not building in flood prone unprotected areas, or through building codes (adapting houses to regular flooding, raised houses or floating houses)
- (1) flood protection, flood defenses to reduce the probability of failure of flood defenses (Slomp, 2012)

Since 1953 the Netherlands have privileged flood protection. This choice has found its way in legal standards for flood defenses (Slomp, 2012).

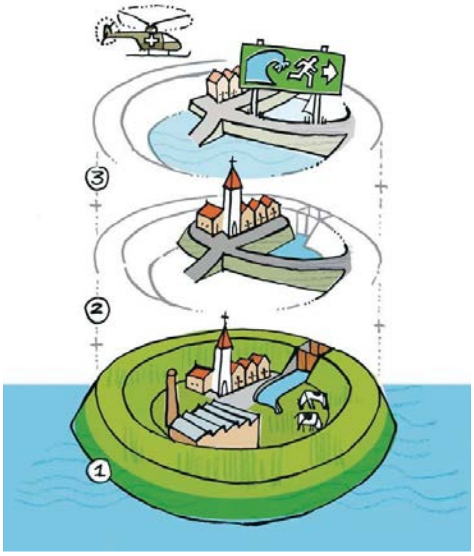


Fig. 3.6 "Multi-layer safety concept" for Flood Risk Management in the Netherlands (Source: ''Flood Risk and Water Management in the Netherlands'', Slomp, 2012)

3.3.2 *Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and Connected Seas, NEAMTWS*

The effects of a large tsunami in the Northern Atlantic, the Mediterranean and Connected Seas would be more disastrous than in the case of historical events, given the huge increase in coastal development in modern times. Because of the relative infrequency of tsunamis, but knowing that tsunamis can have widespread impact across oceans and seas, the UNESCO/IOC and its Member States have been supporting their Intergovernmental Coordination Groups (ICGs) for the regular conduct of tsunami exercises. By the end of 2011, The North-eastern Atlantic, the Mediterranean and Connected Seas (NEAM) region was the only region in the world where a Tsunami Warning System was not yet in operation. The ICG/NEAMTWS was established as subsidiary body of the IOC, at the 23rd Session of the IOC Assembly in June 2005 through the Resolution XXIII-14 (IOC Technical Series, 2012).

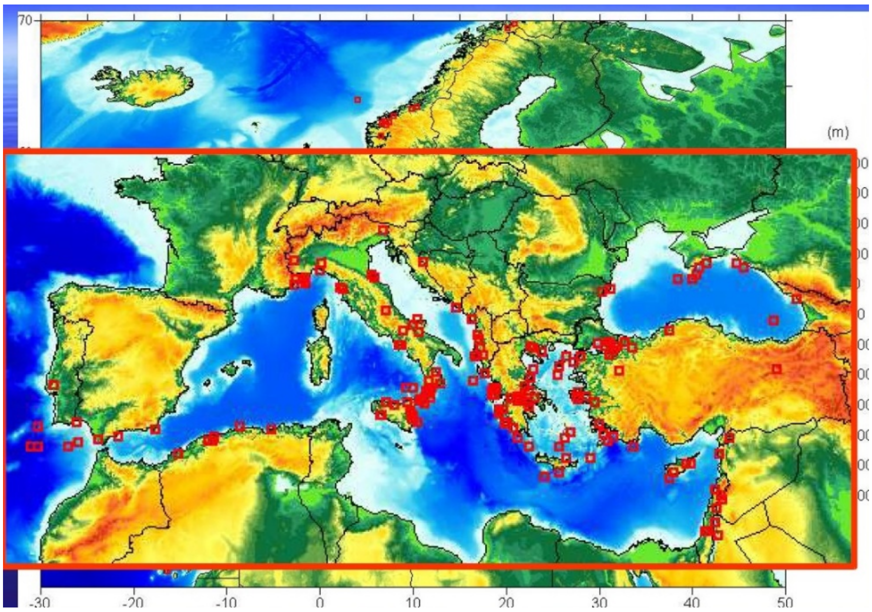


Fig. 3.15 Tsunamis in the NEAM Zone (Source: Zaniboni, International Workshop on Tsunami Modelling, JRC, 2006)

Two initial communication test exercises in 2010 were followed with the involvement of all the Tsunami Warning Focal Points (TWFP) in the 31 countries of the NEAM region. On 22 May 2012, a second communication test was carried out with the additional aim of a preparatory exercise for NEAMWave 12. As of September 2012, several National Tsunami Warning Centers (NTWC) have been established, and some have also declared their availability to operate as Tsunami Watch Provider in interim status. NEAMWave 12, as the first Tsunami Exercise in NEAM, attempted to assess the national and local warning dissemination and response mechanisms put in place by Member State CPAs upon the reception of a Tsunami warning from their TWFPs. In addition, NEAMWave 12 also addressed the questions related to the evaluation of alert messages by Candidate Tsunami Watch Providers (CTWP) and the issuance of the tsunami messages to TWFPs, as in the previous communication test exercises.

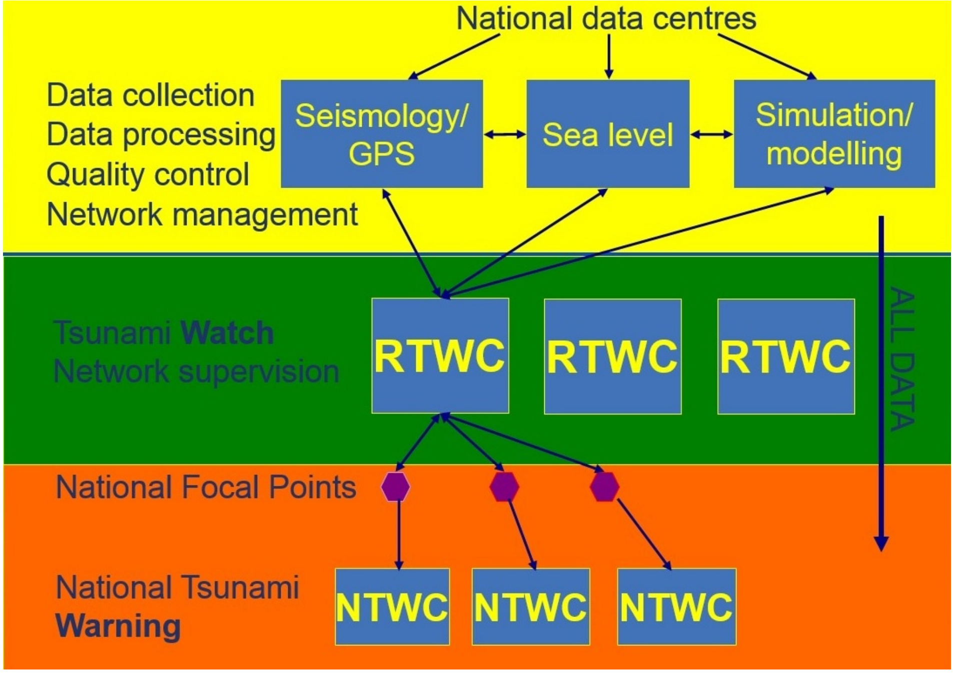


Fig.3.16 Architecture of NEAMWTS (Source: IOC Technical Series, 2012)

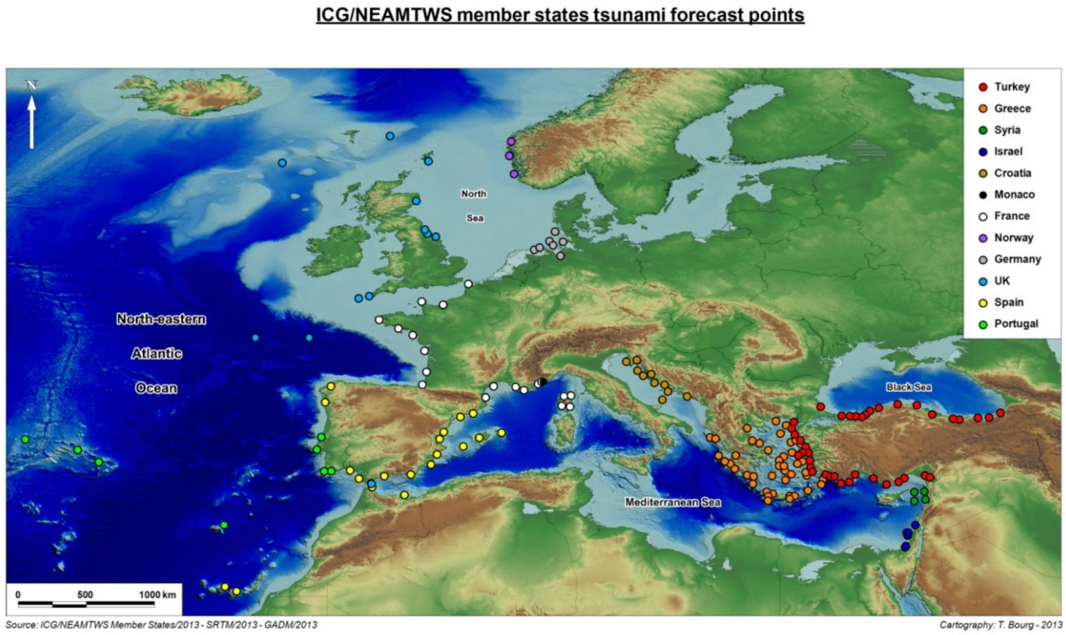


Fig. 3.17 ICG/NEAMTWS member states tsunami forecast points (Source: ICG/NEAMTWS Member States Forecast Points Guideline, 2013)

Several objectives were held within the Intergovernmental Coordination Group for the NEAMTWS. Some of them are to promote the implementation of the ICG/NEAMTWS within a multi-hazard framework and to develop a comprehensive programme of capacity-building on tsunami protection for the north-eastern Atlantic, the Mediterranean and connected seas. Therefore, four intersessional working groups were been established in Rome (November, 2005) as; hazard assessment, risk and modeling group (WG1), seismic and geophysical measurements group (WG2), sea level data collection and exchange, including offshore tsunami detection and instruments (WG3) and finally the group of advisory, mitigation and public awareness (WG4).

Specifically, the Working Group 4 reviews existing practices for mitigation response (emergency and planning) to tsunami and other marine-related hazards in the region with special attention to advisory messages, identifying shortcomings and making recommendations for response procedures appropriate to the region within the context of integrated coastal area management. It will assess perceptions of risk in respect of marine-related hazards, examine the human impacts that contribute to the vulnerability of coastal communities, and make recommendations on how vulnerability could be reduced. It will also promote tsunami education and awareness programmes in the region. The WG 4 recommends that the use by Regional Tsunami Watch Centers of the term “warning” should be avoided. The WG 4 further recommends that the Regional Tsunami Watch Centres use two classes of tsunami alert – “advisory” for a lower level of alert; and “watch” for a higher level. Therefore ,within the completion of the system is realized, recommendations for guidance to authorities will be prepared that relate in general to coastal flood risk management in the context of ICAM (ICZM). They will concern the well-being of coastal communities that are threatened by inundation not only from tsunamis, but also from other catastrophic marine physical hazards including storm tidal surges and unusually large, wind-induced waves.

Table 3.1 Characteristics of, and responses to, marine physical hazards (Source: ICG/NEAMTWS Member States Forecast Points Guideline, 2013)

MARINE HAZARD →	**Tsunami**	**Storm surge***	**Extreme wind-forced waves***	**Long-term sea-level rise**
Likely frequency of event	Decades to millennia, depending on regional tectonic regime	Months to decades, depending on regional climate regime	Months to decades, depending on regional climate regime	On-going, a consequence of global warming and local factors
Type of impact	Initial withdrawal; catastrophic inundation and drainage surges, may be multiple	Catastrophic, single-event inundation	Multiple, localized inundation and drainage surges	Progressive rise of mean high (tidal) water level
Limits of area likely to be affected	Local run-up limit for specified wave amplitudes predicted by modelling	Flood limit for specified surge level predicted by terrain modelling	Flood limit for specified wave heights predicted by terrain modelling	Mean high water mark predicted by terrain modelling with allowance for extreme events
Potential warning time	Minutes to hours, depending on proximity of source location	Hours to days, depending on climatic factors	Hours to days, depending on climatic factors	Decades to centennia
Action by Regional Watch Centre(s)	Issuance of Watches and event information to National Warning Centres			No action
Action by National Warning Centre(s)	Issuance of Warnings to appropriate Local Authorities			No action
Emergency actions by Local Authorities	Launch of emergency response action on receipt of Warning			No action
Mitigation and adaptation by Local and National Authorities	Vulnerability assessment of coastal populations, ecosystems, and infrastructure; Strategic spatial planning and regulation to minimize exposure and vulnerability: Participatory approach; Decision tools and software for analysing hazard loss and risk			
	Public awareness and readiness campaigns, including recognition programs and emergency response exercises (preparedness) and education (preparedness and adaptation); Promoting community resilience.			

It is stated by the Working Group 4 that a key consideration in the preparation of the guidelines will be the assessment of the risk of flooding and its consequences, geographically, socio-economically and temporally. In regard of their statements, within the region, the Mediterranean Sea coasts – and especially the eastern Mediterranean – have the greatest incidence of tsunami impact, while Northern Europe's coasts have the greater risk of storm surge events – southern North Sea coasts and estuaries being most prone. In particular, it is important that implementing national and local authorities understand the levels of vulnerability of coastal communities and infrastructure, as well as the nature of the hazard impacts, including the likely warning time for potential emergency response, the possible return periods of tsunami and storm surge events, and the timescales over which significant sea-level rise may occur.

3.3.3 Practice of evacuation planning in Europe

Very little information is available on tsunami evacuation and relevant plans in Europe. With regard to the framework of the FP6 European co-funded SCHEMA project based (SCenarios for Hazard-induced Emergencies MAnagement, www.schemaproject.org) tsunami test sites it can be stated:

There are no specific evacuation plans against a tsunami event for the region of Setúbal in Portugal. The warning systems and the actions to be taken are directed by the Portuguese National Authority of Civil Protection in the event of a natural disaster. There is a main office that directs the plans to the local offices, search and rescue teams. The rescue teams consist mainly of firefighters and the Red Cross (Scheer et al., 2011). The local fire department of Setúbal Region has recently completed a study about flooding specific to the city which shows the potential flooding areas according to the intensity of the rain. The strategies for these cases are to go to higher ground areas, and this study points out the following parameters:

- Which places are the best choice to go;
- The best route to access to those places;
- The places where the warning and guiding signs would be;
- Which places could be accessible to the rescue teams and what type of equipment could be used in these specific areas?

This study also contemplates other secondary hazards, like fire, and for this there would be specific places with firefighting equipment (Ribeiro J., 2011).

Stromboli Island, where several local tsunamis had happened, is has a network of sign boarded evacuation routes but the signs are quite different from other international signs. Also, in spite of the continuous hazard (volcanic activities leading to landslides into the sea resulting in tsunami waves) in Stromboli region, the governors intentionally try to deny the risk, due to the fact that tourism sector in the area plays an important role in the economy.

Other municipalities in nearby Calabria and Sicily had implemented local emergency programs due to the waves triggered by the volcanic activities in Stromboli. For instance, the municipality of Sicily has applied an emergency plan also including a framework of the various local and regional authorities as well as a map indicating those areas under flood risk along the municipality-owned coastline (*Fig.* 3.18).

Furthermore, this map shows the general aspects of the escape routes, the areas for waiting and particular buildings, like schools that lie within the inundation zone.

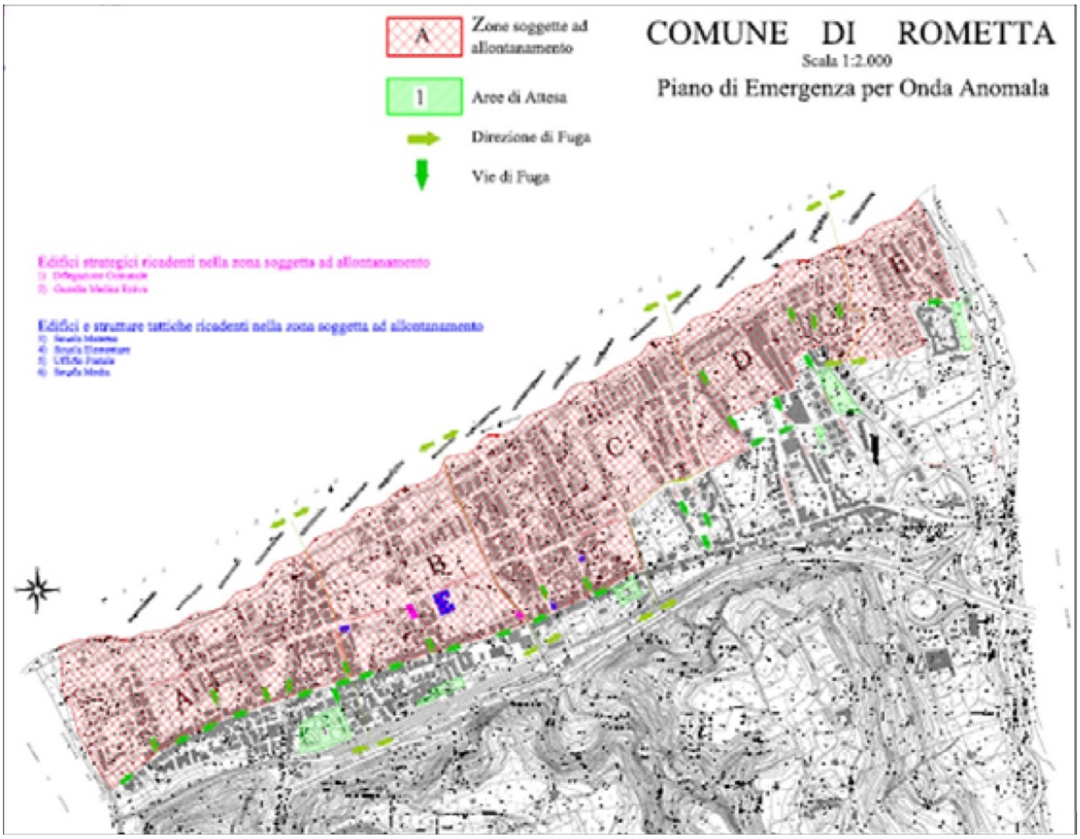


Fig. 3.18 Emergency scenario elements map. (Source: Scheer et al., Handbook of Tsunami Evacuation Planning, 2011. Retrieved from: Comune di Rometta, 2008)

4 Summary and Concluding Remarks

The study has identified the existing structural and non-structural tsunami mitigation strategies in Japan and Europe. The focus has been mainly on structural protection against tsunamis in terms of structural mitigation where many of the coastal protection structures mitigation have been discussed in Deliverable 3 - Comparison of coastal structures in Europe and Japan (http://www.ngi.no/en/Project-pages/RAPSODI/Reports-and-Publications/). The main tsunami source mechanisms differ significantly in Japan and Europe. The most common tsunami sources in the Northeast Atlantic are submarine landslides as well as subaerial rockslides in lakes and fjords, while the active tectonics of the Mediterranean have also caused numerous tsunamis generated by offshore earthquakes. In Japan, co-seismic tsunamis are most common because of its position along a subduction zone.

Coastal dikes are the primary coastal structures built against tsunamis in Japan as well as other four main types of structures such as tsunami barriers, water gates, breakwaters and green belts. The Japanese design approach includes mainly the historical records of tsunami heights, but it is based on storm surge predictions as well in some areas. They have also followed a two-level approach for the design parameters after the Great East Japan Earthquake event. This approach requires all the coastal protection structures to resist a tsunami of a 100-year return period. On the other hand, the design should resist as long as possible for much larger tsunamis such as an event with a 1000 year return period. Information about tsunami mitigation structures in Europe is very limited where only in Norway, constructing dikes against tsunamis is encountered as a structural measure. Although in Europe neither such a variety of coastal structures nor a developed design approach specifically against tsunamis exist, there are extensive storm surge protection measures designed for extreme (100 to 10000 years) events.

A typical Baltic Sea coastal and flood protection which protects the coastline against erosion and in case of storm surges can be found in *Fig.* 4.1 and *Fig.* 4.2.

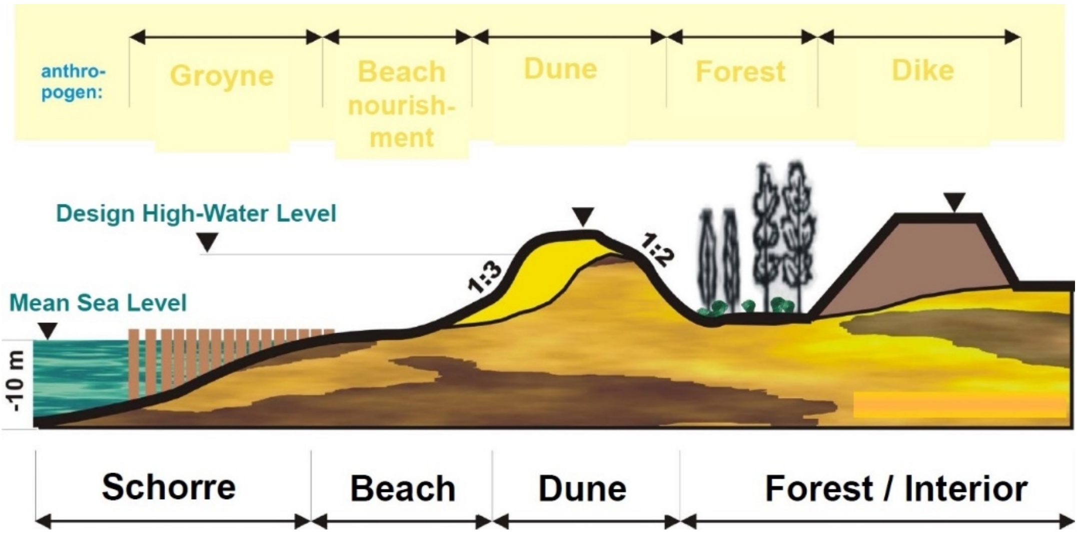


Fig. 4.1 Illustration of Coastal and Flood Protection, Baltic Sea. (Source: "Coastal Protection in Germany" Course Lecture Notes, Coastal Engineering Research Group, University of Rostock)

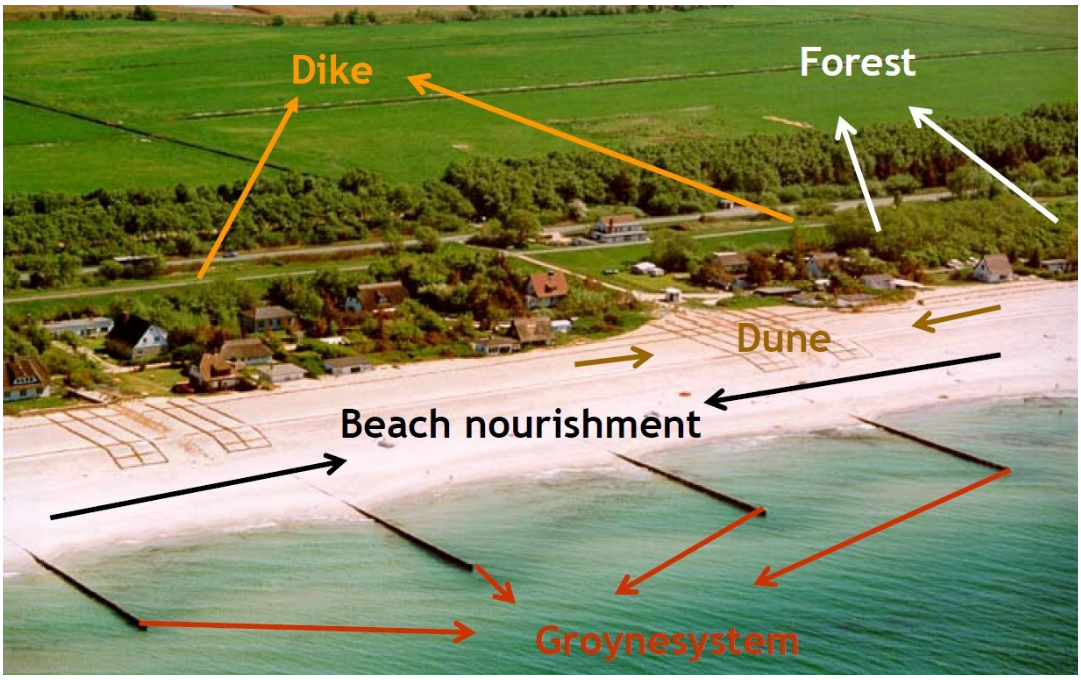


Fig. 4.2 Coastal and Flood Protection, Baltic Sea (<u>Source:</u> "Coastal Protection in Germany" Course Lecture Notes, Coastal Engineering Research Group, University of Rostock)

Tsunami countermeasures in Tohoku region are illustrated in *Fig. 4.3* and *Fig. 4.4* As given in the Great East Japan Earthquake experience study of the Dutch according to their post survey and analysis of the event (Tsimopoulou, 2012).

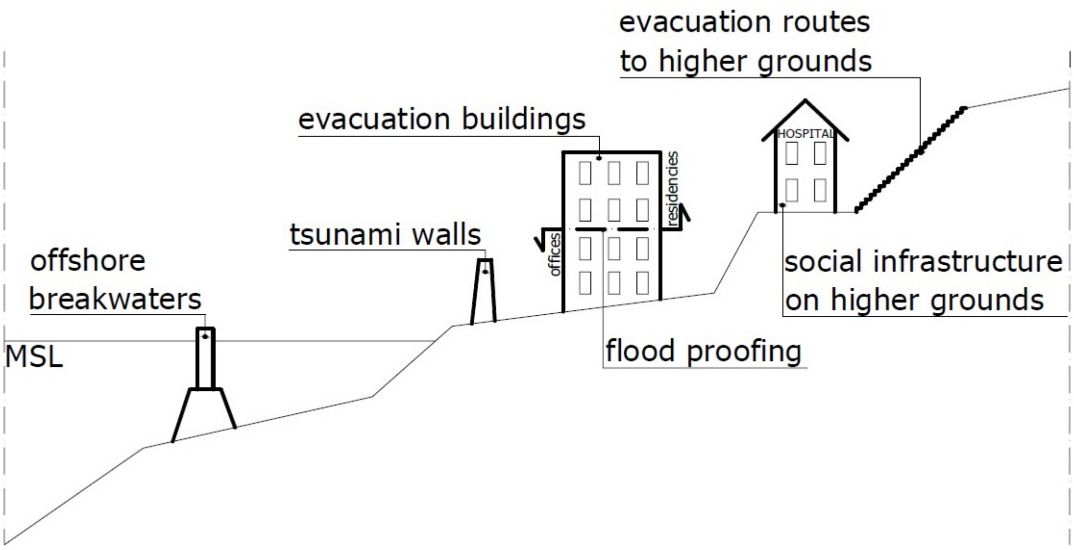


Fig. 4.3 Tsunami countermeasures in the rias (MSL=mean sea level). <u>Source:</u> Tsimopoulou, V., The Great Eastern Japan Earthquake and Tsunami: Facts and implications for flood risk management, 2012

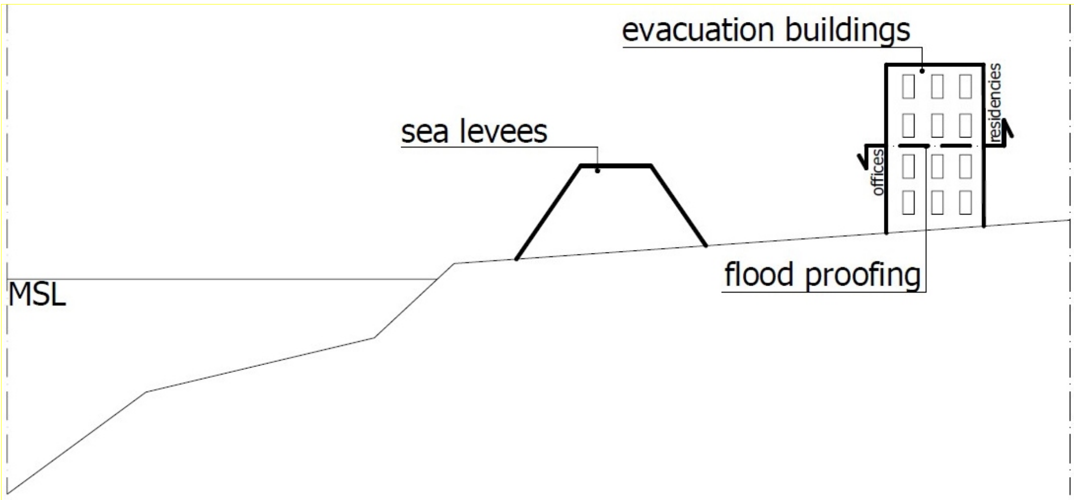


Fig. 4.4 Flood risk countermeasures in flat plain region (MSL = mean sea level). (Source: Tsimopoulou, V., The Great Eastern Japan Earthquake and Tsunami: Facts and implications for flood risk management, 2012)

Figs. 4.1 to 4.4 show typical defence systems in Europe (against storm surges and erosion) and in Japan (against tsunami and storm surges). Although none of the two examples represent all of the defence systems which can be found in these areas they already show some key characteristics which are worth to be looked at in more detail:

- Both systems rely on different mitigation measures rather than just one. At the Baltic Sea this is the high foreshore, groynes, beach nourishment, a dune, a coastal forest and a dike. Note that the number of mitigation options may differ from only one to several ones like in this example. In Japan the defences are typically man-made and ranging from offshore breakwaters over tsunami walls, sea walls, evacuation buildings and buildings on higher ground.
- Large systems in Europe are natural defences like beaches and dunes which are maintained. Therefore, very often the ‘mitigation’ in Europe means to keep natural systems in their original condition, e.g. by sand nourishments. In Japan, due to the high loadings of defences induced by tsunamis and storm surges, this would in most cases be insufficient to defend the coastal areas so that hard measures (e.g. concrete seawalls) are needed.

It should be noted that in Japan evacuation and the respective buildings is very often a part of the coastal defence strategy whereas in Europe coastal authorities often rely on natural or anthropogenic mitigation systems. Of course, as said before, there are exceptions to these observations.

Furthermore, in Japan, many non-structural measures such as tsunami and earthquake warning systems, community-based disaster risk management, evacuation and land-use planning as well as the use of coastal vegetation exist. The fact that tsunami mitigation must be an integration of several different approaches has been highly recognized. On the contrary, only some of those non-structural measures exist in

Europe. In Norway there is monitoring of unstable rock slopes combined with early warning, and capacity building activities for the population. The Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and Connected Seas (NEAMTWS), is also an initiative worth mentioning. There are currently three National Tsunami Warning Centres functioning as Candidate Tsunami Watch Providers (CTWPs) for the entire region, the Centre d'alert aux tsunami in France, the Kandilli Observatory and Earthquake Research Institute in Turkey, and the National Observatory of Athens in Greece. The Tsunami Watch Providers (TWPs) are in charge of: the observation and the detection of the phenomenon, the analysis of the data received in real time or quasi-real data, and sending warning messages to Tsunami Warning Focal Points (TWFP). Additionally, there are some examples of community based evacuation planning in Portugal and Italy.

All in all, it can be stated that structural and non-structural tsunami mitigation measures differ greatly in Japan and Europe due to the difference in existence and perception of the tsunami risk. There is a great variety of measures in Japan extending from constructing coastal dikes of advanced design to community preparedness and protection by coastal vegetation, although some gaps and deficiencies exist. In Europe, tsunami mitigation is rare and limited to a few types of actions. This could be attributed to the fact that the occurrence of most tsunamis in the Pacific region has led to a thought that tsunami hazard in Europe is insignificant, but the hazard is real according to the European records of tsunami both from documentary evidence and the geological records. Similarly, Europe having a much longer natural coast line utilizes the concept of soft and hard measures in combination. The natural protection defences such as dunes are mostly integrated into the hazard mitigation strategies. On the other hand, Japanese mitigation strategies usually consist of hard measures considering the large amount of artificial shoreline. Therefore, it can be suggested that more actions on tsunami mitigation should be taken in Europe considering new research on sources, risk, and performance of existing structures under tsunami loading whereas the mitigation strategies in the Japanese side should be enhanced for a more resilient system against tsunamis.

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Review and reference page

Document information			
Document title Deliverable D¤ - Comparison of mitigation strategies in Europe and Japan			***Document No.*** 20120768-04-R
Type of document Report	***Distribution*** Limited		***Date*** 1 June 2014
			Rev. No & date 1 / February 2015
Client CONCERT-Japan Joint Call Secretariat			
Keywords			

Geographical information	
Country, County	***Offshore area***
Municipality	***Field name***
Location	***Location***
Map	***Field, Block No.***
UTM-coordinates	

Document control

Quality assurance according to NS-EN ISO9001

Rev.	Reason for revision	Self review by:		Colleague review by:		Independent review by:		Inter-disciplinary review by:	
0	Original document								

Document approved for release	**Date**	**Sign. Project Manager**
	1 February 2015	Carl B. Harbitz

Template rev. date: 2014-03-13

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