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REDUCING AND MANAGING THE RISK OF TSUNAMIS

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REDUCING AND MANAGING THE RISK OF TSUNAMIS

ICG/NEAMTWS Working Group 4
Public Awareness, Preparedness and Mitigation

Guidance for National Civil Protection Agencies and Disaster Management Offices as Part of the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas Region – NEAMTWS

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FOREWORD

This document provides guidance to national Civil Protection agencies and Disaster Management Offices in countries of the North-eastern Atlantic, the Mediterranean and Connected Seas region in their assessment and management of risks to countries' coastal populations. The guidance is specific to the tsunami hazard but within a multi-hazard context. Its publication fulfils part of the implementation of the Intergovernmental Coordination Group (ICG) of the Tsunami Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas (NEAMTWS, Annex 1), coordinated by the Intergovernmental Oceanographic Commission (IOC) of UNESCO. It has been produced by Working Group 4 (Public Awareness, Preparedness and Mitigation) of this ICG.

The guidance aims to support and supplement countries' established procedures in respect of preparedness for, and response to, natural hazards and disasters. It highlights the special features of the tsunami hazard and the particular challenges faced by Civil Protection agencies in being prepared for, and responding to, a tsunami event. The guidance has been compiled within the multi-hazard context of the "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters" (UN/ISDR, 2005). It promotes the need for a multi-sectoral approach, introducing risk reduction measures – mainly prevention and mitigation – e.g., in land-use and urban planning, environmental management, health, agriculture, education, transport, construction and tourism.

For maritime countries within the European Union (EU), the guidance relates to the establishment or strengthening of National Platforms or focal points for disaster risk reduction, as promoted by the Hyogo Framework. It is relevant to the requirements of the EU's Floods Directive of 2007 in which Flood Risk Management Plans, focused on prevention, protection and preparedness, are required to be in place by the year 2015 (Box 2.7). The guidance also relates to the requirements on Mediterranean countries that are Contracting Parties to the Integrated Coastal Zone Management Protocol of the Barcelona Convention, adopted in 2008 and entered into force in March 2011. The Parties have obligations in respect of risks affecting the coastal zone, including natural hazards and responses to natural disasters (Articles 22 and 24) (UNEP, undated). These parties include all EU Mediterranean Member States.

The document draws on UNESCO-IOC publications including IOC Manuals and Guides Numbers 49 (UNESCO, 2008), 50 (UNESCO, 2009a) and 52 (UNESCO, 2009b), and the Tsunami Glossary (IOC, 2008b). It acknowledges the contributions of the United Nations International Strategy for Disaster Reduction (UN-ISDR) in their provision of advice on disaster risk reduction, including tsunamis. The outputs of EU research projects TRANSFER and SCHEMA provide important reference material. The document aims to avoid the duplication of general advice relating to natural hazard management that is available elsewhere. The document should be used in conjunction with the Interim Operational Users Guide for the NEAMTWS for large-scale tsunamis, which provides users of the system with, *inter alia,* technical detail on tsunami detection and messaging protocols.

Wendy Watson-Wright
Assistant Director General, UNESCO
Executive Secretary of IOC

EXECUTIVE SUMMARY

THE DISASTER RISK REDUCTION CONTEXT

The tsunami hazard is one of several natural hazards that result in the inundation of low-lying coastal land. Because coastal areas are increasingly favoured for development and recreation, the exposure of people and their supporting assets to these hazards is also on the increase. Depending on the likelihood of incidence of such hazard events, the risks of losses of people and damage to community assets are also rising. This guidance document is intended to assist those engaged in Civil Protection in their understanding and assessment of the risks to which their communities may be exposed in respect of the tsunami hazard. It describes the ways in which those risks can be reduced and managed as part of countries' wider natural disaster risk reduction strategies.

UNDERSTANDING THE LIKELIHOOD OF A TSUNAMI IMPACT AND THE RISKS TO YOUR COMMUNITIES

Whereas coastal flooding hazards such as extreme wind-driven waves and storm surges tend to occur sufficiently frequently for communities to be aware of them and their consequences, the tsunami hazard is generally a rare, or even very rare, event within the region. However, geological and historical records bear testimony of their occurrence, the latter documenting major losses of life. In parts of the region, damaging events have occurred within living memory.

Unlike storm surge and extreme wind-driven waves which are climate-related events that can be forecast a few days ahead, most tsunamis are generated by movements on faults in the earth's crust whose timings and magnitudes are unpredictable. Depending on the location of the tsunami's source, there may be very little time (from a few minutes to 2-3 hours) for people at risk to evacuate to places of safety.

This guidance aims to assist countries in their assessment of the risk of the tsunami hazard to their coastal populations. It summarises the procedures for analysing the possibility and the probability of a country's coasts being impacted, taking into account potential tsunami sources (usually known earthquake zones), the record of past impacts and computer modelling of tsunami propagation and inundation. The outcome of this hazard analysis should provide countries with the information they need to decide on their course of planning action and policy response. If the hazard is perceived as being very low, this might be to take no action.

For higher levels of perceived hazard, Civil Protection agencies may want to know about the consequences of the tsunami hazard to their population and its supporting assets. For this, the guidance describes the procedures for assessing a community's vulnerability – its potential for loss and damage in the event of a credible tsunami scenario. The risk of such loss and damage is a function of the probability of the event, as derived from the hazard analysis.

DISASTER PREVENTION AND RISK REDUCTION THROUGH STRATEGIC MITIGATION, EARLY WARNING AND PREPAREDNESS

The following chapters of the manual consider the procedures for reducing the risk of disaster, or, best of all, taking action to prevent it. For this objective, the guidance continues with a description of the options for structural (such as coastal protection) and non-structural (such as strategic land-use planning, development set-back) mitigation measures that could be implemented, preferably in the context of ICAM (Integrated Coastal Area Management), taking account of other natural hazards, as well as social, economic and environmental issues.

The next aim of the manual is to provide Civil Protection personnel with a basic understanding of the core early warning features of NEAMTWS. These provide an “end-to-end” system of event detection, information processing and messaging which is designed to provide warnings and related information to people at risk in the shortest possible time after a potentially tsunami-generating earthquake. The system depends on the interoperability of its component parts. The management of each part (regional tsunami forecast and information providers, national warning centres, disaster management organisations and related emergency agencies) is governed by its specific standard operating procedures so that their operators know precisely what actions are to be taken in an emergency, even if such an emergency is a very rare event.

The final objective of the guidance manual is to outline procedures for making the coastal communities and administrators at all levels aware of the nature and consequences of a tsunami impact, and for evacuation from a forecast inundation. Enhancing a community’s knowledge of the natural warnings of near-source tsunamis and of the level of preparedness to respond quickly and in an orderly manner to an emergency are key activities. The procedures for evacuation planning are described, followed by a statement of the need for Civil Protection organisations to demonstrate and maintain a capability to respond effectively to a rare, though possibly devastating event by carrying out drills and exercises.

1. INTRODUCTION

1.1 TSUNAMIS—WHAT ARE THEY AND WHY SHOULD YOU BE PREPARED FOR THEM?

Tsunamis are one of the natural hazards that result in the inundation and/or erosion of coastal land, and affect the safety and security of communities, their economies and their supporting ecosystems. Compared with the incidence of flooding from extreme waves or storm surges, the tsunami hazard is, in most parts of the region, a rare, or even very rare, event. Despite this, there are good reasons why tsunamis should be included within maritime countries' policies and management approaches that aim to prevent or reduce the risk of these natural disasters.

A tsunami is a series of travelling waves of extremely long length and period, generated by a vertical displacement of the sea bed; the commonest causes are submarine earthquakes. In the deep ocean, tsunamis may be unnoticeable due to their small slope. Their speed may be in excess of 700 km/hr but, as they enter shallow coastal waters, they slow down, their wavelengths shorten and their wave heights increase. On their impact at the coast, the waves may be several metres high (Fig. 2.3).

Tsunami events become disasters when they harm people and damage property. When a tsunami wave inundates a low-lying coastal area, it creates strong landward currents which exert potentially destructive forces on anything in their pathway. Anything moveable may become entrained. Following the peak of the inundation, its drainage forms strong seaward currents – the draining waters being charged with debris of all sorts (potentially including people) that may be carried out to sea. The arrival of a tsunami at the coast may be presaged by a temporary fall in coastal sea level causing an unusual marine recession.

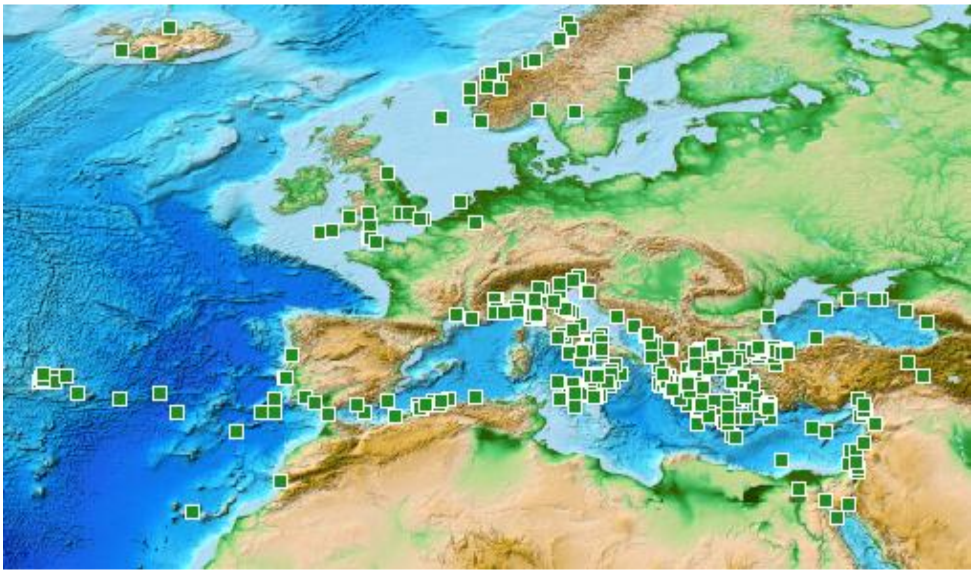


Fig. 1.1. Locations of all recorded tsunami events in the NEAMTWS region.
Source: United States National Geophysical Data Center /World Data Center.
http://map.ngdc.noaa.gov/website/seg/hazards/viewer.htm

In the region covered by the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas (NEAMTWS), the likelihood of significant tsunami impacts on coasts bordering the North-eastern Atlantic Ocean in northern European countries may be considered to be low. In contrast, the likelihood of damaging events affecting the coasts of southern European countries and of northern African countries flanking the Mediterranean – all seismically active areas – is much greater (Fig. 1.1). Most of the seismically active countries within the NEAMTWS region have large coastal populations that may be at risk. In many cases their population numbers become hugely swollen by seasonal visitors.

For a more detailed overview of tsunamis, the IOC International Tsunami Information Centre (ITIC) brochure “Tsunami, The Great Waves” and the “Tsunami Glossary” are recommended reading (IOC, 2008a, b). Another IOC product, “Tsunami Teacher”, an information and resource toolkit, is available online (UNESCO IOC, undated) and as a DVD.

1.2 THE ROLE OF NEAMTWS IN DISASTER RISK REDUCTION

Through their participation in NEAMTWS, maritime countries of the region have a facility to achieve a significant reduction in the risk of disaster to their coastal communities and their related economies that is posed by the tsunami hazard. The provision and delivery of real-time information on tsunami events and of warnings to people at risk forms the core of the system. In addition NEAMTWS embodies the important pre-event functions of forecasting and understanding the risks of a tsunami impact and improving public awareness and preparedness to act in an emergency. Ideally, countries’ Civil Protection agencies in receipt of information through the regional NEAMTWS network that they are likely to suffer a tsunami impact will be prepared to the extent that:

- they are already aware of the local nature and limits of inundation to be expected from credible tsunami scenarios on their coasts (Section 2.2);
- are aware of their vulnerabilities and risks in respect of tsunami inundation (Section 2.3); and
- have emergency plans and procedures in place to deal with evacuation and the safeguarding of lifeline services in the event of inundation (Section 5.3).

Additionally, they may have adopted a disaster prevention policy, involving structural or non-structural mitigation measures to reduce the physical, social, economic and environmental consequences of a tsunami impact (Chapter 3).

Local preparedness and commitment are critical elements for the success of NEAMTWS. An effective tsunami warning and mitigation system is achieved when all persons in coastal communities at risk are prepared and respond in a timely manner upon recognition that a potentially destructive tsunami may be approaching. Ultimately, the system will be judged on its capacity to save lives and minimize damage and losses. Warnings must reach Civil Protection agencies with responsibilities for the safety of critical populations and facilities in the shortest possible time, in order to start the emergency response. For locally sourced tsunamis, which could come ashore within a few minutes, there may be time only to implement certain reactive measures, such as closing critical utility services. For tsunamis from more distant sources (far-field), there may be sufficient time for emergency response agencies to superintend the evacuation of exposed and vulnerable people.

The most important activity for building an effective end-to-end tsunami early warning system is stakeholder coordination. Additionally, high-level government advocacy and commitment are needed to make the system sustainable. Successful systems require cooperation at all levels, a commitment of all stakeholders to work together, not only during an actual tsunami warning emergency, but over the long-term, with a sustained effort to maintain high-level states of awareness and preparedness.

To build organisational support and long-term commitment, a Tsunami Coordinating Committee is a mechanism that can bring together stakeholders from government and non-government agencies, science researchers, and the private sector (Fig. 1.2). Such a committee, possibly embedded in a framework of Integrated Coastal Area Management (ICAM; UNESCO, 2009a), can enable and advocate for policies, initiate needed mitigation programmes, and coordinate emergency procedures before, during, and after a damaging inundation.

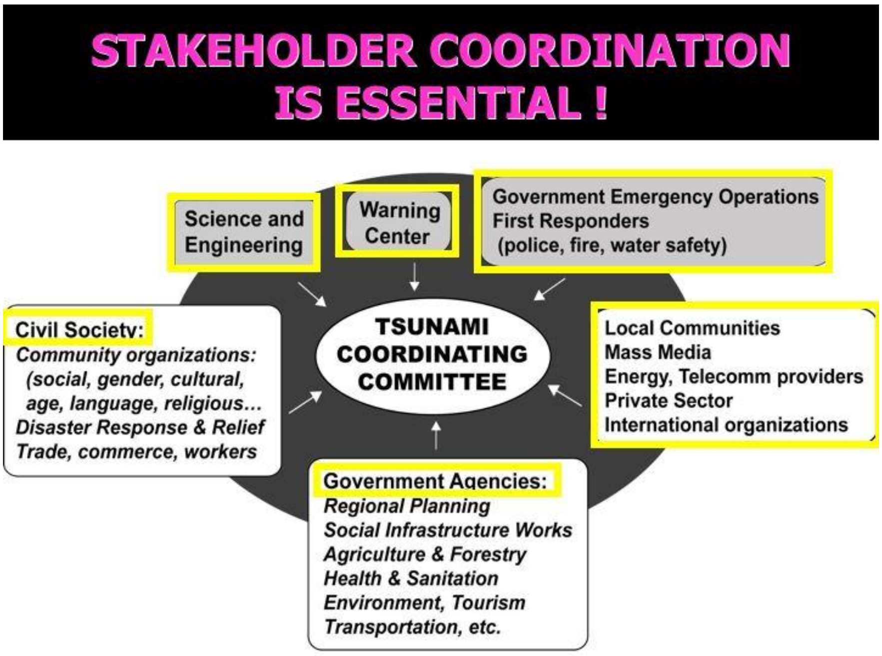


Fig. 1.2. Stakeholder coordination is essential.
A Tsunami Coordinating Committee engages all stakeholders to develop and participate in comprehensively reducing the risk from tsunamis. Key contributors are the scientists and engineers who assess and evaluate the risk, the tsunami warning centre which is responsible for rapid alerts, and government emergency services which must evacuate people before the tsunami arrives.
Source: ITIC.

1.3 WHAT DOES THIS MANUAL COVER?

Following this introductory section, the guidance is presented in four parts. Section 2 covers information and procedures within the framework of NEAMTWS that can assist national and municipal authorities to understand and assess the risks that the tsunami hazard can pose to their coastal communities. It reviews the procedures for countries to appraise the likelihood of a tsunami impact on their coasts – information of value in the formulation of national and local disaster risk reduction policies, including prevention, mitigation, preparedness and Civil Protection policies; also the procedures to forecast the likely limits and nature of the inundations caused by such an impact, informing the demarcation of emergency evacuation zones at the local scale (more scientific information on these aspects is given at Annex 3). It describes the processes for the assessment of the vulnerability of coastal communities and their supporting systems exposed to the tsunami hazard, information that is important to all sectors (land use planning, environment, health, agriculture, tourism, housing, etc.) to reduce risk and to emergency managers in planning for the evacuation of people under threat. This leads to an assessment of the likelihood of loss and damage in respect of the tsunami hazard – information of value in prioritizing mitigation efforts, both for emergency response planning and through the implementation of strategic measures such as coastal protection and sectoral and land-use planning.

Chapter 3 is more policy-oriented and deals with strategic mitigation and prevention measures within the NEAMTWS and ICAM (Integrated Coastal Area Management) frameworks, including coastal protection and land-use planning. This section emphasises the priority that countries are encouraged to place on the prevention of natural disasters, not just tsunamis but other marine hazards as well, whether catastrophic, such as storm surge inundation, or slow-onset (creeping) hazards, notably the erosion of susceptible coastal land and the consequences of sea-level rise.

The third part of the guidance (Chapter 4) opens with a description of countries' participation in the "end-to-end" early warning messaging and warning procedures that form the core of NEAMTWS. This section covers the procedures at the national scale for receiving tsunami alerts, then formulating and issuing warnings for action by national Civil Protection agencies. (Detailed coverage of the procedures and protocols for tsunami detection and messaging in respect of large-scale, earthquake-related tsunamis – tsunamis from seismic sources that have a basin-wide propagation potential and can be destructive far from the source – is the subject of the Interim Operational Users Guide in the NEAMTWS).

The final part (Chapter 5) covers the procedures for reducing the risks to coastal communities by enhancing public awareness of the tsunami hazard and by building preparedness for tsunami emergency response at all levels (including the public) to respond effectively to an official warning (or other indication, such as a felt earthquake) of an impending potential tsunami impact. These procedures cover awareness campaigns, the planning and operation of emergency evacuation, and the execution of test exercises and drills to maintain currency of the warning and response procedures. The role of the NEAMTIC (Tsunami Information Centre) is outlined (Box 5.2).

Summarized principal recommendations to Civil Protection agencies and related emergency management organisations are shown as introductory bullet lists within each of the chapters 2, 3, 4 and 5.

2. UNDERSTANDING THE RISKS FROM TSUNAMI IMPACTS

Recommended actions by Civil Protection agencies concerning the assessment of tsunami risk are:

- Determine the potential for a damaging tsunami to impact your coast.
- Determine the probability (likelihood) of a credible tsunami impact on your coast.
- Determine the likely physical nature of the inundation hazard (extent of inundation; current velocities) caused by such an impact.
- Assess the extent and levels of your communities' exposure to this hazard.
- Assess the estimated damage and loss to your communities and their assets in the event of such an impact.
- Estimate the risk to your communities in respect of the tsunami hazard.

This section presents an overview of procedures that provide a country's Civil Protection agency and other organisations involved in emergency management with information about the potential and likelihood of damage and loss to their coastal communities as a result of tsunami events affecting the region. The procedures apply at national to local levels. The procedures provide an essential science base for disaster prevention and risk reduction through the adoption of strategic mitigation measures (Chapter 3); also for building public awareness of, and preparedness for, the tsunami hazard through community education and evacuation planning (Chapter 5).

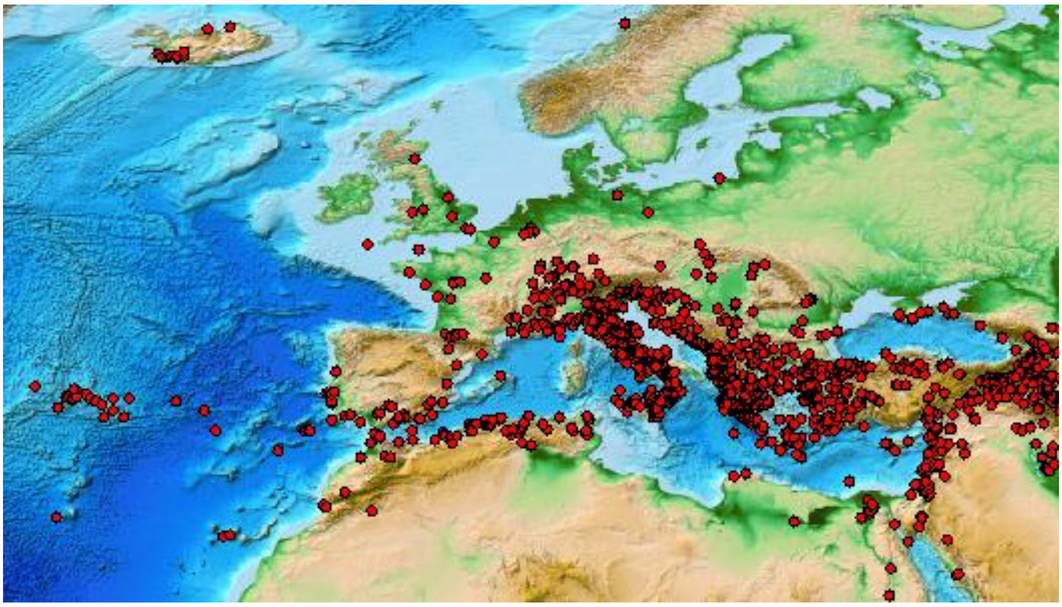


Fig. 2.1. Significant earthquake locations in the NEAMTWS region.
Source: United States National Geophysical Data Center /World Data Center.
http://map.ngdc.noaa.gov/website/seg/hazards/viewer.htm

2.1 APPRAISING THE LIKELIHOOD OF A TSUNAMI IMPACT ON YOUR COASTS

In order to prioritize and, if necessary, implement tsunami risk reduction measures, emergency managers and planners need information about the likelihood of a tsunami impact on their coasts – what and where the source could be (Fig. 2.1), how large the tsunami might be on its impact and what return period for damaging events could be expected. An outline of the analytical approaches that may be used to express the potential for a tsunami impact on any part of a country's coast is given at Annex 2, along with a brief description of the way in which tsunamis propagate from their sources across seas and oceans.

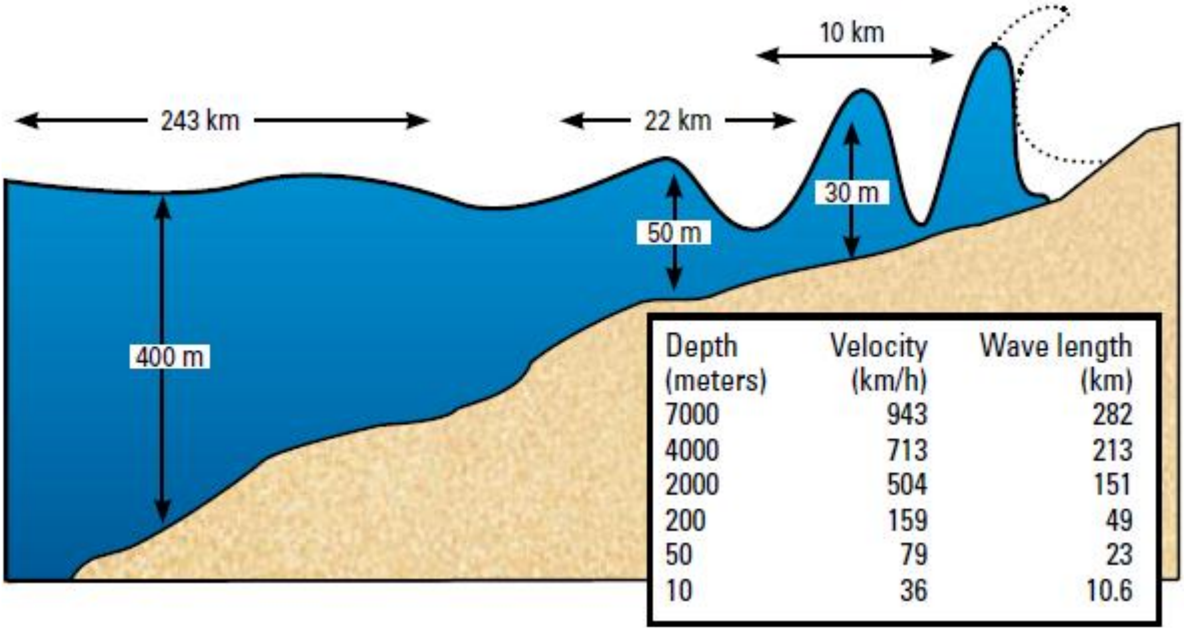


Fig. 2.2. Tsunami shoaling: the effect of water depth on wave height and velocity.
In the open ocean, a tsunami is often only tens of centimetres high, but its wave height grows rapidly in shallow water. Tsunami wave energy extends from the surface to the bottom in the deepest waters. As the tsunami attacks the coastline, the wave energy is compressed into a much shorter distance creating destructive, life-threatening waves.
Source: Tsunami Glossary, UNESCO 2006. (http://ioc3.unesco.org/itic/files/tsunami_glossary_en_small.pdf), with modification

2.2 FORECASTING LIKELY INUNDATION LIMITS

The propagation of a tsunami (Annex 2) is transformed by a shoaling process as it crosses increasingly shallow water to the shoreline, the wavelengths of its component waves reducing and the wave heights increasing (Fig. 2.2). During the shoaling process, the form of the nearshore bathymetry is one of the key determinants of the wave height and velocity, and of the forces exerted on inundation. The extent and nature of any ensuing inundation of coastal land depends not only on the wave height and velocity but also on the onshore topography or geomorphology.

The extent of the inundation and run-up (Fig. 2.3) can be very variable, even within a few kilometres of coastline. Inundation can also be modified by coastal vegetation and the built environment, including engineered coastal defences. The impact of a tsunami may be exacerbated by debris that becomes entrained in its waters during inundation and, importantly, its subsequent seaward drainage or backwash. The inundation and its drainage can result in significant erosion, e.g., by scouring around buildings foundations and sedimentation.

The determination of inundation limits for a range of credible tsunami scenarios at a country's coast is an essential step in the assessment of a community's vulnerability, and thus for evacuation (Section 5.3) as well as for coastal protection and land-use planning (Chapter 3). The processes of inundation modelling and mapping are described at Annex 3.

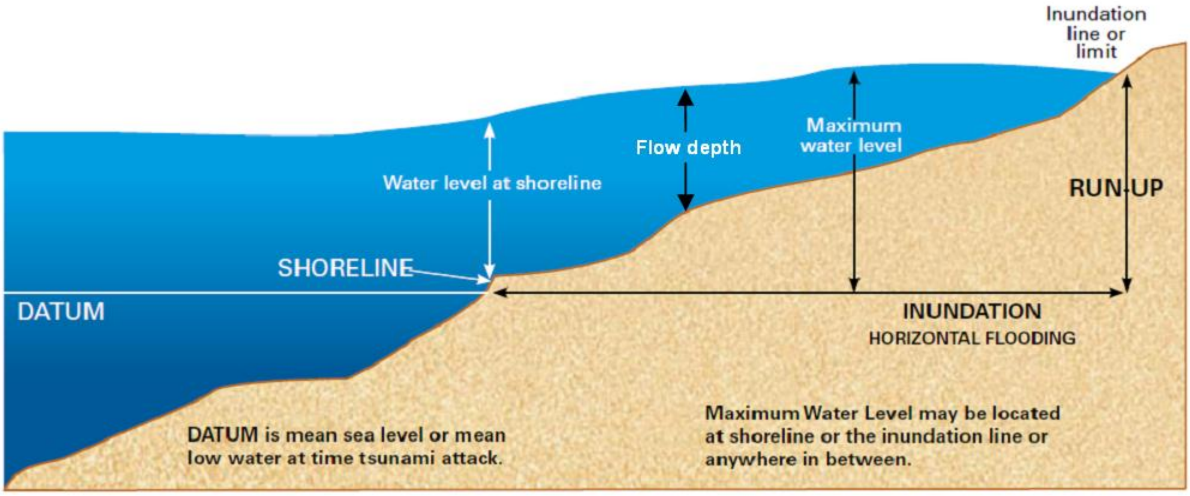


Fig. 2.3 Tsunami impact at the coast: an explanation of terms. “Flow depth” may also be referred to as “inundation depth”. Source: UNESCO-IOC International Tsunami Information Centre (ITIC) with modification.

An inundation map carries information about the parameters of inundation of water over the shoreline and coastal lowland – its run-up heights, its depths, and the flow parameters (velocities and directions), not only during the flood episode but also during the subsequent drainage period. As such, the map represents the spatial and temporal variations in the potential exposure of a community to a tsunami. The information provides a picture of the extent, level and severity of inundation to which the community would be subject.

The inundation map displays information from a deterministic analysis for a specified tsunami scenario (Box 2.1; Annex 3). Deterministic analysis neither involves, nor implies, information on the probability of such a scenario. Thus, a deterministic analysis cannot, by itself, provide an assessment of risk. Despite this limitation, detailed, deterministic modelling, based on particular source scenarios may best serve the needs of emergency managers in evacuation planning; also the needs of coastal engineers and planners in their design and development of effective tsunami counter-measures and in land-use planning. Inundation maps may be configured as true hazard maps by the attachment of probability levels expressed, e.g., as return periods, to the scenario-based map outputs. They may be elaborated to hazard danger maps by the depiction of danger zones, derived, for example, from parameters such as inundation/flow depth, flow velocities, proximity to the shore or a channel, and frequency of inundation.

In displaying inundation limits on a printed base, it may be convenient to depict the limits for a range of credible scenarios on a single base. Alternatively, using GIS technology, the geospatial information relating to individual scenarios within a range may be archived as separate layers.

Box 2.1: Parameters for tsunami hazard assessment and mapping – the SCHEMA approach

From the experience of partners in the SCHEMA project (Box 2.2), taking in consideration the results of interviews with users and stakeholders, and post-impact studies of the 2004 Indian Ocean tsunami, the following approach for hazard mapping was proposed.

One cannot pretend to produce vulnerabilities studies, damage assessment and scenarios if the hazard and the level of uncertainty of this assessment process are not precisely known. This requirement has pushed partners of the project first to propose a set of basic maps and information to describe the hazard in its different modes of impact, and then to carry out a hazard mapping comparison with several modelling tools on a benchmarking site.

A probabilistic approach – the type of hazard assessment treated in the framework of the TRANSFER project (Box 2.5) – is not proposed. Bounding a return period to a given scenario appeared to be quite risky and unfeasible for the NEAM region, due to the very small number of major or recorded events. It appeared more realistic to consider the likely past or potential scenarios from various tsunamigenic sources then compile them to obtain the maximum hazard areas, instead of linking a flooded zone to a given return period, as practised by some teams for Indonesia or Japan.

In the western Mediterranean where tsunami are quite rare, there is a risk that a usual return period of 100 years would give insignificant inundation on most coasts, with the danger of demotivating stakeholders and decision makers to consider the tsunami hazard as a reality or a factor for coastal zone management.

It must be kept in mind also that the recent European directive on flood hazard (Box 2.7) refers to various intensities of the hazard and qualifies the 100-year return period as a strong event, the strongest of extreme events being closer to a 500-year return period.

The minimum components to consider in defining hazard maps for an area exposed to tsunami hazard are defined below. This list takes into consideration and tries to translate to concrete map documents the various elements proposed by NEAMTWS and IOTWS (Indian Ocean Tsunami Warning and Mitigation System) for the definition of tsunami hazard.

The components of hazard definition used in this approach are:

1. **Comparison of several tsunami sources (historical) or scenarios** (in IOC documents a scenario refers generally to one tsunami source and one intensity of the generating mechanism). For each of the identified sources, a comparison of high and low tide impact is done and the maximum of all modelled scenarios at low and high tide is extracted and mapped.
2. **Production of synthetic tide gauges (duration of event, number of waves, amplitude of the waves)**
3. **Prediction of arrival times of first waves**
4. **Prediction of maximum inundation extent (floodable zone limit)**
5. **Prediction of maximum wave height and inundation depth** (or flow depth, Fig. 2.3) **in flooded zone**
6. **Prediction of maximum receding level (minimum sea level off the shores)**
7. **Prediction of maximum current speed (offshore and onshore)**

Most of the results can be presented on maps using a GIS.

Source: http://www.schemaproject.org/.

2.3 ESTIMATING VULNERABILITY AND THE LIKELIHOOD OF DAMAGE AND LOSS

Emergency planning and an effective emergency response to a received tsunami warning requires knowledge of the community's vulnerability – a measure of the potential for loss or damage of people and their supporting systems and assets in relation to a specified tsunami wave height scenario. The term "community", as used here, includes its social aspects, its buildings, economic aspects and infrastructure, and its supporting environmental assets.

In general terms, the greater the hazard, the higher will be the vulnerability. If a range of possible tsunami wave magnitudes is to be considered, so there will be a range of vulnerabilities relating to those respective magnitudes. It is important to distinguish vulnerability from risk. Assessment of the risks takes into account the likelihood or probability of a specified hazard scenario incidence. It provides an indication of the likelihood of quantified loss or damage to a community over a defined time period. Thus, vulnerability in respect of a tsunami of defined wave height does not in itself imply risk, but simply the potential for loss and damage in the event of such an impact.

The emphasis of a vulnerability assessment will be determined by the specific information requirements of emergency managers. The assessment must be appropriate to the geographical scale of interest. While the essential procedure is common to all scales – local to national – the level of detail required is greatest for local assessments. As well as varying spatially, vulnerability is also subject to temporal changes. A community's vulnerability changes significantly between day and night according to people's home and workplace locations; and, in many countries in the region, seasonally with influxes of tourists. Vulnerability is likely to change also on an annual or decadal timescale, reflecting changes in e.g., population and land use or changes in coastal protection or nearshore bathymetry which may affect levels of exposure.

The potential for loss and damage within a community is determined by exposure to inundation, by robustness and resilience, and by deficiencies of preparedness at scales ranging from individual people to national institutions.

Box 2.2: The SCHEMA project

SCHEMA was a research effort co-funded by the European Commission, carried out by a consortium of eleven organizations based not only in the European Union but also in Turkey and Morocco. The partnership aimed at using earth observation data in order to define a general approach suitable for helping experts to build up tsunami scenarios, vulnerability and damage maps as well as evacuation plans, based on intrinsic variables of the stakes, spatio-temporal variables and organizational variables, which determine the efficiency of rescue operation.

The key features of the research and development work under SCHEMA are:

- the clarification of concepts such as vulnerability, hazards and scenarios, in order to produce documents and maps accessible and understood by end-users (Civil Protection, rescue planners);
- an analysis of mathematical modelling limitations to reproduce reality in order to assess the degree of uncertainty when risk is estimated on models and not on real past events;
- the development of a general methodology, validated by end-users, to produce scenarios for tsunami and related phenomena hazardous impact and to elaborate and maintain evacuation plans;
- the extraction of vulnerability and hazard level indicators, as used in the general methodology, from earth observation data;
- a first validation of the methodology on real-life cases as observed during the 2004 Indian Ocean tsunami;
- a thorough validation of the resulting prototype methodology on five test cases typical of different environments, in NE Atlantic (Portugal and Morocco), Mediterranean (France and Italy) and Black Seas (Bulgaria);
- a psycho-social analysis (conducted in the site of Setubal, Portugal) to study the capacity of a selected sample of population and key actors to react to an evacuation warning.

The results of the project are going to be published in scientific papers currently under review and in two handbooks, in preparation, edited by JRC-IPSC and addressed to Civil Protection agencies and decision makers: one describing the developed methodology for tsunami hazard and damage scenarios production, and the other one focusing on the elaboration and the social acceptance of evacuation plans. The handbooks are intended to be available for download on the SCHEMA and JRC websites.

Source: http://www.schemaproject.org/.
The SCHEMA project, co-funded by the European Commission within the Sixth Framework Programme (2002-2006), was launched in August 2007. The project was coordinated by Geosciences Consultants (GSC), a French SME based in Paris.

The parameters of inundation from a wave of defined wave height, as portrayed by the inundation mapping, provide the basis for forecasting the levels to which a community and its supporting assets may be exposed. These parameters include the spatial extents of tsunami inundation and the velocity regime of water currents within the zone of inundation. Knowledge of the spatial distribution of people and their assets (the asset inventory) in relation to the forecast inundation parameters permits the construction of a geospatial exposure database – a key step in the process of vulnerability assessment (Fig. 2.4).

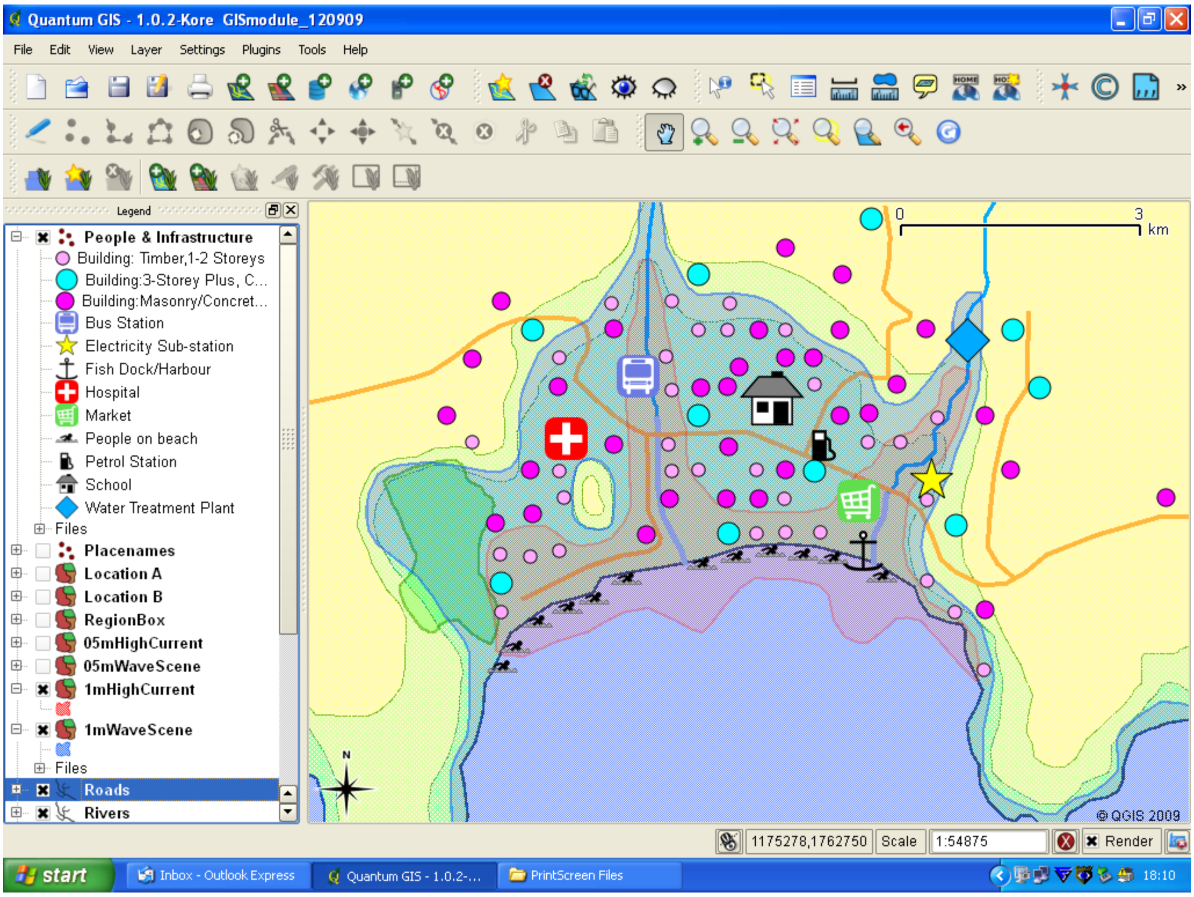


Fig. 2.4. Training GIS display (using Quantum GIS) of exposure of people/buildings and infrastructure in a coastal urban area to inundation from a 1 m (offshore wave height) tsunami. High current velocity zone shown by pink overlay.
Source: Regional Seminar and Training Workshop on Tsunami Risk and Mitigation for Indian Ocean Countries, 3-9 November 2009, Bangkok. UNESCO-IOC and UNDP.

Using the exposure database as a guide, the next step is to appraise the robustness (or susceptibility) of the community, its individual people and supporting assets to the expected levels of exposure.

The assessment of **social vulnerability** takes account of the susceptibility or predisposition of the people that would be exposed to the impact of a defined tsunami, including their ability to respond to a tsunami warning. The time taken for people to travel from their houses, workplaces, schools, beaches, etc. to safe locations is an important consideration of particular relevance in planning for evacuation (Box 2.4). Special account needs to be taken of the poor, women, children and the elderly and infirm or disabled, amongst whom levels of vulnerability tend to be high.

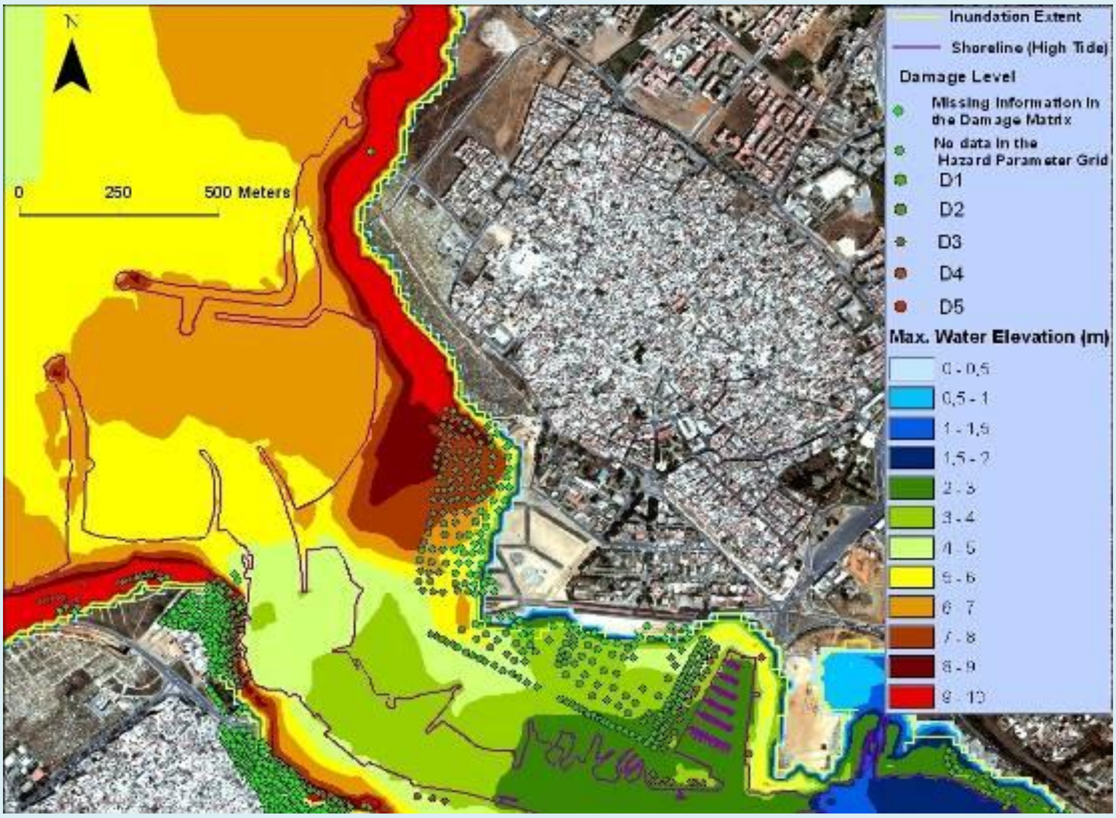
Buildings vulnerability, referred to also as “physical” or “structural” vulnerability, is closely related to social vulnerability in that the robustness of an exposed structure may determine the fate of its occupants in the event of a tsunami impact. Key issues to be taken into account in relation to the anticipated inundation depth (flow depth, Fig. 2.3) and maximum current velocity are the number of stories, the construction materials – timber, or masonry and concrete, the building techniques and the overall architectural design including the foundation type. The compilation of a specific buildings exposure database, identifying critical parameters relating to physical vulnerability, is a starting point for the assessment of this vulnerability dimension (Box 2.3).

Box 2.3: Tsunami hazard, vulnerability and impact assessment of the coastal area of Rabat, Morocco

Among African countries, Morocco is probably one of the most exposed to tsunami hazard. Indeed, Morocco is integrated in the particular geodynamic context of the northern African margin characterized by the existence of the Azores-Gibraltar fault separating two active tectonic plates: the African and the Eurasian plates. This area has generated, and still generates, many large earthquakes exceeding a magnitude of 6. The Moroccan Atlantic coasts are thus exposed to tsunamigenic earthquakes occurring offshore. Tsunamis generated in this area are not frequent but can be really disastrous and could have a huge impact.

In the framework of the SCHEMA project (Box 2.2), the consequences on the Moroccan coastal area of two potential tsunami scenarios have been studied, applying the generic methodology developed during the project for building tsunami vulnerability and impact maps.

The study focuses on the "Rabat Zaïr" region. Centred on the Bouregreg valley, the study area encompasses three densely populated coastal centres: Rabat (Morocco's capital city), Salé and Temara. Using a combination of numerical modelling, field surveys, earth observation and GIS data, the risk has been evaluated for this highly vulnerable area (flat topography, small beaches with many tourists in summer, presence of several bridges on the Bouregreg river separating Rabat and Salé, the presence of a dam upstream of these two cities, and the development of a new coastal residential and touristic complex in the vicinity of the estuary).



Example of the damage assessment on buildings (D1 light damages to D5 total collapse) for a tsunami triggered by an earthquake like the 1755 Lisbon event.

Two scenarios of tsunami have been studied to estimate the hazard on the coastal zone of Rabat: a worst case scenario based on the Lisbon earthquake of 1755; and a moderate scenario based on the Portugese earthquake of 1969. For each scenario, numerical models allowed the production of inundation maps showing inundation limits as well as maximum water heights. Land-use data together with earth observation data interpretation allowed the generation of a classification of buildings according to their vulnerability. Finally, potential damages were derived using damage functions developed during the project by crossing information from hazard maps (maximum water elevations) with buildings vulnerability maps. The damage maps serve as a base for elaborating evacuation plans with appropriate rescue and relief processes useful for decision makers, local authorities and investors.

Sources: Renou, C., Lesne, O., Mangin, A., Rouffi, F., Atillah, A., El Hadani, D. and H. Moudni, Tsunami hazard, vulnerability and impact assessment of the coastal area of Rabat and Salé, Morocco - Part 1: Hazard assessment, Nat. Hazards Syst. Sci., in review, © Author(s) 2010.
Atillah, A., El Hadani, D., Moudni, H., Renou, C., Lesne, O., Mangin, A. and F. Rouffi, Tsunami hazard, vulnerability and impact assessment of the coastal area of Rabat and Salé, Morocco - Part 2 : Building vulnerability and impact assessment, Nat. Hazards Syst. Sci., in review, 2010.

The SCHEMA project was co-funded by the European Commission within the Sixth Framework Programme (2002-2006) and launched in August 2007.

The assessments of **economic and environmental vulnerabilities** are complex in that they may need to take into account the direct (remedial) and indirect (income, utility) losses over a number of years, though with a tapering effect. The destruction of coastal economic assets, such as fisheries and tourism infrastructure, may have impacts that extend beyond the inundation area and that have major implications for social vulnerability.

The estimated values of the various dimensions of a community's asset inventory – its social attributes, its buildings, its economy and infrastructure and its environmental goods and services – are baselines against which potential losses and damage can be forecast. The levels of those losses are commonly estimated by expert judgement, perhaps with the benefit of post-impact data from tsunami-affected sites.

Box 2.4: The vulnerability of the city of Alexandria, Egypt, to the impacts of tsunamis

The Mediterranean Sea has high incidence of tsunamis. The activity is partly a consequence of tectonic activity in the eastern Mediterranean between the Hellenic and Cyprus arcs. The southern Mediterranean, in particular, has been hit by tsunamis several times in recorded history. Two big tsunami disasters have affected the Nile Delta and the city of Alexandria – on 21 August 365 A.D. and 8 August 1303 A.D. respectively (the consequences of earthquakes of magnitude about 8). Much of Alexandria, once a major Greek and Roman port, was destroyed in the 365 A.D. event, with the deaths of at least 50,000 people (Stanley and Jorstad, 2005).

Part of the city of Alexandria, sited between the Mediterranean Sea (top) and the partially reclaimed

Lake Maryut. Picture source: NASA Earth Observatory. Astronaut photograph taken July 27, 2003.

Alexandria is located on and between two ridges nearly parallel to the sea shore with an elevation not exceeding 12 m. Much of the city lies only 1–2 m above sea level, with many areas below sea level. To the south of the city lies the shallow Lake Maryut. The city is one of the largest in the eastern Mediterranean with a population exceeding four million, over 35% of them living in slum areas. It hosts the largest harbour in Egypt and is considered that country's second largest economic centre, hosting over 40% of its industry and 50% of its petroleum industry. The city is also an important summer resort, with over a million visitors during the season.

Much of the city's population, its buildings and its economy are vulnerable to major tsunamis through their exposure on low-lying coastal land as well as the challenges posed by the mass evacuation of such a densely populated inundation zone. Exposure would be exacerbated by sea-level rise and continuing urban growth.

Source: Mohamed El Raey. Adapted from UNESCO, 2009a.
Reference: Stanley, J. D. and Jorstad, T. F. 2005. The 365 A.D. tsunami destruction of Alexandria, Egypt: erosion, deformation of strata and introduction of allochthonous material. Geological Society of America, Annual Meeting Salt Lake City, Program with Abstracts, 75 pages.

Except for people, losses and damage tend to be quantified in financial terms (Box 2.5). They may be categorised according to the dimensions of the inventory or, alternatively, according to specific sectors of development, e.g., transport, health, education. The combined losses from a tsunami event are determined by summing the potential losses into an **aggregated vulnerability**. Depending on the expressed requirements of the community, various elements of an assessment may be weighted before being aggregated to provide a generalised indication of vulnerability.

Deficiencies in preparedness can make a significant contribution to the vulnerability of a community, affecting the potential loss and damage, though they may be difficult to quantify; in some assessments, they are treated separately from vulnerabilities (UNESCO, 2009b). Such deficiencies may be grouped into:

- weaknesses in early warning systems and responses in the event of a warning, e.g. evacuation procedures;
- weaknesses related to the post-impact response; and
- lack of (or weaknesses in) risk transfer mechanisms facilitating post-impact recovery.

The presence of good institutional capacities, effective organisations and good governance may be seen as reducing the risk of loss and damage. From a policy perspective, the responsibility concerning these deficiencies should be placed on those agencies which are in charge of preparedness (national or local emergency committees).

The outputs of the vulnerability assessment may usefully take the form of maps. Vulnerability maps form a key element of the risk assessment process. In addition, the map outputs provide emergency managers and sector agencies with important information about the locations and scales of potential community weaknesses in the event of a tsunami impact – data which are vital in the short term for evacuation planning and which, over the longer term, form a knowledge base for strategic mitigation and coastal land-use planning.

Arriving at a risk assessment

The risk to a coastal community and its supporting systems in respect of a defined tsunami hazard is a measure of the likelihood of loss and/or damage over a defined timescale. The assessed risk is the product of vulnerability and the probability or likelihood of occurrence (Boxes 2.5 and 2.6).

Box 2.5: Risk assessment for a credible tsunami event for Istanbul, Turkey

Tsunami risk and potential loss based on inundation mapping have been analysed for Istanbul. Based on the probabilistic tsunami analysis for a 10% probability of exceedance in 50 years, it is concluded that the eastern coasts of Istanbul are more hazardous than the western. The built environment on Istanbul's shorelines that is exposed to tsunami inundation comprises residential, commercial, industrial, public (governmental/municipal, schools, hospitals, sports and religious), infrastructure (car parks, garages, water tanks, electricity transformers) and military buildings, as well as the piers and ports, gas tanks and stations and other urban elements (e.g., recreational facilities). The total number of the buildings within the inundation zone is estimated at 4,922, with a total monetary value of about Euros 365 million. The inundation zone includes 17 fuel stations and tanks, 198 military buildings and 44 piers and ports. Along the Marmara Sea shore, the important port and petrochemical facilities at Ambarli and the Tuzla shipyards are expected to be exposed to the tsunami hazard, as well as significant lifeline systems for the city of Istanbul such as natural gas, electricity, telecommunication and sanitary and wastewater transmission. In terms of social risk, it is estimated that there are about 32,000 inhabitants exposed to the tsunami hazard.

Source: Eser Cakti, Ufuk Hancilar, Can Zulfikar, Mine Demircioglu and Mustafa Erdik
This work is part of the EC-FP6 project entitled "Tsunami Risk ANd Strategies For the European Region-TRANSFER" www.transferproject.eu.

The quality of the risk estimates depends on the reliability of the hazard assessment and on the availability and quality of vulnerability data. Subject to these requirements, risk estimates may be derived for any chosen scale (e.g., from individual buildings to the coastal built environment at the national scale), for any specified dimension of vulnerability (or aggregated vulnerability), or for any specified development sector. Estimates of risk can (and should) be customised. In this way the assessment can meet the specific requirements of the risk manager, the planner or the emergency manager within the defined geographic area.

Box 2.6: Vulnerability and risk in Cádiz, Spain

The development of appropriate risk and vulnerability reduction strategies to tsunami risks are a major challenge for countries, regions and cities exposed to potential tsunamis. Even European coastal cities, such as Cadiz are exposed to tsunami risk, however, many official risk reduction strategies as well as the local population are unaware of these phenomena and the potential threat that tsunami waves can pose. Thus, tsunami risk can still be called a unconscious risk for most of the exposed European coastal areas.

Socio-economic vulnerability maps taking into account exposed, susceptible elements and coping capacities for Cádiz City have been elaborated in the framework of the TRANSFER Project. Tsunami risk assessment has been elaborated based on two flooding scenarios: the "worst aggregated case" and the "5000-year return period event"; Based on these maps, some risk reduction recommendations have been proposed for the Cádiz City.

The hazard and vulnerability assessment of Cadiz regarding tsunamis revealed that, although the probability of a tsunami is relatively low, its consequences – particularly considering the worst case scenario – would have severe negative consequences for the city and its inhabitants. The systematic analysis of the key components of vulnerability - exposure, susceptibility and coping capacities (recuperation capacity) – revealed that some parts of the population and some areas within the city are clearly more vulnerable than others. The assessment allowed identification of areas where future development should consider tsunami as one of the marine-related risk factors. Awareness and knowledge of what a tsunami means is very limited among the population exposed. Furthermore, the assessment criteria used also underline that measures for improving the coping capacities – such as vertical evacuation options – could be part of strategic future urban development planning. However, until today, such measures or aspects have not been taken into account. Additionally, the survey and its underlying framework also show that the mapping of potential inundation areas for tsunami hazards is important, but not sufficient if there is an aim to develop a comprehensive risk and vulnerability reduction strategy.

Regarding critical infrastructures, data obtained for power plants, transformer stations and power lines show that a tsunami could cut power from many households within seconds. There would be severe consequences for other critical infrastructures, like water supply, as well as for hospitals. Even though the probability of tsunami occurrence is relatively low – this hazard should be considered in the further development and renewal of critical non-mobile and costly infrastructures. Regarding evacuation, the study showed that the only available routes out of the city (N-443 and CA-33) would be inadequate for the city's 50,000 cars at their capacity of only 4000 cars per hour. The only possibility of rapid evacuation for people would be by vertical evacuation within robust buildings of more than one story, or evacuation to safe areas outside beyond the inundation zone. These important messages must be communicated to the people via all possible channels of information, starting in schools and through the media. In addition, evacuation simulations and exercises should be carried out on a regular basis in schools and other important public and private institutions.

Source: Mauricio González

This work formed part of Deliverable D8.2 of project TRANSFER, 6th European Framework Programme.

A convenient and effective way of representing levels of risk (or of estimated risk) is geospatially, by means of risk maps. These maps show the extents of areas with defined risk categories (e.g., high, medium, low) for the required dimension of vulnerability in respect of a specified tsunami scenario. Risk maps can be derived by the integration using GIS technology of tsunami hazard and vulnerability map layers. Risk maps should be defined in relation to a specific tsunami hazard scenario and its forecast return period. They are perhaps the simplest and most effective tool at the community level for input to a wide range of decision making with a view to risk reduction. Under the EU's Floods Directive of 2007 (Box 2.7), risk maps covering *inter alia* the inundation of coastal land by any means are required by December 2013 for countries within the European Union (EU).

Box 2.7: The EU Floods Directive (The European Directive on the Assessment and Management of Flood Risks, 2007/60/EC)

The EU Floods Directive applies to all coastal waters as well as inland waters across the whole territory of the European Union.

Timelines for actions by EU Member States:

- Preliminary Flood Risk Assessments required to be completed by 2011
- Flood Risk Maps required by 2013
- Flood Risk Management Plans focused on prevention, protection and preparedness required to be in place by 2015

Source: WISE – Water Information System for Europe, European Commission (http://ec.europa.eu/environment/water/flood_risk/index.htm)

For more detailed descriptions of the procedures for vulnerability and risk assessment in respect of tsunamis and other coastal inundation hazards the reader is referred to the guidelines *Hazard Awareness and Risk Mitigation in ICAM* (UNESCO, 2009a) and *Tsunami Risk Assessment and Mitigation for the Indian Ocean – Knowing your Tsunami Risk – and what to do about it* (UNESCO, 2009b).

3. PREVENTING AND MITIGATING THE RISKS OF DAMAGE AND LOSS

Recommendations for action by Civil Protection and coastal management agencies in respect of strategic mitigation include:

- Consider the applicability and feasibility of strategic approaches to risk reduction and disaster prevention in a multi-hazard context.
- Consider the benefits and drawbacks of structural and non-structural methods in the context of Integrated Coastal Area Management.
- Evaluate proposed strategic measures by application of decision analysis tools including benefit-cost analysis.
- Involve public support and "buy-in" in the evaluation and implementation of a mitigation scheme.

This chapter considers the options for risk reduction through the application of strategic prevention and mitigation policies and measures. It is based largely on the descriptions of strategic risk reduction procedures given in the published guidelines – *Hazard Awareness and Risk Mitigation in ICAM (Integrated Coastal Area Management)* (UNESCO, 2009a) and *Tsunami Risk Assessment and Mitigation for the Indian Ocean – Knowing your Tsunami Risk – and what to do about it* (UNESCO, 2009b). For more comprehensive descriptions and reviews of the options open to policy makers and coastal engineers in respect of tsunami risk mitigation the reader is referred to those volumes.

Strategic mitigation measures against tsunami risk should be developed within a multi-hazard coastal risk assessment framework as an integral component of an overall coastal area management plan and disaster risk reduction strategies and programmes. The possibilities of other physical coastal hazards including storm surge inundation and coastal erosion affecting a shoreline prone to tsunami impacts should be considered in the formulation of such a plan.

Within the framework of a management plan, measures which mitigate the impact of the tsunami hazard represent a coherent set of interventions. These may be specified in time and space to achieve a certain expected level of protection against existing or anticipated damage from tsunamis as well as other hazards.

Strategic coastal hazard management, as with any part of the ICAM (Integrated Coastal Area Management) process, is an iterative procedure. To be effective, it should include a robust monitoring and evaluation component to assess the effectiveness of the chosen strategy and the adopted measures. Policy makers and coastal managers should be prepared to adjust their hazard management strategy over time to make improvements where needed and to be responsive to other socio-economic, environmental, and political pressures and changes that may occur.

3.1 CONSIDERING OPTIONS FOR STRATEGIC MITIGATION

The goal of strategic risk management is sustainable risk reduction. This entails choosing strategic management options that are appropriate to the scale of the designated coastal management area, balancing environmental considerations against social and economic pressures. Strategic mitigation and prevention of the tsunami risk may involve:

- structural measures, commonly engineered and **protecting** coastal communities and their supporting assets;

- non-structural measures that aim to reduce risk by **accommodating** it through changes of individual to community behaviour and practice; and
- measures that seek to prevent the risk by **retreating** from exposure to the tsunami hazard by means of land-use planning and financial instruments.

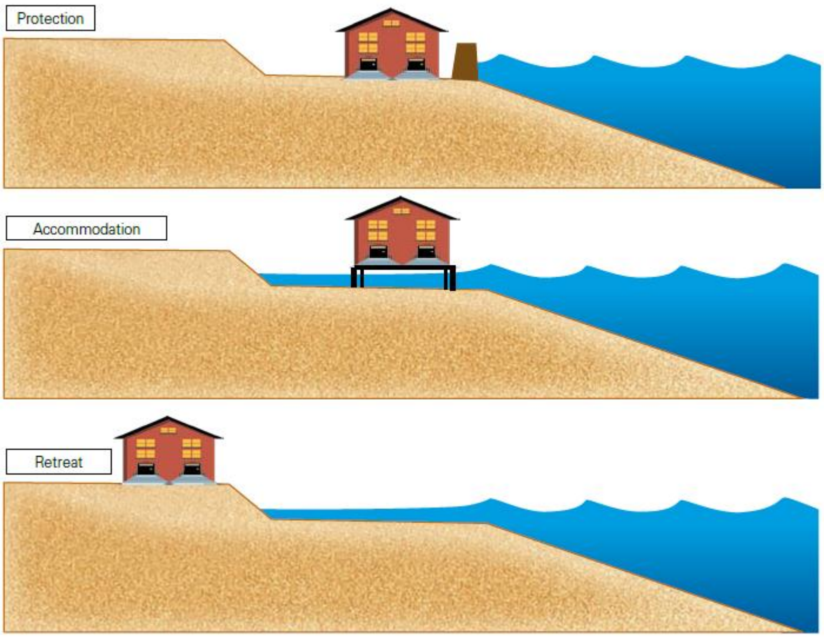


Fig. 3.1: The options for strategic mitigation: protection, accommodation and retreat.
Source: *Tsunami Risk Assessment and Mitigation for the Indian Ocean – Knowing your Tsunami Risk – and what to do about it* (UNESCO, 2009b). Based on Bijlsma et al., 1996.

These three approach options are illustrated in Fig. 3.1. In practice, a coastal management authority may adopt a risk management plan that incorporates measures of all three types. Some of the measures may encompass long timeframes, extending perhaps over several decades. All of them, and particularly the retreat option, are likely to require a coordinated effort on the part of several sectoral agencies, as well as the involvement of the public at all stages of a strategic mitigation scheme.

The application of decision-analysis tools and the need for public involvement

Decision-analysis tools including benefit-cost analysis and multi-criteria analysis can be helpful in evaluating the benefits and drawbacks of the various mitigation options. Benefit-cost analysis involves the comparison of the total cost of one or more strategies with the total benefits it would provide. An effective approach is one in which the benefits to the community outweigh the costs. In order to perform a benefit-cost analysis, all costs and benefits must be translated into a common denominator – typically monetary. Multi-criteria analysis can be helpful for analysing complex, multi-disciplinary strategies with multiple criteria and objectives. Multi-criteria analysis does not require that all alternatives be placed in monetary terms but can incorporate both quantitative and qualitative data, including value judgements.

While there are many different types of decision-analysis tools to select from, policy makers should be sure that the analysis will provide a reasonable comparison of the short- and long-term costs of protection, accommodation and retreat, and account for the major socio-economic and environmental costs of the alternatives as well.

Public opinion and wide stakeholder involvement are also valuable tools to be included in the decision-making process as the risk management strategy is developed. Public support and “buy-in” are important for the success of the strategy as they are for the wider aspects of coastal management. To engage the public, policy makers should educate them about the risks and benefits and drawbacks of various management options. The public should have the opportunity to provide input on the level of risk that is acceptable or needs to be managed. Such involvement helps to ensure that the aims of science research programmes are relevant and focused to the community needs, and that the application of the science in the management practice is effective.

3.2 PROTECTING AGAINST INUNDATION USING STRUCTURAL METHODS

This part of the guidance deals with the options for reducing risk by coastal protection through structural means (Fig. 3.1). While the underlying principles of protection against coastal inundation and erosion are similar irrespective of the type of physical hazard, the scale of the structures capable of withstanding the hydrodynamics of tsunami flow needs to reflect the perceived level of tsunami hazard (Section 2.2). Furthermore, the possibility of long-term changes in coastal sedimentation and erosion, caused by changes in nearshore bathymetry resulting from a tsunami impact, should be considered.

Because shorelines are dynamic, structural mitigation measures at a particular location should not be developed in isolation. It is important to understand the hydraulic behaviour of the wider coastline, including its sediment transport regime, which may determine the stability of the shore. Care should be taken to ensure that structural mitigation works at one location do not lead to instability on an adjacent shore.

Structural protection against tsunami impacts may be achieved not only by artificial methods employing coastal engineering design such as offshore breakwaters, dykes and revetments, but also by natural methods, harnessing the full potential of coastal ecosystems including sand dunes and coastal vegetation. Natural solutions provide cost effective, environmentally friendly solutions to mitigate tsunami risk where there is with a low frequency of occurrence. The type of protection adopted may also mitigate other physical hazards (storm surges and extreme wind-forced waves), while sustaining multiple uses of the coastal zone. This might be achieved through adoption of a single measure or, more usually, of a well integrated hybrid solution, comprising several measures and satisfying environmental concerns. Hybrid methods refer to combinations of artificial methods or a combination of natural and artificial methods.

Measures which prevent the impact of a tsunami may be classified into three types, depending on their location and protecting function. These measures are:

- a partial barrier located in the nearshore zone reducing the impacts of tsunamis before they reach the shoreline;
- a full barrier at the shoreline preventing the inland movement of tsunamis; and
- a partial barrier at the shoreline reducing the impacts of tsunamis on crossing the shoreline.

Full and partial barriers, whether artificial or natural, are physical interventions which may be considered a protection solution for populated coasts. In designing artificial barriers it is necessary to ensure the continuity of sustaining multiple uses of the existing natural environment. From an engineering point of view, the design must be robust, functional and reliable. Due consideration should be given to convenient maintenance and effective operation. Equally it is important to minimize negative impacts on socioeconomic, livelihood and environmental issues. Sensitive landscaping of the environment is a priority.

Partial tsunami barriers are usually offshore breakwaters which dissipate part of the incoming tsunami's energy before its waves reach the shore. These may also be designed as full barriers with the inclusion of a tsunami gate for complete closure, a solution that would be relevant to strategic port development.

Full barriers against tsunami inundation may be provided by high-rise seawalls (dykes) constructed on the shoreline at or above the high water mark. Where the shoreline is interrupted by river mouths, tsunami gates can be installed within seawalls to allow for normal flows and traffic access. Sand dunes can provide natural full barriers against tsunami inundation. Their effectiveness was proved in many countries around the Indian Ocean during the tsunami of 2004. When overtopped, the dunes tend to fail progressively by erosion, though vegetation cladding can provide reinforcement of the barrier.

Partial barriers against tsunami flow may be provided by medium-rise seawalls (dykes) preventing propagation up to specified design water levels but permitting overtopping beyond those levels. The stability of such barriers during overtopping and inland drainage issues need to be given due consideration. Coastal vegetation can be used to dissipate tsunami energy via turbulent flow through the media. The effectiveness of dissipation is dependent on the density of vegetation, its overall porosity and its tortuous characteristics of porous matrix. It is important that the vegetation is itself resilient against tsunami propagation with a root structure that can resist a high velocity regime of inundation.

3.3 ACCOMMODATING INUNDATION

Coasts tend to be highly populated areas of high economic activity. Where there is a high level of tsunami-related risk, it may not be feasible to transfer all activities to safe areas beyond inundation zones. Instead there may be a need to accommodate the risk by the adoption of structural or non-structural measures.

Building codes

The development and application of design guidance and building codes for tsunami-resistant housing and infrastructure form parts of this accommodation. It may be expected that properly designed structures will withstand the impacts of tsunami with only limited damage.

Although cost may be an impediment to tsunami-proofing structures, national authorities may choose to make tsunami-proof structures, e.g. with flow-through basement designs (Fig. 3.1) and deeper scour-resistant foundations, mandatory in areas of high risk. The orientation of buildings with respect to the ocean is another factor for consideration. Particular attention should be directed to the security of structures used for vertical evacuation shelters. In potential inundation areas of low risk the extent to which communities should accommodate the tsunami hazard should be governed by the precautionary principle.

Design guidance may be developed from experience gained from post-tsunami impact damage assessments from other countries that have been affected by tsunamis. Damage assessments should cover infrastructure that was destroyed, damaged or survived (least affected). Such guidance should be applicable to the rehabilitation of damaged structures, the strengthening of existing structures (retrofitting) and the design of new structures.

Risk transfer

Insurance plays an important role in offering financial protection from the costs of flooding. By spreading risk across policy-holders, insurance enables householders and businesses to minimize the financial costs of damage from inundation. Furthermore, because lenders are unlikely to offer mortgages on properties that cannot obtain buildings cover, insurance plays a critical role in the operation of the property market. However, insurance can provide an effective mechanism for spreading the risk only if the risk is at a manageable level.

Reinsurance is the insurance that insurers themselves take out to deal with catastrophic events/claims. It provides a mechanism that can help insurers provide financial protection to developments located within the limits of potential inundation, and at risk from an inundation event. However, it is anticipated that reinsurers will become increasingly selective of the portfolios they are prepared to take on. Reinsurers model exposure based on the best-available estimates of risk. These are revised as more information becomes available, for instance following a catastrophic event. Where this reassessment leads to a limitation or withdrawal of reinsurance cover, insurers would need to reflect this in the extent of insurance coverage and the premiums they charge. This underlines the need to take a precautionary approach to large aggregations of new development in potential inundation zones.

3.4 RETREATING FROM POTENTIAL INUNDATION ZONES

Land-use planning can be an effective, strategic means of reducing the risks to coastal communities from tsunami inundation. Information to inform policy on land-use planning, which countries may apply within a regulatory framework, is contained in the hazard, vulnerability and risk maps produced as outputs from the risk assessment process. Hazard maps, particularly those derived from inundation parameters for scenarios that are considered to pose significant levels of risk to a community, are a particularly appropriate tool for land-use planning decisions.

A possible option for consideration in land-use planning is the introduction of development setback (Fig. 3.1). Development setbacks to cope with, amongst other issues, the threat of coastal physical hazards (coastal erosion and storm surge inundation as well as tsunamis) have become mandatory in a number of countries. Setback lines are determined by national authorities, in some cases within a national legislative framework, to delimit exclusion zones for development in coastal areas that are perceived to be exposed to inundation or at risk from coastal erosion. In the Mediterranean region, countries that ratified the Integrated Coastal Zone Management Protocol of the Barcelona Convention are now obliged to adopt setback planning regulation, the Protocol having entered into force on 24 March, 2011 and becoming part of EU Law with binding effects.

Development setbacks are intended to direct new development or redevelopment out of identified hazard areas and to protect natural hazard mitigation features such as beaches and dunes by restricting development seaward of a designated setback line, established parallel to the shoreline. The type of setback used, including how, and from where, it is established, can vary widely. The application of setbacks is a globally accepted good practice in coastal area management (UNESCO, 2009a).

While a retreat or setback option may be an effective tool for disaster prevention and risk reduction in respect of the built environment and its associated infrastructure, it should not be viewed as a panacea for the elimination of the hazard. Communities that are subject to development setback regulation and enforcement may remain vulnerable in respect of people, particularly seasonal visitors to beach resorts.

For a more detailed description of the procedures for strategic mitigation the reader is referred to the guidelines *Hazard Awareness and Risk Mitigation in ICAM* (UNESCO, 2009a).

4. TSUNAMI EARLY WARNING THROUGH NEAMTWS

Recommendations for action by Civil Protection agencies and related disaster management organisations in respect of messaging and emergency response procedures include:

- Establish or enhance your capacity for the early warning of tsunami events through participation in NEAMTWS.
- Nominate your Tsunami National Contact person to represent your country in the coordination of international tsunami warning and mitigation activities.
- Nominate your Tsunami Warning Focal Point through which tsunami alerts are received from Tsunami Watch Provider(s) and tsunami warnings are issued to national Civil Protection agencies.
- Establish or enhance a National Tsunami Warning Centre with Standard Operating Procedures (SOP).
- Determine your national coastal Forecast Points in collaboration with your chosen Tsunami Watch Provider(s).
- Ensure capacity and preparedness in the National Tsunami Warning Centre to formulate and issue tsunami warnings according to your SOP.
- Ensure capacity and preparedness in your Civil Protection agency or Disaster Management Office to receive and respond to warnings according to your Tsunami Emergency Response procedures.

This chapter describes the architecture for the detection and messaging procedures that form the core of the “end-to-end” system, in particular the procedures recommended for the formulation of tsunami warning messages and their provision by Civil Protection agencies to people that could be affected.

The structural and messaging terms used in the development of the IOC-coordinated Tsunami Warning and Mitigation Systems have been applied in different ways, with different meanings between ocean regions, and even between countries in the same region. Such differences reflect the evolution of procedures within the respective Systems as well as differences in national and regional languages and customs. Through its TOWS Working Group (Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems), IOC is promoting the harmonization of the procedures associated with tsunami warning systems, including their terminology (UNESCO, 2011). The terms and their meanings as used in this manual are those as set out and defined in the NEAMTWS Interim Operational Users Guide.

4.1 PARTICIPATION IN NEAMTWS

While disaster prevention or, at least, disaster risk reduction in respect of coastal inundation hazards should be a strategic aim in disaster management (Section 3), countries can have more immediate Civil Protection benefits through their participation in the regional real-time tsunami early warning network provided by the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas (NEAMTWS).

For countries within the European Union (EU), the content of this section is relevant to the requirement under the EU's Floods Directive of 2007 to have Flood Risk Management Plans, focused on prevention, protection and preparedness, in place by the year 2015 (Box 2.7). This requirement extends to the provision of plans covering the marine inundation of coastal land. This section is also relevant to Mediterranean countries that are Contracting Parties to the Integrated Coastal Zone Management Protocol of the Barcelona Convention (Box 4.1). The Parties have legal obligations in respect of natural hazards and responses to natural disasters.

Box 4.1: Disaster management and tsunami early warning in an Integrated Coastal Management framework in Tunisia

In Tunisia, the National Commission for Disaster and Emergency Organization is in charge of the management plans provided for the prevention of natural disasters such as floods, fires and earthquakes. This Commission is chaired by the Minister for Transport to which the National Institute of Meteorology is attached. In January 2010, Tunisia signed the Integrated Coastal Zone Management Protocol of the Barcelona Convention, adopted in 2008. The Protocol entered into force on 24 March, 2011. The protocol includes close cooperation on the establishment of a Tsunami Early Warning System. Adherence to the recommendations of the Protocol is promoted by the National Commission on Sustainable Development chaired by the Minister of the Environment and Sustainable Development. The National Agency for the Protection of the Coastline (APAL) is in charge of the implementation of mechanisms to ensure participation in the Early Warning System. Moreover, INSTM are in contact with APAL to implement a National strategy on tsunamis.

Source: Cherif Sammari, INSTM, Tunisia

Most countries of the region have established systems and procedures that provide their populations with warning of the likely or possible incidence of natural hazard events. National systems commonly link to regional multi-hazard networks. Extreme climate-driven events, including storm surges, can usually be predicted days ahead, giving Civil Protection agencies and emergency managers time to mobilise an effective response. Geologically driven events – earthquakes, volcanic eruptions, landslides (including submarine landslides) and their possible ensuing tsunamis – may also be predictable spatially; but their timing is usually unpredictable on a scale that is relevant to a Civil Protection response. Despite this unpredictability, there is usually some opportunity for people at risk to be warned of a potentially damaging or disastrous inundation event.

The potential opportunity for issuing a warning of an impending tsunami is constrained by the time taken by a tsunami to propagate between its source and the coastal point(s) of impact. Depending on the location of the tsunami source relative to the coast, this lead time may range from just a few minutes to a few hours. In the landlocked Mediterranean and Connected Seas parts of the region, tsunami propagation times, and thus the potential warning window, would generally be less than two hours, though in much of the North-eastern Atlantic area they could be considerably longer. In practice, the available opportunity for issuing a warning depends on the effectiveness of event detection and communications within the NEAMTWS.

Acting on their own, individual countries may not have the capability of detecting tsunamigenic events to which they might be exposed. By their participation in the regional network "NEAMTWS", they can be informed in the shortest possible time of impending tsunami hazard events which might impact their coasts and threaten their coastal populations.

The regional Tsunami Early Warning and Mitigation System (NEAMTWS) has been developed with the aim of informing communities at risk about impending tsunamis following the detection of the causative geological event. The basic structural elements of the system (as currently under development) leading to the issue of warnings are: Tsunami Watch Providers (TWPs) in different parts of the region, National Tsunami Warning Centres (NTWCs) and their associated national Tsunami Warning Focal Points (TWFPs) (Figs 4.1 and 4.2). A TWP corresponds with other TWPs and has a dual role as the NTWC for the country in which it resides. A National Tsunami Warning Centre (NTWC) operates within the legal framework of its sovereign nation. It provides warnings for transmission through its TWFP to its national Civil Protection agency or Disaster Management Office (DMO) for dissemination as appropriate to its citizens and public and private agencies. If the NTWC has seismic detection and processing capabilities, it may also function as a Tsunami Watch Provider to other NTWCs.

Within NEAMTWS, a Member State's government is represented by a designated Tsunami National Contact (TNC) who represents his/her country in the coordination of regional tsunami warning and mitigation activities (Fig. 4.2). A list of nominated national Tsunami Warning Focal Points for countries of the NEAM region is given at Annex 4.

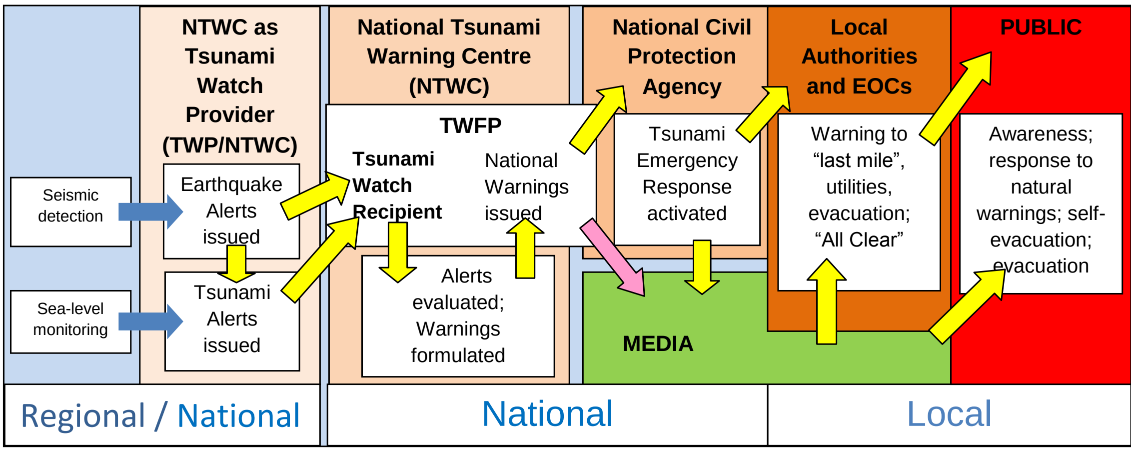


Fig. 4.1. NEAMTWS end-to-end architecture: data and messaging flow from detection to local warning for people at risk in a tsunami event. Data streams are shown in blue, messaging routes in yellow (or pink according to national protocol). TWFP = Tsunami Warning Focal Point; EOCs = Emergency Operations Centres.

4.2 EVALUATION, MESSAGING AND ISSUING WARNINGS

The real-time core of the System covers the following process and messaging operations (Fig. 4.1):

- Detection (usually of seismic shocks, followed as relevant by sea-level changes);
- Transmission of seismic and sea-level data to Tsunami Watch Providers (TWPs);
- Processing of seismic and sea-level data by TWPs, including information exchange between TWPs;
- Transmission by TWP(s) of alerts about earthquakes and tsunamis to National Tsunami Warning Centres (NTWCs) through national Tsunami Warning Focal Points (TWFPs; Table 4.1);
- Evaluation by NTWCs of information in alerts received from TWP(s); NTWCs with "in-house" seismic processing capability may independently assess tsunami threat and potentially act as Tsunami Watch Providers to other NTWCs;
- Formulation by NTWCs of targeted warnings and transmission of warnings through TWFPs to national Civil Protection agencies/Disaster Management Offices;
- Onward transmission of warnings, as appropriate, to Local Authorities, Emergency Operations Centres, media and communities at risk.

It is a so-called "end-to-end" system, with critical warnings issued by National Tsunami Warning Centres to national Civil Protection agencies and delivered locally to "the last mile", including to beaches if appropriate (Fig. 4.1). The technical details of these operations in respect of large-scale earthquake-related tsunamis – tsunamis from seismic sources that have a basin-wide propagation potential and can be destructive far from the source – are published in the NEAMTWS Interim Operational Users Guide. These include the protocols for messaging and communication issues, and decision support matrices for the benefit of emergency managers (Tables 4.2 and 4.3). The roles and responsibilities of TWPs, TWFPs and NTWCs are set out in Table 4.1.

Fig. 4.2. Established TNCs and TWFPs and Candidate TWPs in the NEAM region.
Source: http://www.ioc-tsunami.org/content/view/287/1123/ ; map based on the General Bathymetric Chart of the Oceans - GEBCO)

Table 4.1: Roles and responsibilities for TWPs, NTWCs and TWFPs in NEAMTWS
Based on ICG/NEAMTWS Interim Operational Users Guide; mandatory roles are indicated in bold type.

NTWC acting as Tsunami Watch Provider (TWP/NTWC)	National Tsunami Warning Centre (NTWC)	Tsunami Warning Focal Point (TWFP)
ROLE		
Watch • **Reception and interpretation of RT seismic and sea-level measurements** • **Determination of seismic parameters** • **Forecasting of tsunami arrival times and level of alert at each forecasting point specified by MS** • **Exchange of seismic parameters and information with other TWP/NTWCs** • **Dissemination of watch and cancellation messages to TWFPs based on the alert-level decision matrix** • **Monitoring tsunami propagation and dissemination of updated information in priority tsunami amplitude measurements** • **Capability of acting as a back-up centre to other TWPs** • **Functioning as a basic NTWC (as next column)**	**Watch and Warning** • Reception and interpretation of RT seismic and sea-level measurements • **Reception of alerts and other messages from TWP as relayed through TWFP** • **Evaluation of alerts and formulation of warning messages** • **Dissemination of warning and cancellation messages through TWFP to national CP agencies according to the national emergency response plan** • Monitoring tsunami propagation and updating information to national CP authorities • Determination of seismic parameters • Forecasting tsunami arrival time, amplitude and run-up for the national coastline • Provision of information to other NTWCs and TWP/NTWCs • Acting as Tsunami Warning Focal Point (TWFP)	**Watch and Warning** • **Reception of alerts and other messages transmitted by TWP(s) for relay to NTWC** • **Dissemination of warning and cancellation messages, as formulated by NTWC, to the National CP agencies** • **If no NTWC exists, evaluation of alerts from TWP(s) and formulating and disseminating warnings to CP agencies**
ACTIVITIES ABOVE AND BEYOND WATCH TIME		
• Monthly tests of the watch system • Procedures and documentation • Regional tsunami exercises • Conduct training courses with other TWPs and IOC • Participate actively and report to the ICG and WGs	• **National Tsunami Emergency Response Plan** • **National Standard Operating Procedures (SOP), documentation** • National tsunami exercises • Catalogue of inundation scenarios • National tsunami data base	
REQUIREMENTS		
• **Seismic as well as tsunami/oceanographic expertise** • **Direct access to a tsunami and large earthquakes data base** • **Real-time transmission systems for reception of data** • **Real-time alert reception and transmission systems, e.g. GTS, Internet** • **Back-up/independent power supply** • **Permanent staff on 24/7 watch** • **Tsunami modelling capacity to produce and update canned scenarios**	• Seismic as well as tsunami/oceanographic expertise • Access to tsunami and large earthquake data base • Real-time transmission systems for reception of data • **Real-time alert reception systems, e.g. GTS** • **Back-up/independent power supply** • **Permanent staff on 24/7 watch** • **Inundation modelling capacity**	• **Permanent staff on 24/7 watch** • **Real-time alert reception systems, e.g. GTS** • **Back-up/independent power supply**

4.3 PROCEDURES FOR RESPONSE BY TWPS, TWFPS AND NTWCS

The Tsunami Watch Provider (TWP) initiates its functions with its detection of an earthquake. Given the short distance of the potentially tsunamigenic sources to a coast in the NEAM region, it is desirable that a first evaluation of the earthquake parameters is computed by the TWP duty staff in less than 5 minutes after its origin time. The earthquake analysis includes automatic and interactive processes for determining the earthquake's epicentre, its depth and its origin time, as well as its magnitude. The magnitude scale adopted by the ICG/NEAMTWS is the moment magnitude, M_W. Normally, the first estimates of M_W have to be derived from a small length of the seismic waveforms by some standard procedures that have been agreed upon by the ICG/NEAMTWS. The earthquake evaluation will continue after the first message is issued, integrating more data and allowing more extensive analysis. If there are significant changes to the initial parameters, then the TWP may issue a supplement message.

Applying the tsunami Decision Matrix to the earthquake parameters will determine the appropriate message type that will be issued by the TWP. Whenever any kind of tsunami alert is issued, the TWP will continuously monitor the water-level data from the sea-level stations located near the epicentre, and from deep-ocean sea-level gauges, for evidence of a tsunami. Based on these data, and on any credible reports of tsunami wave activity from national authorities or the media, and using historical data and numerical forecast model outputs for decision guidance, an evaluation of the tsunami threat is made and updated. If a tsunami has been generated that poses a continuing threat, the current level of alert will continue, or be upgraded or downgraded, until the tsunami waves no longer cause a threat to the coastal areas.

As part of their Standard Operating Procedures (SOP) for responding to potentially tsunamigenic events, the Tsunami Watch Providers (TWPs) calculate expected tsunami arrival times (ETA) to various, pre-determined coastal Forecast Points. These forecast points are agreed-upon points chosen by countries in consultation with TWPs. They may correspond to important coastal cities or populations, and/or to the locations of sea-level gauges. TWPs (and/or NTWCs) may be able also to forecast tsunami wave amplitudes at the forecast points in order to decide on the level of tsunamigenic threat.

The level of threat for a given country or region is defined in terms of its distance to the earthquake source and not by the estimated tsunami arrival time, as it happens in Pacific, for example (Tables 4.2 and 4.3). When a country is in a “Watch” or “Advisory” status, the ETAs for its forecast points that meet the criteria will be listed in the tsunami alerts issued by the TWPs.

Table 4.2: Decision matrix for the North-eastern Atlantic showing tsunami message types related to detected earthquake depth, location and magnitude. Source: ICG/NEAMTWS Interim Operational Users Guide.

Decision matrix for the North-eastern Atlantic						
Depth (km)	**Epicentre location**	**Earthquake magnitude** (M_W)	**Tsunami potential**	**Type of tsunami message**		
				Local	**Regional**	**Ocean-wide**
<100	Offshore or close to the coast (≤ 40 km inland)	5.5 – 6.5	Weak potential for a destructive local tsunami	Advisory	**Information**	**Information**
	Offshore or close to the coast (≤ 100 km inland)	6.5 – 7.0	Potential for a destructive local tsunami	Advisory	**Information**	**Information**
		7.0 – 7.5	Potential for a destructive local tsunami	**Watch**	Advisory	**Information**
		7.5 – 7.9	Potential for a destructive regional tsunami	**Watch**	**Watch**	Advisory
		≥ 7.9	Potential for a destructive ocean-wide tsunami	**Watch**	**Watch**	**Watch**
≥ 100	Offshore or inland (≤ 100 km)	≥ 5.5	No tsunami potential	**Information**	**Information**	**Information**

No message if the earthquake is localised inland beyond 100 km distance; no message if M_w < 6.5 and distance to the coast > 40 km; no message if M_w < 5.5.

Table 4.3: Decision matrix for the Mediterranean showing tsunami message types related to detected earthquake depth, location and magnitude. Source: ICG/NEAMTWS Interim Operational Users Guide.

Decision matrix for the Mediterranean						
Depth (km)	**Epicentre location**	**Earthquake magnitude** (M_W)	**Tsunami potential**	**Type of tsunami message**		
				Local	**Regional**	**Basin-wide**
< 100	Offshore or close to the coast (≤ 40 km inland)	5.5 – 6.0	Weak potential for a local destructive tsunami	**Advisory**	**Information**	**Information**
		6.0 – 6.5	Potential for a destructive local tsunami	**Watch**	**Advisory**	**Information**
	Offshore or close to the coast (≤ 100 km inland)	6.5 – 7.0	Potential for a destructive regional tsunami	**Watch**	**Watch**	**Advisory**
		≥ 7.0	Potential for a destructive basin-wide tsunami	**Watch**	**Watch**	**Watch**
≥ 100	Offshore or inland (≤ 100 km)	≥ 5.5	No tsunami potential	**Information**	**Information**	**Information**

No message if the earthquake is localised inland beyond 100 km distance; no message if M_w < 6.5 and distance to the coast > 40 km; no message if M_w < 5.5.

Because of the geographical contrast between the North-eastern Atlantic part of the NEAM region and the Mediterranean part, each of these parts has its own messaging protocol in relation to detected earthquake magnitudes:

- For the relatively restricted basins of the **Mediterranean**, the bulletins relate either to regional tsunamis, effective over distances of 100–400 km, or to basin-wide tsunamis, effective over distances in excess of 400 km.
- For the open ocean of the **North-eastern Atlantic**, regional tsunamis have a designated range of 100–1000 km, while more extensive tsunamis are categorized as ocean-wide.

Bulletins from a TWP informing of a tsunami event (or its downgrading or cancellation) are of two types. Each shows the Areas Affected (AA) by country or country zone and each is accompanied by an Authority Statement (AS) and an Evaluation Statement (ES).

- A **Tsunami Watch** message is issued by the TWP whenever the seismic information or/and sea-level data indicates that any part of the NEAM coastline may be impacted by a tsunami with a wave height greater than 0.5 m, and/or when tsunami run-up is expected to be higher than one metre. A Tsunami Watch is the highest severity level of a tsunami alert message and it must be considered that the tsunami waves, if generated, pose a real threat to exposed coastal populations and may be damaging.

- A **Tsunami Advisory** message is issued by the TWP whenever the seismic information or/and sea-level data indicates that any part of the NEAM coastline may be impacted by a tsunami with a wave height from 0.2 to 0.5 m, and/or when tsunami run-up is expected to be less than 1 metre (Table 4.4).

The alert status definitions for Tsunami Watch and Tsunami Advisory messages are given in Box 4.2.

Table 4.4: Decision matrix relating to Tsunami Advisory and Tsunami Watch messages received by a National Tsunami Warning Centre. Source: IGC/NEAMTWS Interim Operational Users Guide.

	Tsunami Advisory	**Tsunami Watch**
Wave amplitude	0.2–0.5 m	> 0.5 m
Run-up	< 1 m	> 1 m
Impact	Current, bore, damage in water; possible minor inundation on beaches	Advisory impact + inundation of low-lying coastal land

Initial Tsunami Watch and Tsunami Advisory messages are based solely on seismic data received from detection networks by the TWP(s). Supplementary, follow-up messages based on tide-gauge data as well as seismic data may confirm the generation of a tsunami. Or, depending on the sea-level data received by the TWP, they may downgrade or cancel the Tsunami Watch or Tsunami Advisory message. A list of the 10 possible message type lines is shown in Box 4.3. A sample Tsunami Watch message is shown at Annex 5 and a full suite of sample message types is included in NEAMTWS Interim Operational Users Guide.

The estimated tsunami arrival times (ETA) received by the TWFP should be used with caution by the NTWC. All times given are in UTC (Coordinated Universal Time) and it is the task of the NTWC to convert these to local time as required. ETA will be provided only for coastal Forecast Points, with the forecast point localities ordered by ETA. If or when tsunami wave data become available – usually after the issue of the initial alert – the TWP will report wave measurements at key coastal and deep ocean sea-level gauges. Each measurement includes the name and coordinates of the gauge, the time of the measurement, the maximum observed amplitude of the wave in metres (the height relative to normal sea level) and, if available, the period of the wave cycle in minutes.

Box 4.2: NEAM-TWP alert status definitions

Tsunami Watch

- A Tsunami Watch message is issued by the TWP when a potential tsunami with significant widespread inundation is expected. Watches alert the national TWFPs, the NTWCs and the Civil Protection agencies that widespread, dangerous coastal flooding accompanied by powerful currents is possible and may continue for several hours after arrival of the initial wave. Watches alert emergency management officials to take action for the entire tsunami hazard zone. Appropriate actions to be taken by local officials may include the evacuation of low-lying coastal areas, and the repositioning of ships to deep waters when there is time to safely do so. Watches may be updated, adjusted geographically, downgraded, or cancelled. To provide the earliest possible alert, initial Tsunami Watch messages are based only on seismic information.

Tsunami Advisory

- A Tsunami Advisory message is issued by the TWP when a tsunami with a small inundation potential is expected in very specific areas. In this case the effects of the tsunami on the coast are reduced and no extensive destruction is expected. No evacuation is usually required. However, the effects of the tsunami can cause bores, strong currents, recession of the sea and small inundation on beaches or along river shores. Resonance can cause damage in harbours and disrupt harbour operations. These effects may continue for up to a few hours. Advisories alert the national TWFPs, the NTWCs and the emergency management agencies to take appropriate actions for the entire tsunami hazard zone, like alerting people and boats along the coastline, take out swimmers from the water, alerting harbour authorities. Advisories may be updated, adjusted geographically, upgraded, or cancelled. To provide the earliest possible alert, initial Tsunami Advisory messages are based only on seismic information.

Source: NEAMTWS Interim Operational Users Guide.

Two other types of message may be issued by the TWP – a **Tsunami Information** message to advise on the occurrence of a major earthquake in the NEAM region but with an evaluation that there is no tsunami threat; and, usually at unannounced times, a **Tsunami Communication Test** message. The use of the test is:

- to identify possible delays in disseminating tsunami messages by different methods of transmission, e.g., GTS, Internet, etc;
- to test the operation of the system by requiring a response; and
- to keep TWP and NTWC operations personnel familiar with the procedures for handling tsunami message traffic.

Following the receipt, through a country's TWFP, of an alert message with information relating to one or more of that country's coastal Forecast Points, the NTWC forecasts the arrival times, amplitudes and run-ups for specific coastal locations or zones. Then, according to its judgment, the NTWC may issue warning and subsequent cancellation messages to its national Civil Protection agency, for dissemination and further action according to that agency's SOP.

Box 4.3: Possible message types issued by Tsunami Watch Providers

... TSUNAMI WATCH ...
... TSUNAMI WATCH ONGOING ...
... TSUNAMI WATCH CANCELLATION ...
... END OF TSUNAMI WATCH ...
… TSUNAMI ADVISORY …
… TSUNAMI ADVISORY ONGOING …
… TSUNAMI ADVISORY CANCELLATION …
… END OF TSUNAMI ADVISORY …
… TSUNAMI INFORMATION …
… TSUNAMI COMMUNICATION TEST …

Source: NEAMTWS Interim Operational Users Guide.

The "Watch" and national "Warning" operations, referred to above, form the real-time, event detection, processing and messaging parts of NEAMTWS. An effective response by the NTWC to its receipt, through the TWFP, of a Tsunami Watch or Tsunami Advisory message depends on the forecast wave amplitude(s) at the coastal Forecast Point(s), and on the existence and application of the pre-event knowledge that the NTWC can draw upon. Such knowledge includes *inter alia*:

- a database of pre-computed tsunami propagation scenarios relating to possible tsunami sources;
- risk assessment data for the forecast zones of the country's coasts (e.g., as inundation, vulnerability and risk maps) for credible tsunami scenarios (Sections 2.2 and 2.3); and,
- where relevant, the tidal state expected at the Expected Tsunami Arrival Time (ETA).

The NTWC may be able to identify inundation hotspots within minutes of receipt of a watch message and, if it so decides, issue a Warning through the TWFP to the national Civil Protection agency or appropriate emergency managers.

The issue of a warning based solely on receipt of an initial Tsunami Watch message carries its own risks. In order to avoid disruptive and possibly unnecessary responses, notably implementing evacuation, any such warning should carry a clear caveat that a tsunami is yet unconfirmed. In these circumstances emergency managers may take the opportunity of carrying out provisional responses in anticipation of a real damaging event. Only the receipt by the NTWC of a supplementary Tsunami Watch message which confirms the generation of a tsunami provides a sound basis for the issue of a warning and the triggering by the Civil Protection agency of full emergency operational procedures for those parts of the coastal community at risk.

The dissemination by the Civil Protection agency of warning messages received from the NTWC and the consequent response procedures by the Civil Protection agency and Emergency Operations Centres constitute the last links in the “end-to-end” real-time detection and messaging part of NEAMTWS. The detailed execution of these operations will take place according to the SOPs of established national and local authority emergency response plans. In cases of local tsunami threat, community awareness and responses to possible physical precursors to tsunami impacts – felt earthquakes, unusual shoreline recession and wave noise – may be a vital asset in enabling warnings to Civil Protection agencies, EOCs and the public in advance of messages conveyed by the technical warning system (Fig. 4.1; see also Annex 8 for description of an automated detection and warning system for near-field tsunamis which is under development).

NTWCs with seismic processing capability

A National Tsunami Warning Centre which has an in-house capability of seismic processing can potentially fulfil a Tsunami Watch Provider function in respect of earthquake information and tsunami threat forecasting, subject to accreditation (Fig. 4.1; Table 4.1). It may have a “watch” role not only for its own national purposes of tsunami warning but, potentially, also for the benefit of other NTWCs with whom it has agreed to cooperate. An in-house seismic detection and processing capability is especially relevant for the evaluation of local earthquakes, for which there may be only a few minutes for Civil Protection agencies to activate an emergency response before a tsunami’s coastal impact.

5. IMPROVING PUBLIC AWARENESS AND PREPAREDNESS FOR AN EMERGENCY

Recommendations for action by Civil Protection agencies and related disaster management organisations in respect of preparedness and public awareness include:

- Establish and review Standard Operating Procedures (SOP) for Tsunami Emergency Response in all organisations involved in disaster management.
- Improve awareness of the tsunami hazard at all levels, especially the general public.
- Develop your plan for evacuation in response to the receipt of a tsunami Warning.
- Test the effectiveness of your procedures by drills and exercises as appropriate to your levels of risk.

This section describes the procedures for emergency response to a received tsunami Warning; the means of raising the pre-event awareness of the tsunami hazard among coastal populations; the planning and operation of procedures for evacuation; and the conduct of test exercises and drills to maintain currency of the warning and response procedures. The promotion of public awareness of and preparedness for tsunamis is a principal aim of NEAMTIC, the regional Tsunami Information Centre for NEAMTWS. The role of NEAMTIC in support of NEAMTWS is described in Box 5.5.

5.1 PROCEDURES FOR TSUNAMI EMERGENCY RESPONSE

Standard Operating Procedures (SOP) for implementation of an emergency response in anticipation of a tsunami impact should be developed by every facility or organisation located within high risk zones as defined by the risk assessment process (Section 2.3; Boxes 5.1 and 5.3); in particular, critical facilities such as the police department, schools, health centres and hospitals, energy and telecommunication facilities, mass transport systems.

Box 5.1: Taking tsunami warning into account in France

Monitoring and detection

The Ministry of Interior and the Ministry of Sustainable Development have decided to entrust the “Commissariat à l'énergie atomique et aux énergies alternatives” (CEA) the mission of creating and operating the National Tsunami Warning Centre (NTWC), in partnership with “le Service Hydrographique et Océanographique de la Marine” (SHOM - Hydrographic and Oceanographic Service) and the “Centre National de Recherche Scientifique” (CNRS - National Scientific Research Centre).

Supported by specialists in seismic data analysis, the NTWC will be located in the Paris region and will be operational by mid-2012. As a NTWC, it will responsible for:

- Monitoring an area stretching from the North-eastern Atlantic Ocean to the western Mediterranean Sea.
- Alerting the authorities responsible for Civil Protection.
- Providing those authorities with expertise and assistance in decision making.

The design and functionality of the centre are based entirely on the architecture defined internationally by the ICG/NEAMTWS.

Alerting the authorities in charge of Civil Protection
The warning centre will not disseminate tsunami warnings directly to the population. This action is a sovereign function of the state through prefects, the sole representatives of the State departments. The NTWC will transmit warnings to the prefects of coastal departments who will organise the response of Civil Protection in areas expected to be impacted. Tsunami alerts and weather advisories or warnings are similar in approach because both concern the potential occurrence of an event whose intensity must be estimated. Therefore, in order to facilitate understanding of the alert, the messages issued by the NTWC, translated into French, will include alert levels similar to those used in France for more 10 years for weather alerts (early warning colours for four levels – Green / Yellow / Orange / Red – corresponding to increasing intensity). Moreover, the National crisis management will be notified of any warning, not only to inform the State authorities and the media but also to organise national solidarity and to anticipate the necessary operational reinforcements.

Alerting the population
In view of the message transmitted by the NTWC, prefects will rely in particular on early warning and public information sirens to alert the coastal population. Established originally for military defence, this system has evolved over time to accommodate the needs of alerting the population in case of a natural disaster or technological incident. This system will now be upgraded to accommodate new technologies for mass distribution of an alert, such as cell broadcasts (broadcast text messages to mobile phones located in the same area). This redesign will also allow the specific needs of the tsunami warning (e.g. location and means) to be taken into account.

Providing adequate operational response
The operational response to be implemented to cope with a tsunami is being set up through the National planning system, ORSEC (Organization of the Civil Protection Response). This organisation takes a multi-risk approach. It considers not only the event itself but all of its potential consequences in terms of protecting people, property and environment. The response revolves around the activation of generic modules which can offer a harmonised response to situations with similar consequences. The tsunami warning is taken into account by providing the accommodation of specific tasks, such as the identification of shelters and the preparation for the vertical evacuation of residents (Section 5.3). ORSEC covers not only the response time in reaction to the event but also post-accident management, including support for disaster victims in areas impacted to return to "normal life".

Source: Mlle Emilie CROCHET, CF Philippe ESTIEZ. See also Annex 8.

SOPs can include tasks to be executed shortly before, during, or after an event to minimize its impact on routine operations, processes or resources; they can promote the safety of people through evacuation to safe areas or similar procedures. In the case of schools, for example, SOPs for areas where the earthquake sources are known to lie close to the shore should contemplate tasks to be executed after an earthquake. These may include the immediate and orderly evacuation of children to safe areas; the management of critical paperwork (class lists and emergency contact information), custodian responsibilities (e.g., turning off gas lines), and teaching resources which may be required after the event to re-start the education process as soon as possible. In case of the police, SOPs may include the designation of specific teams to assist in the evacuation process; management of critical information; the set-up of special security measures in particular buildings or places, the evacuation of the premises; and the use of back-up communication systems should the main systems fail. A template for planning Tsunami Emergency Response is given at Annex 6.

Because tsunami events can affect several countries, regional emergency response efforts should be incorporated into national and local efforts headed by Civil Protection agencies and other relevant authorities (maritime, municipal, police or eventually military if needed). In Europe at the regional level, the European Commission is responsible for supporting and supplementing efforts at national, regional and local levels with regard to disaster prevention, mitigation and preparedness of those responsible for Civil Protection and intervention in case of an event or disaster. The legislative framework for European Civil Protection has enabled the Commission to establish a framework through its Monitoring and Information Centre (MIC) for effective and rapid co-operation between national Civil Protection services when mutual assistance is needed (Box 5.2).

Box 5.2: The European Commission's Monitoring and Information Centre (MIC)

The Monitoring and Information Centre (MIC), operated by the European Commission in Brussels, is the operational heart of the Community Mechanism for Civil Protection. It is available on a 24/7 basis and is staffed by duty officers working on a shift basis. It gives countries access to the community civil protection platform. Any country affected by a major disaster – inside or outside the EU – can launch a request for assistance through the MIC.

During emergencies the MIC plays three important roles:

- Being at the centre of an emergency relief operation, the MIC acts as a focal point for the exchange of requests and offers of assistance. This helps in cutting down on the 31 participating states' administrative burden in liaising with the affected country. It provides a central forum for participating states to access and share information about the available resources and the assistance offered at any given point in time.
- **Provides information**: The MIC disseminates information on civil protection preparedness and response to participating states as well as a wider audience of interested. As part of this role, the MIC disseminates early warning alerts (MIC Daily) on natural disasters and circulates the latest updates on ongoing emergencies and Mechanism interventions.
- **Supports co-ordination**: The MIC facilitates the provision of European assistance through the Mechanism. This takes place at two levels: at headquarters level, by matching offers to needs, identifying gaps in aid and searching for solutions, and facilitating the pooling of common resources where possible; and on the site of the disaster through the appointment of EU field experts, when required.

Source: http://ec.europa.eu/echo/civil_protection/civil/prote/mic.htm

Box 5.3: Tsunami risk and emergency response procedures in Ireland

The document that guides management of and response to major emergencies in Ireland is the "Framework for Major Emergency Management". The Framework was devised to enable An Garda Síochána (police), the Health Service Executive and Local Authorities (the Principal Response Agencies) to prepare for and make a coordinated response to major emergencies resulting from local and regional events such as fires, transport accidents, hazardous substances incidents and severe weather. The Framework puts in place arrangements that facilitate the three Principal Response Agencies to co-ordinate their efforts whenever a major emergency occurs. A Protocol to the Framework on multi-agency response to tsunami events is at a draft stage.

The Framework notes that "the emphasis of the Framework is on bringing the full capacity of the principal response agencies to bear effectively on a major emergency situation and extending this where necessary, *rather than creating extra capacity for very unlikely scenarios*" (emphasis added). We (i.e., those developing a TWS for Ireland) need to change the perception that can be taken from the Framework that tsunami risk is beyond mitigation, by demonstrating that the risk is real for Ireland, and mitigation is a relatively low-cost option.

The Framework recognizes that an important aspect of any mitigation effort is the development and strengthening of resilient communities. Resilient communities are particularly important in coping with certain kinds of emergency, such as flooding or those involving evacuation or sheltering. Educating and informing the public on possible emergencies is a vital element of that process and the development of key messages for targeted audiences is an essential first step.

The Framework suggests that provision of public information in the event of an emergency, where members of the public are seeking information on actions which they can take to protect themselves, may include the use of dedicated “help-lines”, web-pages, Aertel, automatic text messaging, as well as through liaison with the media. In an emergency situation, the lead agency may request the media to carry Public Information Notices to disseminate important messages, such as how individuals may help themselves and their neighbours in a particular situation. Indeed, it may be necessary to put significant efforts into managing public perceptions of the risks, in addition to managing the actual risks.

The emergency event closest to tsunami that has been fully considered in the Framework to date is the Severe Weather Plan. Met Eireann’s Severe Weather Warning System includes coastal storm surge when significant resulting flooding is expected. As with the envisaged TWS, Met Eireann issue severe weather warnings to the Local Authorities who are designated as the lead agency for co-ordinating the response to severe weather events. Local Authorities should ensure that effective arrangements are in place to receive and respond promptly to public service severe weather warnings issued by Met Éireann. Similarly, the Local Authorities will probably be designated as the principal response agency for tsunami events. An obvious difference between a severe weather warning and a tsunami warning is that for the former the target time for the issuing of a warning is 24 hours before the start of the event, whereas tsunami warning times will be approximately 4 hours at best, depending on the distance from the generating event to the detection instruments and to the Irish coast.

Source: Brian McConnell

5.2 ENHANCING AWARENESS OF THE TSUNAMI HAZARD

Experience over recent years regarding the impacts of tsunamis in developed and developing countries throughout the world has shown that inadequate preparation for, and response to, emergency situations has contributed to widespread damage and loss of lives and livelihoods. These shortcomings have been due in part to a lack of warning in the absence of regional detection and communication systems. In many cases, however, they have reflected inadequate awareness, planning and coordination on the part of the national and local authorities, agencies, and people exposed to such hazards. In some cases, such shortcomings have contributed to catastrophic human losses which could and should have been avoidable.

Activities for raising awareness of the tsunami hazard and of the need for tsunami-related risk reduction are relevant at all levels in the governance of coastal areas where the coastal communities are perceived to be at risk. Their successful implementation requires a solid base of political support, appropriate laws and regulations, clearly defined institutional responsibilities and trained people. Target audiences need to be identified and the means and formats to communicate the risk chosen. Recommended steps for raising awareness for disaster risk reduction compiled by UN/ISDR (2007) are given at Annex 7. A particular challenge for local authorities and agencies is to create and maintain awareness among communities of the hazard in situations where events may recur only after intervals of perhaps hundreds of years. This difficulty is compounded by the changing demographics of coastal areas within the NEAM region, and in particular by the seasonal influx of visitors to the shores of many countries. Tourists, students and other persons visiting coastal areas may be unfamiliar with the tsunami hazard as well as with the local geography and language.

A coastal community at risk must be educated and made fully aware of the risks from the tsunami and other natural hazards (storms, heavy precipitation, etc) and the potential for disaster and the evacuation routes and procedures (see below) as part of a wider disaster reduction programme (Box 5.4). Conducting evacuation drills for training the community on disciplined evacuation may be appropriate. A mechanism for this entire public awareness and preparedness process needs be monitored on a community-led and community-owned, sustainable basis. The community must have an effective mechanism for communication duration the evacuation process, helping to handle and swiftly resolve the problems and issues of a panic-stricken population who are on the move, thereby minimizing the level of prevalent chaos.

Box 5.4: Template for a list of actions to be taken by the public in the event of a received tsunami warning

The Emergency Services authority has ordered the evacuation of low-lying parts of coastal towns and villages in the following coastal zones: [*insert* list]

- This evacuation order is issued under [*insert* relevant national legislation].
- Take only small, essential items that you can carry including important papers, family photographs, and medical needs.
- Go to higher ground at least 10 metres above sea level, or, if possible, move at least 1km away from all beaches, harbours and coastal estuaries.
- It will be in your own interests to walk to safety if possible, to avoid traffic jams.
- If you cannot leave the area, take shelter in the upper storey of a sturdy brick or concrete multi-storey building.
- Boats in harbours, estuaries and shallow coastal water return to shore. Secure your boat and move away from the waterfront.
- Vessels already at sea should stay well offshore and remain there until further advised.
- Do not go to the coast or headlands to watch the tsunami

Source: Indian Ocean Tsunami Warning and Mitigation System (IOTWS): Implementation Plan for Regional Tsunami Watch Providers (RTWP). IOC Technical Series 81.

Coastal communities, particularly those in many northern European countries, may already be aware of the storm surge and heavy precipitation hazards, significant events recurring at intervals of, say, 5 to 10 years. However, within the region generally the tsunami hazard is less well known and, even in areas prone to tsunamis, events may be so sporadic that there may be little or no social memory of them. Thus awareness strategies may have to be devised by Civil Protection agencies specifically for the tsunami hazard within the context of the risks to the community from natural hazards in general.

Media and formats

Means and formats used to communicate the risk should be tailored to the proposed target audience, e.g. children; senior citizens, disabled persons, etc. In the context of disaster preparedness, risks are usually represented by means of maps and matrices with complementary text tailored to national, provincial, municipal, or local users. Communication should be conducted in readily understandable plain language or languages, taking into consideration local experience and education, traditions, and culture.

Media formats and channels must be appropriate to the assessed levels of risk to the communities and to the capacities of those communities at risk. In high risk areas short-term campaigns may be appropriate. These may include posters and leaflets, as well as publications in mass media – newspapers, magazines and the Internet. Longer-term social awareness of tsunami hazard along with other natural hazards may be best achieved by education in local school curricula as well as outreach methods. The Tsunami Information Centre, NEAMTIC (Box 5.5), which forms part of the regional Tsunami Early Warning and Mitigation System, NEAMTWS, has a key role as an information resource for the development and distribution of awareness, educational and preparedness materials.

5.3 PLANNING FOR EVACUATION

A key element of the emergency response in anticipation of a tsunami impact is the evacuation (or self-evacuation) of exposed people and mobile assets (e.g., vehicles and important information) to safe areas, or, in the case of harbour craft, offshore to deep water (Fig. 5.1; Box 5.6). In the event of a basin-wide tsunami in the Mediterranean, for example, the lead time between the receipt of a formal Warning and the expected time of tsunami arrival (ETA) at a particular coast could be as much as two hours, depending on the distance from the tsunami source. For local tsunamis, the lead time could be non-existent (see below) or perhaps only a few minutes. In any event, depending on the expected tsunami wave height or the severity of a felt earthquake, there may be a need to set an evacuation process in train as quickly as possible.

Box 5.5: Objectives of the Tsunami Information Centre for the North-eastern Atlantic, the Mediterranean and Connected Seas region (NEAMTIC)

- **Providing information** to civil protection authorities on warning systems for tsunamis and other sea-level related hazards, and on the activities of IOC and European Union (EU) in the field of tsunami preparedness.
- **Making citizens, especially youth, aware of risks** of floods from the sea in coastal areas, such as tsunamis, storm surges and strong swells and acquiring knowledge on and practicing safe behaviour.
- **Identifying, sharing and disseminating good practices** in plans, methods and procedures to strengthen preparedness for sea level related hazards.
- **Fostering linkages between the EU and IOC** on intergovernmental and transnational actions to develop NEAMTWS.

Source: http://neamtic.ioc-unesco.org/images/documents/neamtic%20english%20poster%20printer.pdf

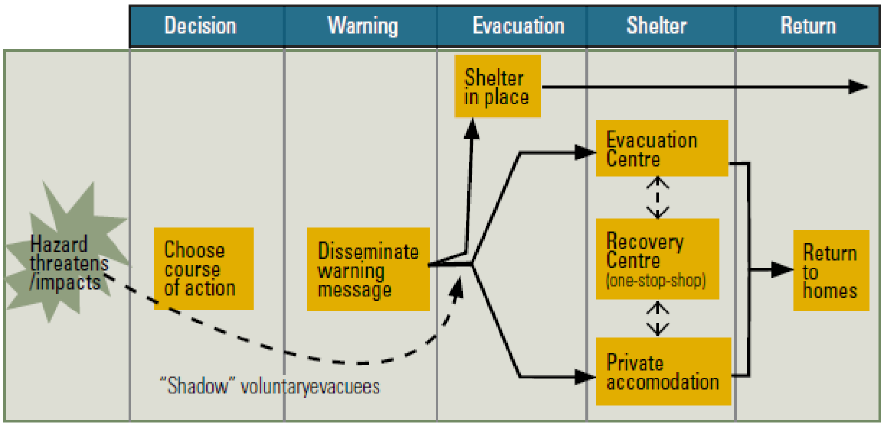


Fig. 5.1. Phases of the evacuation process. Source: David Coetzee.
Extracted from *Tsunami Risk Assessment and Mitigation for the Indian Ocean – Knowing your Tsunami Risk – and what to do about it* (UNESCO, 2009b).

The trigger for the evacuation process at the local community level may be the receipt through the Civil Protection agency of a Warning message from the National Tsunami Warning Centre (NTWC). Alternatively in seismically active coastal areas, the trigger for response could be that a strong earthquake has been felt by the coastal community. In such cases, although the magnitude and location of such an earthquake and the likelihood of a consequent damaging tsunami may be unknown to that community, precautionary evacuation procedures should be considered. It could be several minutes before a Warning message is received from the NTWC, and, in the case of a local tsunami, these minutes could be vital in saving lives, e.g., by self-evacuation or by clearing people from beaches. In cases where local, possibly tsunamigenic earthquakes have caused physical damage to coastal buildings and infrastructure, and maybe also injuries and loss of life, evacuation could be seriously hampered, whatever the lead time.

Evacuation planning is a lengthy process and should be considered an ongoing endeavour which continues to improve in successive iterations. Consideration may be given to embedding such planning in the ICAM (Integrated Coastal Area Management) process. The time taken for planning activities will be directly related to the:

- geographical size of the management area;
- regional topography;
- regional hazards and vulnerabilities;
- demographics;
- size and density of the population;
- number of agencies involved in the planning process; and
- resources available.

Evacuation in response to tsunamis generally implies voluntary and/or mandatory evacuation, both of which can place a significant burden on the resources of emergency managers in terms of caring for the displaced people. The demands on emergency managers will change as the evacuation progresses though each of its phases (Fig. 5.1).

Using the maps produced in the vulnerability assessment process (Section 2.3), the identification of people at risk allows emergency and disaster planners to develop evacuation plans and strategies tailored to their needs and capacities. The identification of safe areas and potential evacuation routes is carried out using information about the dynamic features of the inundation from the hazard mapping (Section 2.2). If vertical evacuation in buildings is considered necessary, structural assessments of the chosen buildings should be carried out to ensure that such buildings offer adequate safety in the event of inundation.

Box 5.6: Aspects to be addressed in a tsunami evacuation plan

- Conditions under which an evacuation may be necessary.
- Conditions under which to support people sheltering in place, including vertical evacuation.
- Identified "at risk" people/communities who may require evacuation.
- Command, control and coordination instructions (including designation of those authorised to order an evacuation).
- Warning instructions to be issued to the media, public and businesses.
- Procedures for assisting special categories of evacuees (for example vulnerable communities).
- Specific plans and procedures that address:
    - the circumstances of the emergency;
    - transportation (for example, arrangements for those without vehicles);
    - dealing with community disregard of mandatory evacuation;
    - the evacuation of specific locations; and
    - evacuation routes.
- Means of accounting for evacuees.
- Welfare support for evacuees; designated reception areas.
- Security of evacuated areas.
- Procedures for the return of evacuees.
- Maintaining the plan, drills and exercises.

Extracted from: *Tsunami Risk Assessment and Mitigation for the Indian Ocean – Knowing your Tsunami Risk – and what to do about it* (UNESCO, 2009b).

Tsunami evacuation zones and maps

A key consideration for tsunami planning and information requirements is the number of zones that should be used for evacuation management and the way in which the information might be depicted for the public. Use of a single tsunami evacuation zone has the advantage of simplicity for both emergency planning and public understanding. However, because a single evacuation zone must accommodate the very wide range of local risk scenarios that may exist, this can result in regular "over-evacuation" of the entire zone for common, small-scale events. Recurrent over-evacuation is likely to result in decreasing levels of community trust in emergency managers. Use of more than three or four evacuation zones may better reflect the range of local tsunami risk scenarios. However, such differentiation requires far greater resources and a higher degree of coordination for planning and response, and the complexity of information may create public misunderstanding.

The elevations and methods used to establish evacuation zones are developed at local level, based on local hazard analysis and inundation modelling. Ideally, zones need to represent an envelope around all possible inundations from all known tsunami sources, taking into account all of the ways each of those sources may generate a tsunami (see Section 2.2).

The installation in prominent places in homes, holiday homes, tourist facilities, workplaces and public buildings in areas subject to tsunami risk of simple maps carrying internationally recognized signs indicating hazard zones, evacuation routes, vertical evacuation shelters and safe areas may be considered (Fig. 5.2). In addition to demarcation of evacuation zones on maps, the basic legend, instruction messages and supporting information on maps should be nationally, or preferably regionally consistent. To ensure common understanding across communities, maps should use the same or closely similar colours, the same names for evacuation zones, and common symbols.

Fig. 5.2. Informing communities about hazards and responses.
Maps should be used to provide tsunami safety instructions and identification of the hazard zones, evacuation routes and safe places.
Source: ISO 20712-1:2008--Water safety signs and beach safety flags--Part 1: specifications for water safety signs used in workplaces and public areas, and from ISO 20712-3:2008--Water safety signs and beach safety flags--Part 3: Guidance for use. Reproduced with the permission of the International Organisation for Standardisation, ISO. This standard can be obtained from any ISO member and from the Web site of the ISO Central Secretariat at the following address: (www.iso.org/isostore). Copyright remains with ISO.

Evacuation routes and signage

Evacuation routes have to be designed to permit human and vehicle movement to safe places and evacuation structures. The design should be based on the expected volume of humans and vehicles, speed of evacuation and safety (Box 5.7). The design should primarily present the number of routes required, the width and the overall safety of the evacuation process. The design must ensure the safe passage of evacuation and consider the risk of failure of the route itself under disaster conditions. Such an approach will identify weak links which may have to be rectified in advance and also recommend alternative routes in the event of failure of a prescribed route.

Signage is an integral part of practical tsunami risk management. Signage depicting evacuation zones and routes raises public awareness of local tsunami risk and provides information to increase the efficiency and effectiveness of an evacuation (Fig. 5.3). Well placed evacuation signage is the critical link between an actual event and the emergency response plan. The maintenance of the evacuation route should be given high priority.

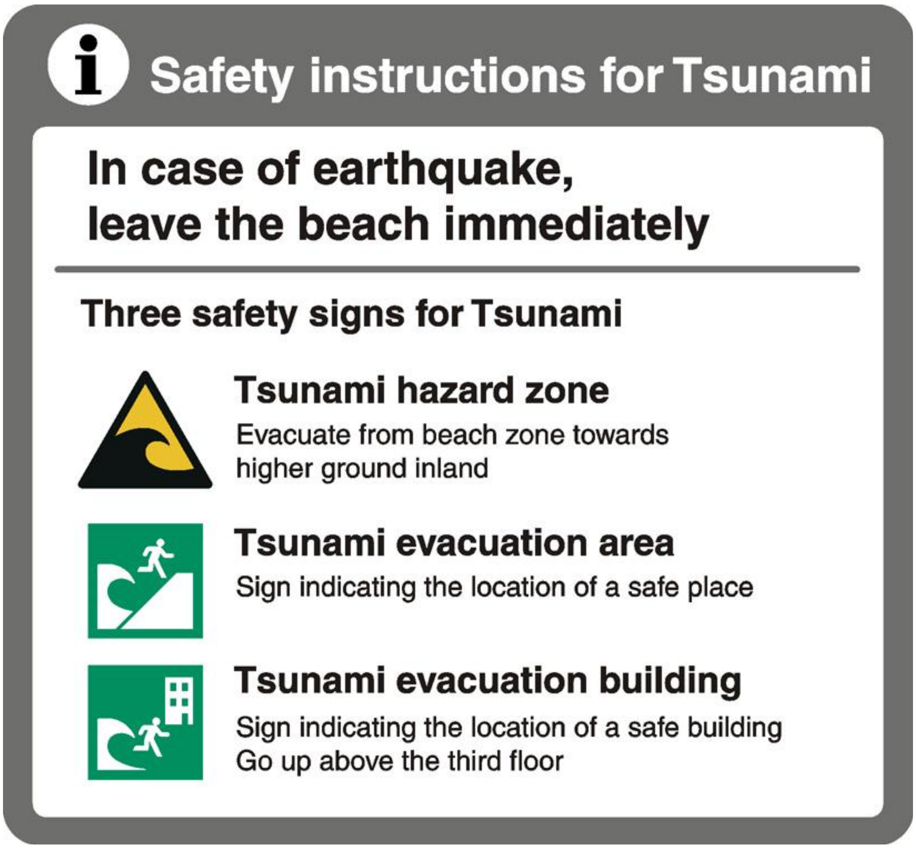


Fig. 5.3. Safety instructions and signage for tsunami events.

Source: ISO 20712-1:2008--Water safety signs and beach safety flags--Part 1: specifications for water safety signs used in workplaces and public areas, and from ISO 20712-3:2008--Water safety signs and beach safety flags--Part 3: Guidance for use. Reproduced with the permission of the International Organisation for Standardisation, ISO. This standard can be obtained from any ISO member and from the Web site of the ISO Central Secretariat at the following address: www.iso.org/isostore. Copyright remains with ISO.

Evacuation structures

The need for evacuation structures should be identified with respect to the population at risk and time available for evacuation to safe places, if such places have been identified. Evacuation structures are mandatory in the absence of safe places such as high ground or elevated infrastructure which can safely accommodate people at risk. Even if such safe places and facilities are available, it is necessary to be certain that the people at risk can be safely evacuated to such locations. If not, supplementary evacuation structures should be provided (for vertical evacuation).

For this purpose it is necessary to determine the critical time for the tsunami to reach a proposed safe place for a worst-case scenario after the Warning is issued; also the maximum time required for evacuation. In the analysis, a safety factor should be included to accommodate any potential delay in the evacuation process. Sometimes the need for evacuation structures may be avoided by having additional routes to the safe zones, thereby accommodating a reduced density of the human evacuation rate on a given route, leading to a higher rate of evacuation.

Further information regarding evacuation can be found in the Handbook of Tsunami Evacuation Planning, a publication of the EU SCHEMA Project (Scheer et al., 2011).

Box 5.7: Planning an evacuation route

In defining the best evacuation route from a given point, one needs to calculate the fastest path from that point to a safe area. The fastest path may not be the shortest (a direct line between the point and the safe area); in fact the most direct line might intersect natural barriers, buildings, rivers, lakes, sandy areas, or have a high relief. Any of these factors can dramatically hamper or even block evacuation. Thus, when we compute the best route, we must consider not only the geometric distance but also the cost (in terms of time and effort) of following a particular path.

During the CRATER project (see below) a team of experts produced a flexible and user-friendly "Evacuation Routes Tools ArcGis® toolbox", including a User's Manual to support local authorities in Thailand in evacuation planning. The methodology introduces the concept of Cost Weighted Distance. The calculation of the Cost Weighted Distance, together with land-use information, digital terrain elevation data and existing ArcGis® tools, give the possibility to a local authority or Civil Protection technician to build and visualize the best possible evacuation routes for a given area.

Source: Alessandra Cavalletti and Filippo Dall'Osso

The CRATER project – Coastal Risk Analysis of Tsunamis and Environmental Remediation, 2005–2007, was funded by the Italian Ministry of Environment Land and Sea for technical support to Thailand in the aftermath of the 2004 Indian Ocean Tsunami. Manuals for "Evacuation Routes Tools" and an associated part of the project "Risk Assessment and Evaluation" are available at: http://www.medingegneria.it/page.jsp?idPagina=709&idSettore=552

5.4 SIMULATIONS AND DRILLS

Simulations and drills constitute exercises to test and improve the degree of preparedness of an institution or a community to react efficiently and in a timely manner to an event, to test the soundness of SOPs, to improve inter-institutional coordination mechanisms, and to promote awareness of response procedures. Simulations usually refer to more passive exercises whereby SOPs are put to the test to identify their strengths and weaknesses, but no actions take place in the field. Drills refer to field exercises that test the effectiveness of SOPs and response capacities in a controlled way.

Simulations and drills follow similar procedures regarding planning, but drills are more complex in the preparation for their execution, involving the mobilization of people and resources. Simulations and drills, typically for evacuation training, can be executed at any level from an institution, e.g., a single school, to a municipality. All participants and others who might be affected need to know that the action is only a drill or exercise.

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ACRONYMS AND ABBREVIATIONS

AA	Area(s) affected (relating to alert message)
AS	Authority Statement (relating to alert message)
DMO	Disaster Management Office
EOC	Emergency Operations Centre
ES	Evaluation Statement (relating to alert message)
ETA	Expected Tsunami Arrival Time
EU	European Union
GIS	Geographical Information System
ICAM	Integrated Coastal Area Management
ICG	Intergovernmental Coordination Group
IOC	Intergovernmental Oceanographic Commission
IOTWS	Indian Ocean Tsunami Warning and Mitigation System
ITIC	International Tsunami Information Centre
JRC	Joint Research Centre (European Commission)
MCDEM	Ministry of Civil Defence and Emergency Management, New Zealand
MIC	Monitoring and Information Centre (European Commission)
NEAM	North-eastern Atlantic, the Mediterranean and Connected Seas region
NEAMTIC	Tsunami Information Centre for NEAMTWS
NEAMTWS	Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas
NTWC	National Tsunami Warning Centre
SOP	Standard Operating Procedures
TER	Tsunami Emergency Response plans
TNC	Tsunami National Contact
TWP	Tsunami Watch Provider
TWFP	Tsunami Warning Focal Point
UN/ISDR	United Nations International Strategy for Disaster Reduction
UNDP	United Nations Development Project
UNESCO	United Nations Educational Scientific and Cultural Organisation

GLOSSARY

Accommodation: The continued use of land at risk, without attempting to prevent land from being damaged by the natural event. This option includes erecting emergency flood shelters, elevating buildings on piles, converting agriculture to fish farming or growing flood/salt tolerant crops (Bijlsma et al., 1996).

Coping capacity: The means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a coastal disaster (UN/ISDR, 2004).

Early warning: The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to avoid or reduce their risk and prepare for an effective response (UN/ISDR, 2004).

Emergency management: The organization and management of resources and responsibilities for dealing with all aspects of emergencies, in particularly preparedness, response and rehabilitation (UN/ISDR, 2004).

Exposure: Elements at risk, an inventory of those people or artefacts that are exposed to a hazard (UNDP-BCPR, 2004). In these guidelines, “exposure” provides the spatial context for integrating hazard and vulnerability.

Flow depth: Depth of water attained during process of inundation (synonymous with “inundation depth”.

Hazard: A potentially damaging physical event or phenomenon that may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. A hazard is characterized by its location, intensity, frequency and probability (UN/ISDR, 2004).

Inundation: The state of flooding of coastal land resulting from the impact of a tsunami, storm surge or other coastal flood hazard.

Inundation distance: Horizontal distance of inundation limit, measured perpendicular to the shoreline.

Inundation line / limit: The line marking the maximum horizontal inland penetration of a tsunami, storm surge or other coastal flood hazard from the shoreline.

Mitigation: Structural and non-structural measures undertaken to limit the adverse impact of natural hazards (UN/ISDR, 2004).

Preparedness: Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations (UN/ISDR, 2004).

Protection: Involves the use of natural or artificial measures to protect landwards development and/or attempt to hold the shoreline in its existing position in an effort to reduce hazard impacts (Bijlsma et al., 1996).

Public awareness: The processes of informing the general population, increasing levels of consciousness about risks and how people can act to reduce their exposure to hazards. This is particularly important for public officials in fulfilling their responsibilities to save lives and property in the event of a disaster.

Resilience: The capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures (UN/ISDR, 2004).

Retreat: Abandonment of coastal area and the landward shift of ecosystems. This choice can be motivated by the nature of assets to be protected (Bijlsma et al., 1996).

Risk: The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between hazards and vulnerable conditions (UN/ISDR, 2004).

Risk assessment: A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend (UN/ISDR, 2004).

Run-up: The difference between the elevation of maximum tsunami penetration (inundation line) and the sea level at the time of the tsunami.

Structural measures: Structural measures refer to any physical construction to reduce or avoid possible impacts of hazards, which include engineering measures and construction of hazard-resistant and protective structures and infrastructure (UN/ISDR, 2004).

Vulnerability: The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards (UN/ISDR, 2004).

ANNEXES

ANNEX 1

Box A1: Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS) – background and objectives

The Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS) was formed in response to the tragic tsunami on 26 December 2004, in which over 250,000 lives were lost around the Indian Ocean region. The Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) received a mandate from the international community to coordinate the establishment of the System during the course of several international and regional meetings, including the World Conference on Disaster Reduction (Kobe, Japan, 18 – 22 January 2005), and the Phuket Ministerial Meeting on Regional Cooperation on Tsunami Early Warning Arrangements (Phuket, Thailand, 28 and 29 January 2005). The IOC Assembly, during its twenty-third Session (21-30 June 2005), formally established the ICG/NEAMTWS through Resolution IOC-XXIII-14.

The objectives of the ICG/NEAMTWS are:

1. To coordinate the activities of the ICG/NEAMTWS;
2. To organize and facilitate, as appropriate, the exchange of seismic, geodetic, sea-level and other data in or near real-time and information required for interoperability of the ICG/NEAMTWS;
3. To promote the sharing of experience and expertise related to tsunami warning and mitigation for the north-eastern Atlantic, the Mediterranean and connected seas;
4. To promote tsunami research;
5. To promote the establishment and further development of national tsunami warning and mitigation capacities in accordance with standard protocols and methods;
6. To develop, adopt and monitor implementation of work plans of the ICG/NEAMTWS, and to identify required resources;
7. To promote implementation of relevant capacity-building;
8. To liaise and coordinate with other tsunami warning systems;
9. To liaise with other relevant organizations, programmes and projects;
10. To promote the implementation of the ICG/NEAMTWS within a multi-hazard framework;
11. To develop a comprehensive programme of capacity-building on tsunami protection for the North-eastern Atlantic, the Mediterranean and connected seas, including the Black Sea;
12. To keep under constant scrutiny the status of the system and how it satisfies the needs.

ANNEX 2

Modelling tsunami propagation and analysing the potential for a tsunami impact on a coast

Two complementary approaches are used for expressing the potential for a tsunami impact – Scenario-based Tsunami Hazard Analysis (STHA) and Probabilistic Tsunami Hazard Analysis (PTHA). The scenario-based approach, focusing on a maximum credible event supported by historical evidence, is normally used for compiling inundation maps and as a basis for evacuation procedures. The probabilistic approach considers a broad range of potential events and their likelihoods using *inter alia* geoscience as well as historical data. The credibility of each approach depends on characterization of the tsunami (usually earthquake) sources, a representation of tsunami propagation (for example, bathymetry data) and the uncertainties in these parameters.

Propagation is the process by which the tsunami's wave or waves travel from the tsunami source. The pattern of propagation depends on source factors such as the amplitude and lateral extent of vertical seabed displacement associated with the earthquake (see Figure). It is influenced by variations of water depth along the oceanic path, by submarine features and by islands. On reaching coastal waters, the propagating tsunami may be diffracted around headlands and islands, refracted by changes in water depth and even reflected from a coast on impact. The possibility of a tsunami impact coinciding with other inundation forces, notably high Spring tide events, thus compounding the levels of coastal inundation, should be considered. A tsunami is a series of waves and the initial wave may not be the largest. The time between successive waves can range from a few minutes to more than one hour.

Representations of tsunami sources and propagation by computer modelling have been the subjects of research by the international science community. Information on these modelling programmes and their outputs is given below:

Countries may have access to pre-calculated, modelled tsunami propagation information to assist them in estimating the propagation patterns and travels times to their National Forecast Points for tsunamis generated from a range of possible seismic sources. The pre-calculated tsunami propagation database created by the European Commission's Joint Research Centre (JRC) is one of several off-line initiatives which may be helpful in this regard (Box A1).

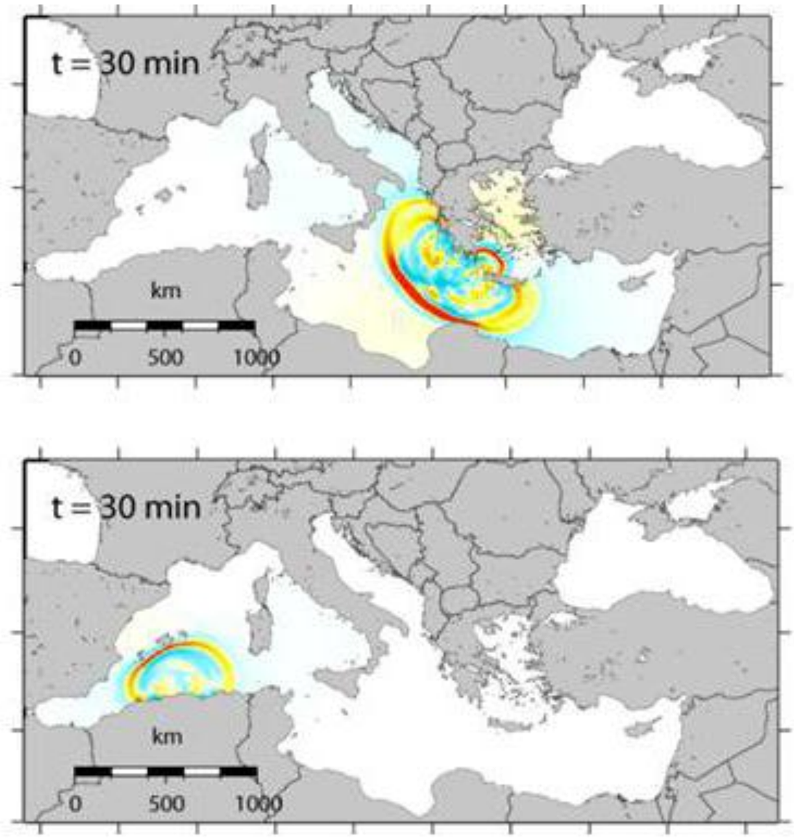


Figure: Modelled tsunami fronts after 30 minutes propagation time from sources located in the western Hellenic arc (above) and in northern Algeria (below).
Source: ICG/NEAMTWS Implementation Plan 2007, IOC Technical Series No. 73.

Box A2: JRC Tsunami Assessment Modelling System

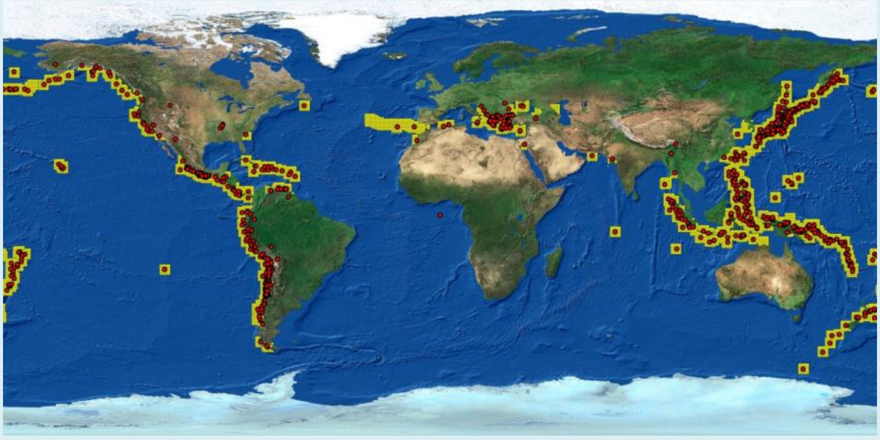
The Tsunami Assessment Modelling System was developed by the European Commission's Joint Research Centre (JRC), in order to serve tsunami early warning systems such as the Global Disaster Alerts and Coordination System (GDACS) in the evaluation of possible consequences by a tsunami of seismic origin. The JRC system includes three main components: a) the global scenario database; b) the on-line calculation system; c) the Tsunami Analysis Tool.

The Global Scenario Database (GSD) is a set of 136,000 calculations performed in eight months of calculations using a modified SWAN [1] model, using a grid of 10,500 possible epicentres (with a 0.5 x 0.5 degrees interval) determined using historical tsunami event epicentres. Calculations for each magnitude between 6.5 and 9.5 have been performed. This database (2 TBytes) is ready to give a first immediate estimate of the tsunami consequences as soon as the earthquake epicentre is known. The scenario database identifies the locations potentially affected as well as the predicted wave height. The overall database is accessible online through a web interface (user/password required) or can be used locally for a quicker access through the TAT software.

The epicentres (yellow) correspond to the tsunami scenario database. For every single point, 13 calculations with magnitudes in the range 6.5–9.5 have been calculated. A total of 136,000 calculations are available.

The Online Calculation System (OCS) uses the same model as the scenario database but it is automatically initialized with the real earthquake parameters (epicentre and magnitude). The calculations start as soon as an earthquake with potential tsunami consequences is identified and the calculation time is in the order of 30–40 minutes.

These results are not very different from those of the GSD, but they should be more accurate because of being initialized with the real parameters.



The Tsunami Analysis Tool (TAT) is the software that allows quick visualization of the results of the scenario database and on-line calculations and compares them with real, online sea-level measurements.

The JRC system is now operationally serving the GDACS system and, soon after any event with possible tsunami consequences, the calculations from the GSD and from the OCS are automatically freely available on the web site http://www.gdacs.org. JRC is open to support any other early warning systems: as an example, an agreement has been recently established to support Portugal's Institute of Meteorology for the development of the Portugese Tsunami Early Warning System through the use of the scenario database and the Tsunami Analysis Tool. To this purpose the scenario database has been enlarged to include some areas in the Atlantic Ocean.

Alessandro Annunziato, JRC. (http://tsunami.jrc.it/model/index.asp)
Extracted from: *Hazard Awareness and Risk Mitigation in ICAM* (UNESCO, 2009a)

ANNEX 3

Procedures for inundation modelling and mapping

Source: Based on UNESCO, 2009b

A first-order approach to define inundation limits is the use of the “bathtub” model in which the inundation of coastal land is determined based simply on a uniform maximum elevation – perhaps 5 m – above sea level. A more realistic output may be achieved using GIS technology to incorporate local knowledge and a measure of rule-based wave attenuation inland from the coast. A further refinement would be a computer-derived simulation model that theoretically allows for complexities that a simpler rule cannot, such as varied surface roughness, water turning corners etc. Finally, the most complete modelling would be based on an envelope around all inundations from multiple well-tested computer models. Such an approach would require a comprehensive scientific understanding of all possible tsunami sources, wave propagation and inundation behaviours across a range of magnitudes.

The application of computer modelling to represent inundation has been the subject of research by the international science community. Parameters required for input to the inundation models include bathymetry and topography, tidal variation, the built environment, the distribution and type of vegetation, etc. Survey data may be obtainable from national survey and defence organizations, from the IOC-GEBCO coastal bathymetric atlas, from LIDAR surveys and Digital Elevation Models (DEMs). Usually the source model and the propagation and inundation models (see above) use three separate computer programmes, the output from one forming the input to the next in the sequence. Some codes are capable of doing multiple steps, e.g., combining the propagation and inundation modelling steps.

ANNEX 4

Table A1: Established NEAMTWS Tsunami National Contacts (TNCs) and Tsunami Warning Focal Points (TWFPs) as of 17 November 2011

Member State	TNC	TWFP
BELGIUM	**Centre Gouvernementale de Coordination et de Crise**	**Centre Gouvernementale de Coordination et de Crise**
BULGARIA	**Bulgarian Institute of Oceanology (BAS)**	**Bulgarian Institute of Oceanology (BAS)**
CAPE VERDE	**Instituto Nacional de Meteorologia e Geophísica**	**Instituto Nacional de Meteorologia e Geophísica**
CROATIA	Institute of Oceanography and Fisheries*†	**National Protection and Rescue Directorate – National Center 112**
CYPRUS	Cyprus Oceanography Centre, University of Cyprus*	Cyprus Oceanography Centre, University of Cyprus*
DENMARK	**Danish Meteorological Institute**	**Danish Meteorological Institute**
EGYPT	**National Institute of Oceanography and Fisheries (NIOF)**	**National Research Institute of Astronomy and Geophysics (NRIAG)**
ESTONIA	Estonian Marine Institute, University of Tartu*	Estonian Marine Institute, University of Tartu*
FINLAND	**Finnish Institute of Marine Research**	**Monitoring Center for Natural Disasters, Finnish Meteorological Institute**
FRANCE	**Ministère de l'Ecologie, du Développement et de l'Aménagement Durables**	Centre national d'alerte au tsunami (Cenalt)†
GERMANY	**Federal Maritime and Hydrographic Agency (BSH)**	
GREECE	**National Observatory of Athens (NOA)**	**National Observatory of Athens (NOA)**
IRELAND	Geological Survey of Ireland*	
ISRAEL	Israel Oceanographic and Limnological Research*	
ITALY	**Dipartimento della Protezione Civile**	**Dipartimento della Protezione Civile**
LEBANON	Geophysical National Center, National Council for Scientific Research*	Geophysical National Center, National Council for Scientific Research*
MALTA	Ministry of Foreign Affairs*	Ministry of Foreign Affairs*
MONACO	**Centre Scientifique de Monaco**	**Compagnie des Sapeurs-Pompiers de Monaco**
NETHERLANDS		**KNMW Royal Netherlands Meteorological Institute**
NORWAY		**Directorate for Civil Protection and Emergency Planning (DSB)**
POLAND		**National Centre for Coordination of Rescue Operations and Protection of Population, National Headquarters of the State Fire Service**
PORTUGAL	**Instituto de Meteorologia**	**Instituto de Meteorologia**
ROMANIA	**National Institute for Earth Physics**	**National Institute for Earth Physics**
RUSSIAN FEDERATION	**State Institute Research and Production Association “Typhoon”**	**State Institute Research and Production Association “Typhoon”**
SLOVENIA	**Environmenta Agency of the Republic of Slovenia (EARS)**	
SPAIN	**Instituto Español de Oceanografía**	**Jefe del Area de Riesgos Naturales, Dirección General de Protección Civil y Emergencias**

Member State	TNC	TWFP
SYRIA	**Syrian Wireless Organization (SWO), Ministry of Telecommunication and Technology**	**Syrian Wireless Organization (SWO), Ministry of Telecommunication and Technology**
SWEDEN	Swedish Civil Contingencies Agency*†	Swedish Meteorological and Hydrological Institute (SMHI)*†
TURKEY	**Kandilli Observatory and Earthquake Research Institute (KOERI)**	**Kandilli Observatory and Earthquake Research Institute (KOERI)**
		Office of Prime Ministry, disaster and emergency management Directorate
UKRAINE	Marine Hydrophysical Institute, National Academy of Sciences of Ukraine*†	
UNITED KINGDOM	**National Oceanographic Centre (NOC)**	**Humanitarian Operations, Department for International Development (DFID)**

Bold: all information provided
* Official form not provided
† Validation needed through either the Permanent Delegate to UNESCO, the Head of the UNESCO National Commission or the Minister of Foreign Affairs

ANNEX 5

Box A3: Sample Tsunami Message - Tsunami Watch Initial – Type 1

Source: NEAMTWS Interim Operational Users Guide.

TSUNAMI MESSAGE NUMBER 001
NEAM TSUNAMI WATCH PROVIDER
ISSUED AT 0947Z 01 NOV 2014

... TSUNAMI WATCH...
THIS ALERT APPLIES TO FRANCE … IRELAND … MOROCCO … PORTUGAL … SPAIN … UNITED KINGDOM

... TSUNAMI INFORMATION ...
THIS INFORMATION APPLIES TO ALBANIA … ALGERIA … BOSNIA AND HERZEGOVINA … BULGARIA … CROATIA … CYPRUS … EGYPT … GEORGIA … GREECE … ISRAEL … ITALY … LEBANON … LIBYA … MALTA … MONTENEGRO … PALESTINE … ROMANIA … RUSSIA … SLOVENIA … SYRIA … TUNISIA … TURKEY … UKRAINE

THIS MESSAGE IS ISSUED AS ADVICE TO GOVERNMENT AGENCIES. ONLY NATIONAL AND LOCAL GOVERNMENT AGENCIES HAVE THE AUTHORITY TO MAKE DECISIONS REGARDING THE OFFICIAL STATE OF ALERT IN THEIR AREA AND ANY ACTIONS TO BE TAKEN IN RESPONSE.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS
ORIGIN TIME - 0940Z 01 NOV 2014
COORDINATES – 35.90 NORTH 10.22 WEST
DEPTH - 30 KM
LOCATION – SW CAPE SAN VINCENT, PORTUGAL
MAGNITUDE – 8.5

EVALUATION OF TSUNAMI WATCH
IT IS NOT KNOWN THAT A TSUNAMI WAS GENERATED. THIS WARNING IS BASED ONLY ON THE EARTHQUAKE EVALUATION.
AN EARTHQUAKE OF THIS SIZE HAS THE POTENTIAL TO GENERATE A TSUNAMI THAT CAN STRIKE COASTLINES WITH A WAVE HEIGHT GREATER THAN 0.5M AND/OR CAUSE A TSUNAMI RUN-UP GREATER THAN 1M. AUTHORITIES SHOULD TAKE APPROPRIATE ACTION IN RESPONSE TO THIS POSSIBILITY. THIS CENTRE WILL MONITOR SEA LEVEL DATA FROM GAUGES NEAR THE EARTHQUAKE TO DETERMINE IF A TSUNAMI WAS GENERATED AND ESTIMATE THE SEVERITY OF THE THREAT.

A TSUNAMI IS A SERIES OF WAVES AND THE FIRST WAVE MAY NOT BE THE LARGEST. TSUNAMI WAVE HEIGHTS CANNOT BE PREDICTED AND CAN VARY SIGNIFICANTLY ALONG A COAST DUE TO LOCAL EFFECTS. THE TIME FROM ONE TSUNAMI WAVE TO THE NEXT CAN BE FIVE MINUTES TO AN HOUR, AND THE THREAT CAN CONTINUE FOR MANY HOURS AS MULTIPLE WAVES ARRIVE.

EVALUATION OF TSUNAMI INFORMATION
BASED ON HISTORICAL EARTHQUAKE AND TSUNAMI MODELLING THERE IS NO THREAT THAT A TSUNAMI HAS BEEN GENERATED THAT CAN CAUSE DAMAGE OR MAJOR EFFECT IN THE REGION. THIS MESSAGE IS FOR INFORMATION ONLY.

ESTIMATED INITIAL TSUNAMI WAVE ARRIVAL TIMES AT FORECAST POINTS WITHIN THE WATCH AREA ARE GIVEN BELOW. ACTUAL ARRIVAL TIMES MAY DIFFER AND THE INITIAL WAVE MAY NOT BE THE LARGEST. A TSUNAMI IS A SERIES OF WAVES AND THE TIME BETWEEN SUCCESSIVE WAVES CAN BE FIVE MINUTES TO ONE HOUR.
LOCATION, FORECAST POINT COORDINATES, ARRIVAL TIME, ALERT LEVEL (A = ADVISORY, W = WATCH)
-------------------------------- ------------ ------------
PORTUGAL - VILA DO BISPO 37.04N 8.89W 0955Z 01 NOV W
PORTUGAL - VILAMOURA 37.07N 8.12W 1009Z 01 NOV W
SPAIN - LA BARROSA 36.37N 6.18W 1006Z 01 NOV W
SPAIN - TORRE DEL PUERCO 36.34N 6.16W 1010Z 01 NOV W
MOROCCO - ASILAH 35.42N 6.07W 1007Z 01 NOV W
MOROCCO - EL BEHARA 34.68N 6.40W 1023Z 01 NOV W
FRANCE - CAPBRETON 43.64N 1.45W 1243Z 01 NOV W
FRANCE - LACANAU 44.98N 1.20W 1254Z 01 NOV W
IRELAND - SCHULL 51.53N 9.55W 1317Z 01 NOV W
IRELAND - TOP CROSS 51.83N 10.17W 1324Z 01 NOV W
UNITED KINGDOM - FALMOUTH 50.14N 5.07W 1417Z 01 NOV W
UNITED KINGDOM - MULLION 50.02N 5.26W 1424Z 01 NOV W
SUPPLEMENT MESSAGES WILL BE ISSUED AS SOON AS NEW DATA AND EVALUATION ALLOWS. THE TSUNAMI ALERT WILL REMAIN IN EFFECT UNTIL AN END OF ALERT IS BROADCAST.

ANNEX 6

Table A2: Tsunami Emergency Response planning template for Civil Protection/DMO

Source: Based on ITIC, May 2008 (unpublished).

Continuous operations	Emergency centres should have a 24/7 (24 hours, 7 days a week) watch. Tsunamis can come day or night, and people need to be ready to respond at any time. Workers conducting overnight operations should be qualified to do so, and should involve at least one person with experience.
Notification	It is the responsibility of the emergency centres to evaluate the tsunami information received from the warning centre and decide on the appropriate action. A significant challenge associated with notification procedures is the decision-making process about evacuations, which can be costly and disruptive. Decision-making may be further hindered by false alarms, due to the lack of adequate sea-level data in some regions. Notification procedures for emergency centres should include: • Rapid notification of decision-making authorities • Decision-making regarding the ordering of evacuations and other protective measures • Rapid and comprehensive notification of the public at risk Countries using internationally collected data should be aware of differences in time and accuracy. Countries should pay full attention to the possibility of a tsunami when strong earthquakes occur in or near the area. If travel times are indicated, countries should expect a lapse in time of wave arrival before or after the tsunami event.
Alert system	All notification plans should incorporate some kind of alert system. Because tsunamis are infrequent, many people on the coastline will either not know what events precede a tsunami, or how to respond. Some people are overwhelmed by curiosity and are attracted to the coast. Others who stay make terrible judgments on the seriousness of the situation. The people need to be informed and warned when their lives are in danger. When designing an alert system, some things to consider are: • Who receives the warning? • How does the warning get to emergency centres? • How is the message received by the public? • What kind of communications are currently in place? • Who can hear the alert? • Where will alert posts be stationed? • How do people who cannot hear the alert be notified? • Who can activate the alert? • What groups will be around at any given time, which can activate the alert?
Natural warning signs	During a local tsunami event, natural warning signs may be the first and only alert before the first wave arrives onshore. Natural signs can complement gaps in tsunami warning systems that are designed to provide an early alert to vulnerable communities. These signs can alert people to impending tsunamis. Understanding the behaviour of tsunamis onshore can help inform people about the appropriate actions to safeguard themselves and others.
Evacuation planning	Planners should keep in mind that response for local and distant source event will differ. A distant source tsunami may allow several hours to evacuate. A local tsunami may require immediate self-evacuation through areas damaged by an earthquake at some risk of aftershocks. The amount of time required to execute an evacuation should be analyzed, and built into the decision-making procedure. Tsunami and earthquakes should be planned for together, as a significant earthquake may possibly generate a tsunami.

Identifying inundation affected areas	All areas affected by inundation should be identified and marked. Evacuation zones should extend up to the maximum expected inundation limit. It is important to note that wave activity in areas such as harbours or narrow bays may amplified by harbour resonance. Critical infrastructure and/or facilities that may produce hazardous effects, affected by tsunamis should also be identified.
Evacuation preparation	Preparations should be made prior to evacuation. Some questions to consider are: • What are the procedures, and when will centres be activated? • Who will be recalled? • What instructions will be given for non-disaster workers? • What areas need to be evacuated? • How can people who are hearing impaired receive the alert? • How will non-native speakers be addressed and informed? • What training and procedures can be reviewed prior to the event? • Will people be evacuated entirely on foot, or will mass-transit be available for parts of the population? • Should boats be secured in the harbour or put out to sea? • How will incoming vessels be notified not to proceed inshore?
Evacution routes/traffic control	Planners should identify optimum evacuation routes inland towards higher ground. Not all areas will have access to higher ground. Evacuation routes should avoid narrow and heavily used routes in densely populated areas to avoid bottlenecks in traffic. Ideally, the public should evacuate by foot as much as possible, to avoid creating more traffic congestion. Once areas have been evacuated, roadblocks, barricades, and/or a system of patrols should be set in place to keep the public from wandering into evacuation zones. Public and volunteer involvement in evacuation and traffic control procedures frees up emergency workers to handle more critical tasks. Special planning considerations must be made to address the portion of the public sector that is willing, yet incapable of evacuating inundation zones. The benefits of committing resources to develop special needs planning are plentiful; it relieves some of the pressure on search and rescue efforts, it frees up others to evacuate themselves, it helps in carrying out a controlled evacuation, among other positive things.
Self-evacuation	Sometimes the community will need to be the “eyes and ears” of a tsunami alert system. In the event of a local tsunami, there is little time to coordinate, respond, and provide a formal warning. Technology designed to detect tsunami data may not always provide an alert, and communication lines affected by earthquakes can be severed. Those receiving calls from others who have already learned of the disaster may be warned too late to evacuate. Where no time is allowed, evacuation must begin instantly. Planners should help communities to be prepared to self-evacuate, without any formal warning. • Planners should help communities identify evacuation zones, possible refuge areas, and nearby areas that are accessible to higher ground • Planners should promote tsunami public awareness, train community members how to recognize natural tsunami warning signs, and instruct them on proper procedures for the movement of peoples and traffic control • Planners should help members of the community designate where to have their family members meet, where they should evacuate, what they should bring, and where to re-group Planners should have communities develop social networks within the community that can take care of their community members. This also includes identifying individuals who may need assistance in evacuation, and possibly designating community members (i.e., relatives, friends, neighbours) who can pick them up while evacuating.

“All Clear”	Evacuated areas should remain closed to the public until after the threat of a tsunami no longer exists. Tsunami waves arrive in series, and it may be more than 2 hours before impacted areas are safe for re-entry. The decision to allow re-entry will be made by proper local Emergency Management officials. Residents should enter through control points to ensure that safety and sanitary precautions are provided.

ANNEX 7

Box A4: Raising awareness of disaster risk reduction – recommended steps

Source: UN/ISDR, 2007

Awareness campaigns need to include a wide variety of activities focused on various audiences and implemented by different actors.

To develop an appropriate awareness campaign strategy, a country needs to:

- secure continued resources for implementing awareness campaigns;
- determine which communication channels will appeal to the widest range of stakeholders, to ensure the campaigns reach women and other high-risk groups;
- seek to engage and inform different age groups so as to build sustained understanding across generations;
- establish relationships for the involvement of media professionals and other commercial and marketing interests; and
- engage respected local officials, religious and community leaders, and women's and other special interest groups, in order to disseminate information and encourage participation.

Measures that can support effective implementation of an awareness campaign include:

- selecting and undertaking activities that will appeal to target groups - such as educational campaigns in schools and community centres, community fairs, annual commemorative events or festivals, and neighbourhood safety drills and simulations;
- promoting activities that enable school-aged children to influence parents;
- encouraging private and commercial enterprises to raise awareness among their employees, and create incentives for employees' wider involvement in awareness campaigns, through such activities as sponsorships and advertising opportunities; and
- organising workshops, forums and educational activities for communities at local, social and cultural facilities.

Basic principles of awareness programmes:

- Programmes to be designed and implemented with a clear understanding of local perspectives and requirements, descriptive materials reflecting local conditions.
- All sections of society to be targeted, including decision makers, educators, professionals, members of the public and individuals living in threatened communities.
- Different types of messages, locations and delivery systems are necessary to reach the various target audiences.
- Sustained efforts are crucial to success, although single activities such as commemorative disaster reduction events and special issue campaigns can be useful if they are part of a larger, consistent programme.

ANNEX 8

Box A5: The RATCOM project for near-field tsunami warning

The RATCOM project (Réseau d'Alerte aux risques Tsunamis et CÔtiers en Méditerranée), a 2.5-year project started in December 2008, is a multi-disciplinary initiative funded by the French ministry and local authorities that intends to develop a robust and rapid near-field warning system for coastal submersions and tsunami risks. This demonstrator aims at monitoring the tsunami hazard of the Ligurian Sea coastal area (south-eastern France, Corsica and north-western Italy) generated by local earthquakes or submarine landslides.

The RATCOM system has an architecture designed to manage a complete tsunami alert, ranging from the detection of an event to the warning of the population. It comprises two major functional components:

- Upstream: the system relies on seismological and oceanographic data acquisitions that are automatically processed and compared to pre-computed scenarios in a data centre, in order to provide in a short time an assessment of the tsunami threat (map of pre-established coastal points with a list of water heights and arrival times of the phenomenon at these points). Among these scenarios, the particular case of the collapse of an embankment at Nice airport in 1979 that generated a tsunami is the object of a detailed study concerning the alert and the coastal impact (ACRI-ST leader).

- Downstream: the rapid diffusion of the alert bulletin at a local scale is insured by a powerful and secured communication network (Secunet), further linked to larger alert systems including mass media for population warning: sirens (National Alert Network), mobile network using various innovative technologies (including satellites), radio, TV and electronic billboards (Thales Alenia Space leader).

The demonstrator allows for the development of acquisition and processing techniques relevant to early detection and alert of locally generated tsunamis.

The final objective of RATCOM is to deploy a demonstrator, based on specific requirements and objectives in order to validate the solution according to technological, functional and operational criteria. Lastly RATCOM will sensitize alert actors, disseminating the results with the intention of contributing to a better knowledge of the problems. At the end of the project it will produce recommendations which will facilitate up-scaling to deployment at national or even international scales.

Source: Jean-Louis Fondere
RATCOM Project Team: Thales Alenia Space, ACRI-ST, ACRI-IN, BRGM, CEA DAM, Cedralis, CNRS GEO-AZUR, C2 Innovativ'Systems, DCNS, Eurecom, Eutelsat, IFREMER, IProcess, ISEN, J&PGeo, MeteoFrance, SFR.

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