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GUARDING AGAINST TSUNAMIS: THE CHALLENGE OF BUILDING PREPAREDNESS AT THE NATIONAL AND LOCAL LEVELS

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The December 2004 tsunami was, above all, a natural catastrophe, but much of the death and destruction that followed was a collective failure of human institutions. The international community was shocked by the magnitude of the Indian Ocean tsunami disaster: Nearly 250,000 people are reported dead or still missing; and more than 1 million people were displaced, losing their homes, property, and their livelihoods. Not surprisingly, hindsight has informed the global response. As will be discussed below, in addition to the outpouring of relief aid, there has been immediate and continued support from many nations, the private sector, and individuals wishing to support the building of a tsunami warning system in the Indian Ocean; in total, the United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Oceanographic Commission (IOC) International Tsunami Information Centre (ITIC) estimates more than US $175 million has been pledged by nations and donors to date. Moreover, starting immediately after the event, interim tsunami advisory services were begun by the U.S. National Oceanographic and Atmospheric Administration (NOAA) Pacific Tsunami Warning Center in Hawaii and the Japan Meteorological Agency, and better real-time monitoring networks are currently being established. At the same time, active awareness and education efforts were begun to start to build a prepared public.

Tsunami early warning systems must provide timely, understandable warnings within minutes that will then motivate ordinary citizens to quickly move out of harm's way. While implementation of the Indian Ocean tsunami warning and mitigation system is being pursued with highest urgency, we must acknowledge that the tsunami hazard exists in all oceans and seas (Figure 1).

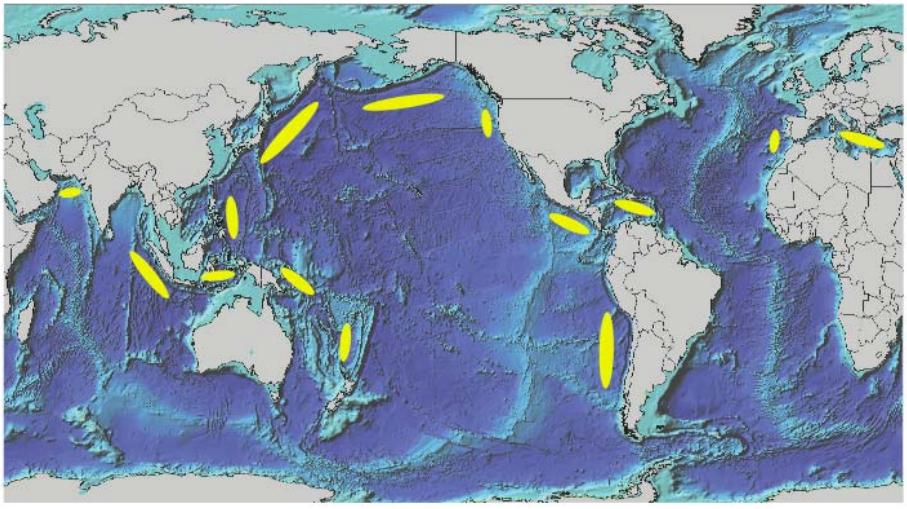

Figure 1. Tsunami hazard zones for destructive tsunamis, indicated by yellow ovals. Every ocean basin and sea can be impacted by tsunamis, which can occur at any time without a precursor signal. In fact, some countries may be impacted by tsunamis from two or more basins. Destructive tele-tsunamis have originated in Chile, northern Japan and the Kurile Islands, Aleutian Islands, and the western coast of Indonesia. Until 2005, no tsunami early warning systems existed outside the Pacific. The IOC of UNESCO is currently leading the efforts to establish comprehensive tsunami warning and mitigation programmes globally. Source: ITIC

And, because more than 80% of the world's tsunamis occur in the Pacific, it is very probable that the next tsunami catastrophe will impact the Pacific Basin (Figure 2).

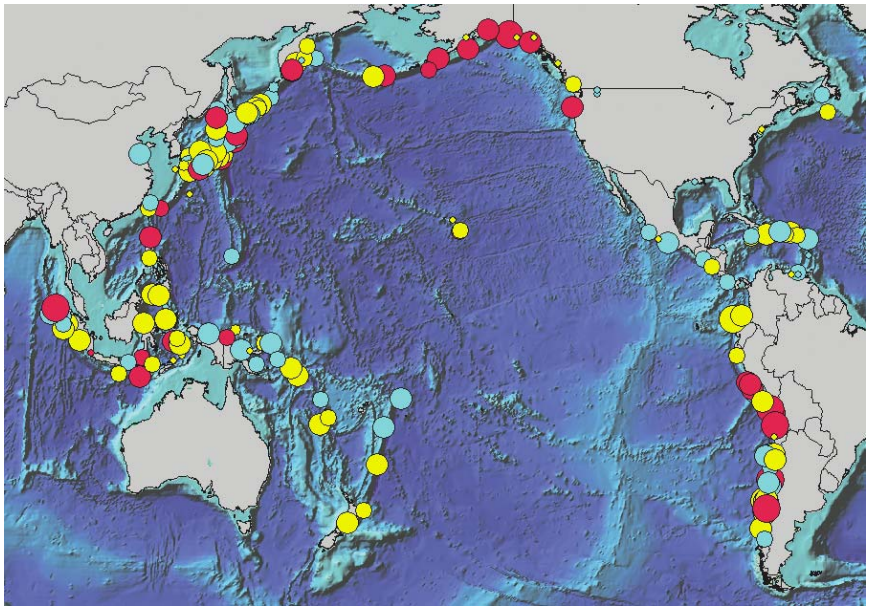

Figure 2. Tsunami sources in the Pacific. Most tsunamis are generated by large earthquakes occurring as tectonic plates are subducted (forced underneath other, over-riding plates) along the margins of the Pacific basin. Red and yellow circles show tsunami sources causing the greatest damage according to the Imamura-Soloviev tsunami intensity scale. The size of the circle is scaled to the magnitude of the earthquake. Note that there is not necessarily a correlation between magnitude of an earthquake and the intensity of the tsunami it generates. Source: Integrated Global Historical Tsunami Database, 2005.

BUILDING A GLOBAL TSUNAMI EARLY WARNING SYSTEM

Through its Intergovernmental Oceanographic Commission (IOC), United Nations Educational, Scientific and Cultural Organization (UNESCO) organized in 1965 the Tsunami Warning System for the Pacific Ocean, termed ITSU. The International Coordination Group of ITSU (ICG/ITSU, now referred to as the ICG/PTWS [Pacific Tsunami Warning System]), composed of national experts from 28 countries in the Pacific region, is a subsidiary body of the IOC, and, as such, reports to the IOC Assembly, which is composed of 132 Member States. During the last 40 years, UNESCO and its IOC have accumulated invaluable experience and knowledge on how to assess tsunami risk at the national and local levels, how to promote awareness and preparedness amongst the population, and how to build national and regional tsunami warning systems in the Pacific region.

Furthermore, at a number of high-profile meetings in 2005, the IOC was widely recognized as the appropriate intergovernmental body to facilitate the development of both interim and permanent tsunami warning systems for the Indian Ocean and other oceans and marginal seas. At the 23rd Session of the IOC in June 2005, three new intergovernmental bodies were established, demonstrating the high level of commitment by governments to initiate comprehensive tsunami risk-reduction programmes. Intergovernmental Coordination Groups were established for the Indian Ocean; the Caribbean Sea and adjacent regions; and the Northeastern Atlantic, the Mediterranean, and its connected seas (Figure 3). A fourth group, the IOC Intersessional Ad-Hoc Working Group, was also established to discuss a global framework for the establishment of an early warning system for all coastal marine hazards.

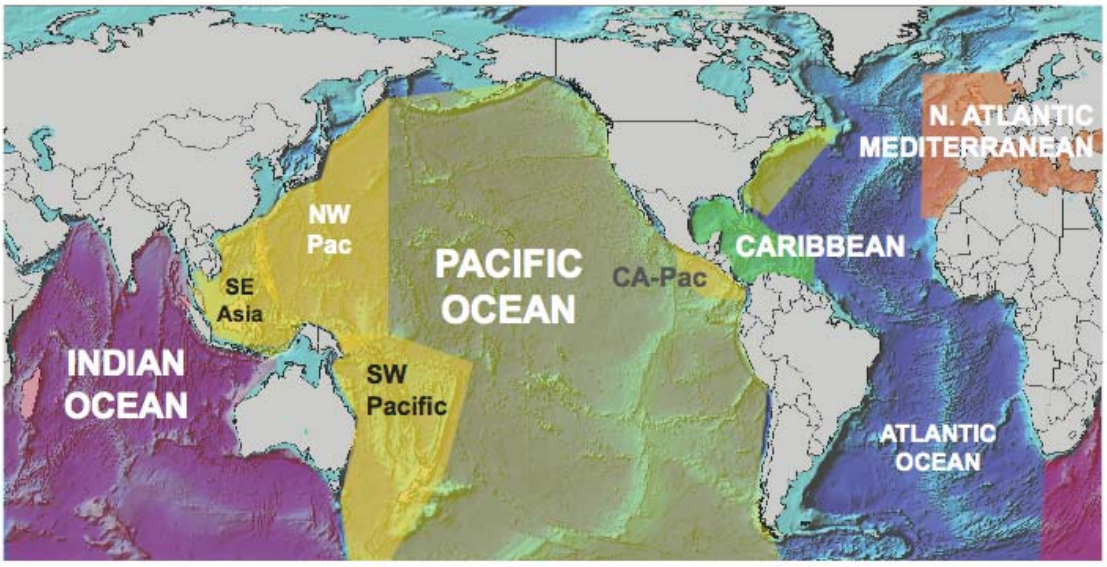

Figure 3. Altogether, four Intergovernmental Coordination Groups (ICG) have been established under the governance system of the IOC of UNESCO to oversee the implementations of internationally-coordinated tsunami warning and mitigation systems globally. In addition to the 40-year old Pacific Ocean system, new systems are being built in the Indian Ocean, Caribbean, and the North Atlantic and Mediterranean. Additionally, Pacific sub-regional systems exist for the Northwest Pacific and are being discussed for the Southwest Pacific,, Southeast Asia and Central America – Pacific Coast. The ICG meet regularly to discuss the tsunami technical monitoring and warning disseminations requirements and improvements, coordinate tsunami risk assessment and preparedness activities, and to share national experiences in building tsunami awareness through education and outreach in their countries. Presently, NOAA's West Coast / Alaska Tsunami Warning Center provides tsunami warnings for the east and gulf coasts of the U.S. and the eastern Canada provinces for Atlantic events, and the PTWC provides interim warnings for Puerto Rico and the U.S. Virgin Islands in the Caribbean. Source: ITIC.

The risk of tsunamis exists, to different degrees, in all oceans and coastal seas. UNESCO has been advocating in favour of an early warning system in the Indian Ocean and in some other regions of the world, but such a system is in fact needed in all oceans and seas. This is why UNESCO is now calling for the establishment of a Global Tsunami Warning and Mitigation Programme.

We have learned that such systems can only be built with strong and sustained commitment by the national governments and that these systems can only operate if countries agree to collaborate in a regional framework by sharing data and by jointly bearing the cost for the regional elements of the network. In addition, some nations are threatened by tsunamis generated in more than one ocean basin, increasing the importance for regional and international coordination.

In general, we must be able to respond to both local tsunamis, (i.e. those generated by a small earthquake or an underwater landslide that only affect areas less than 200 km away) and to a huge earthquake, like the one in Sumatra on 26 December 2004, which generates a destructive ocean-wide tsunami that travels thousands of kilometers across the ocean before hitting the coastline. In 1960, the Pacific experienced a tsunami generated by a magnitude 9.5 earthquake in Chile (Figure 4). The tsunami caused deaths in Hawaii and in Japan, 14 hours and 22 hours, respectively, after the earthquake. Because of the existence of tsunamis from far distant sources, a single country cannot adequately protect itself from tsunami risks without a regional network of observation stations.

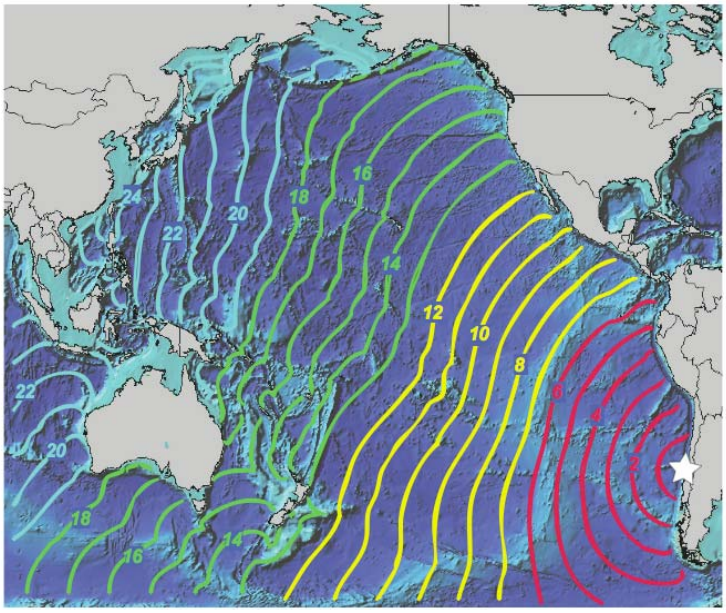

Figure 4. Travel times (in hours) for the 22 May 1960 Chile tsunami crossing the Pacific basin. The tsunami was extremely destructive along the nearby coast of Chile, and caused significant destruction and casualties in Hawaii and Japan. The awareness and concern raised by this Pacific-wide tsunami led to the formation of the Pacific Tsunami Warning and Mitigation System in 1965. Contour intervals are every one hour with colour changes every six hours. Source: ITIC.

A tsunami warning system can exist only through international regional cooperation under the principle of open, free, and unrestricted exchange of observational data, and the availability of an effective National Tsunami Response Plan that is activated when warnings are issued. These are important lessons learned from our past experience. Important as they are, the instrumental networks used for tsunami detection and early warning are just one element in the chain to achieve mitigation of the hazards from tsunamis.

To issue a warning without having prepared and exercised how the population should respond to the warning is useless. The IOC's approach requires progress in three mutually dependent components:

- **First**, assessing the tsunami hazard and risk at the local level to identify vulnerable communities;
- **Second**, preparing the population so they know what action to take in case of a tsunami warning; and
- **Third**, building a technological framework that warns us of an advancing tsunami wave.

Preparedness needs a good understanding of social and cultural conditions, and programme activities need to be targeted at all levels within the government, down to households at the community level. The fact that the some specific populations survived while many others did not, points to certain lessons to be learned from traditional, indigenous knowledge. For example, residents of Simeulue Island off of northwestern Sumatra had previously experienced strong tsunami with many deaths in 1907, and elders had orally passed on the stories of what they saw and how to respond when seawater receded so that when the 26 December 2004 earthquake occurred, villagers knew that a tsunami would come ashore and quickly evacuated to higher ground. A similar example has been recounted in Native American literature of the USA Pacific Northwest where a children's story tells of a boy who learns that dangerous tsunami can strike after a strong earthquake. The story tells of how he uses this knowledge to warn and save his fellow Hoh tribe.

US NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM

In the United States, the U.S. National Tsunami Hazard Mitigation Program (NTHMP) has led the way in promoting a comprehensive approach to tsunami mitigation by involving the tsunami warning centers, state tsunami programme managers, and scientists as stakeholders working together to build a prepared citizenry. The NTHMP is a federal, state, and local partnership of government agencies formed in 1997 to reduce tsunami impacts along US coasts. From the start, the Program has been led by the U.S. NOAA, which operates the Pacific Tsunami Warning Center and the West Coast / Alaska Tsunami Warning Center; and by the NOAA Pacific Marine Environmental Laboratory. The latter pioneered: (1) the development of the deep-ocean tsunami detection systems (DART) systems for the real-time detection of tsunamis in the deep-ocean; and (2) the development of operational tsunami wave forecasting tools that make predictions utilizing pre-computed complex numerical estimates of wave impact from a number of different tsunami-generating scenarios. The NTHMP's central activities focus on:

- Local hazard planning through the construction of tsunami inundation and evacuation maps based on numerical models of tsunami scenarios and community-based decision-making on evacuation routes and shelters;
- Real-time tsunami detection and warning guidance through the real-time monitoring of large earthquakes;
- Confirmation of a tsunami through coastal and deep-ocean tsunami detection systems;
- The immediate issuance of timely warnings;
- Active programmes in tsunami preparedness through the "TsunamiReady Community Program"; and
- The development of preparedness documents on planning, warning system design requirements, and engineering of the built environment to mitigate tsunami flooding.

PACIFIC TSUNAMI WARNING AND MITIGATION SYSTEM

The Pacific Tsunami Warning and Mitigation System (PTWS) is one of the most successful international scientific programmes, with the direct humanitarian aim of mitigating the effects of tsunamis to save lives and property. In response to the 1960 magnitude 9.5 Chile earthquake that caused ocean-wide deaths in Hawaii and Japan, the IOC convened an experts' meeting in 1965 to discuss the coordination of timely tsunami warnings for distantly generated, destructive tsunamis. In November 1965, the IOC of UNESCO established the International Tsunami Information Centre (ITIC), and in 1968, the IOC first convened the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU, now ICG/PTWS) to coordinate tsunami mitigation activities, including the issuance of timely international tsunami warnings.

ITIC supports the IOC by:

- Monitoring the activities of the PTWS and recommending improvements in communications, data networks, acquisition and processing, tsunami forecasting methods, and information dissemination;
- Coordinating and facilitating tsunami technology transfer to nations interested in establishing regional and national tsunami warning and mitigation systems;
- Acting as a clearinghouse for risk assessment and mitigation activities and an information resource on historical tsunami events; and
- Serving as a resource for the development, publication, and distribution of tsunami education and preparedness materials.

The NOAA Richard H. Hagemeyer Pacific Tsunami Warning Center (PTWC) serves as the operational headquarters for the Pacific Tsunami Warning System. The system makes use of more than 150 seismic stations throughout the world that are available in real- or near real-time to locate potentially tsunamigenic earthquakes (i.e., those generating tsunamis). It has near real-time access via satellite, internet, and telephone to more than 100 sea level stations throughout the Pacific and Indian Oceans that can be used to verify the generation of a tsunami and possibly estimate its severity. The system disseminates tsunami information and warning messages to well over 100 points across the Pacific. The PTWC also provides interim tsunami advisories for the Indian Ocean in cooperation with the Japan Meteorological Agency.

Additionally, since the devastating magnitude 9.3 Sumatra earthquake and tsunami in December 2004, the UNESCO IOC ITIC has acted as a leading source of information on tsunami warning and mitigation. Both the ITIC and PTWC are supporting regional and national efforts as the IOC coordinates the establishment of a global tsunami warning and mitigation system that covers the Pacific, Indian, and Atlantic Oceans and the Caribbean and Mediterranean Seas and adjacent seas and basins.

BUILDING PREPAREDNESS

The United Nations has been engaged for fifteen years in a process of creating awareness and promoting the development of policies to diminish the loss of life and property from natural and man-made disasters. This was first done through efforts during the International Decade for Natural Disaster Reduction and then through the International Strategy for Disaster Reduction that followed, as well as by the establishment of the UN Disaster Task Force, in which UNESCO and IOC participate. Awareness-raising and policy development issues in disaster reduction were raised to a high level at the World Conference on Disaster Reduction held in Kobe, Japan, in January 2005 in which more than 6,000 delegates from 155 countries, and numerous intergovernmental and non-governmental agencies, United Nations, and other specialized organizations participated.

Delegates at the Kobe Conference adopted the “Hyogo Framework for Action 2005-2015”, a document that commits governments and the international community to achieving a set of concrete goals, among them the commitment to halve the loss of life caused by disasters, to make all schools and hospitals disaster-proof, and to establish national natural disaster platforms in each country.

The Hyogo Declaration states that “[W]e are far from powerless to prepare for and mitigate the impact of disasters. We can and must alleviate the suffering from hazards by reducing the vulnerability of societies. We can and must further build the resilience of nations and communities to disasters through people-centered early warning systems, risks assessments, education and other proactive, integrated, multi-hazard, and multi-sectoral approaches and activities in the context of the disaster reduction cycle, which consists of prevention, preparedness, and emergency response, as well as recovery and rehabilitation.” (Figure 5)

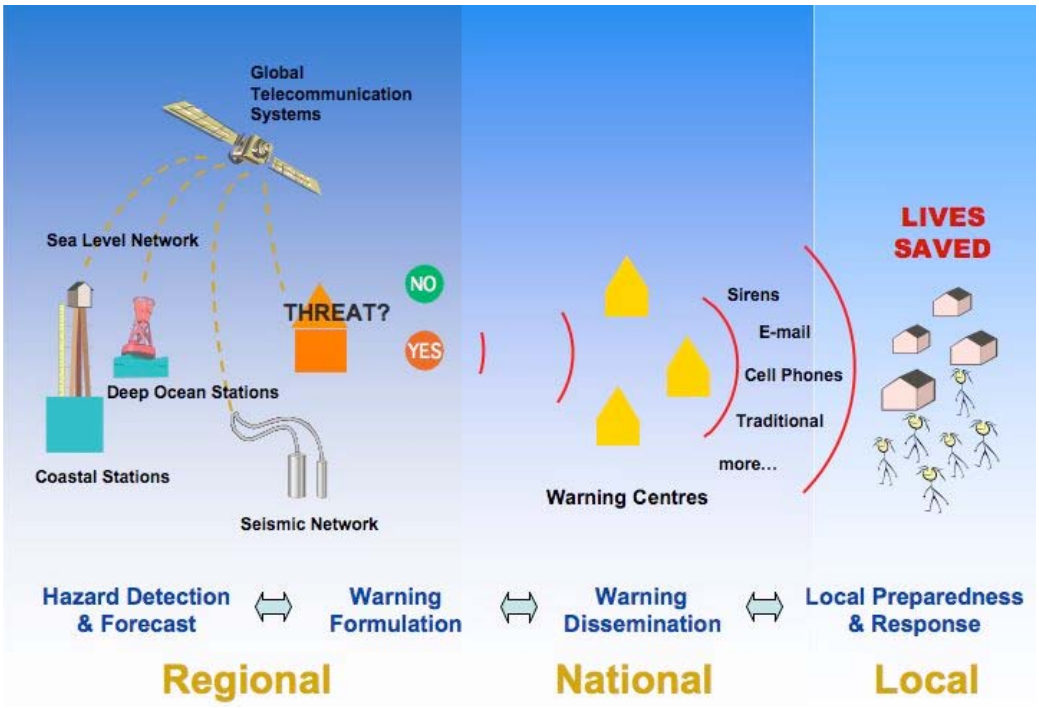

Figure 5. Components of a successful early warning system. For the case of tsunamis, rapid evaluations of earthquakes are essential to be able to provide the fastest early warning to emergency officials. Sea level data is then used to confirm that a tsunami has been generated. Research continues to provide new techniques to better detect and evaluate the tsunamigenic potential of earthquakes and to improve tsunami wave forecasts at coasts. Source: UNESCO IOC

Specifically, tsunami preparedness programmes educate not only the general public, including transient populations, such as tourists staying at beachfront hotels, but also government officials and other local community leaders so that good government emergency action decisions will be made without delay. The programmes should build capacity and awareness at the local level, place the tsunami hazard and response in the local context and empower communities to collectively engage in developing an appropriate tsunami response and in pre-disaster mitigation activities.

National pre-disaster mitigation programmes must identify vulnerable coastal communities through an assessment of each nation's tsunami risks, and implement plans at the local level for tsunami response through the development and widespread publication of evacuation or tsunami safe zone maps along with instructions to the public on how to respond. Equally important pre-disaster activities include non-structural countermeasures, such as sea walls, water gates and vegetative barriers, and the design and construction of seismic- and tsunami-resistant buildings and critical lifeline infrastructure, to reduce the impact of tsunamis on life and property. These measures are just part of government disaster risk management, which should evaluate risk, and adopt coastal zone management and land use (or non-use) policies that provide reasonable public safety from all natural hazards. Finally, social science plays a crucial role in understanding how humans perceive and respond to natural disasters and disaster warnings. These perceptions must be taken into account to ensure that the tsunami risk is communicated in an understandable and practicable manner to the public.

Early Warning Systems can save lives. In particular, a number of elements are critical for an effective system to operate, and can be summarized as follows:

1. **Proper instruments that enable the early detection** of potentially harmful earthquakes and tsunamis. The data obtained by these instruments must be readily available to all nations continuously and in real-time to be effective.

2. **Warning systems that reliably inform the vulnerable populations** immediately and in an understandable and culturally appropriate way. The Warning Centre must be able to analyze and forecast the impact of tsunamis on coasts in advance of the waves' arrival, and the local, regional, and/or national Disaster Management Organizations (DMOs) must be able to immediately disseminate information on the threat and to enable evacuation of all vulnerable communities. The communications methods must be reliable, robust, and redundant, and work closely with the mass media and telecommunications providers to accomplish this broadcast.

3. **Awareness activities that enable ordinary citizens to recognize** a tsunami so that they know what to do. Citizens should recognize a tsunami's natural warning signs and respond immediately. This is especially true for the case of a local tsunami, which may hit within minutes and before an official tsunami warning can reach their communities.

4. **Preparedness activities which educate and inform** a wide populace, including government responders and those providing lifeline and critical infrastructure services, on the procedures and activities that must be taken to ensure public safety. Drills and exercises before an actual event, and proactive outreach and awareness activities are essential for reducing tsunami impact.

5. **Planning activities which identify and create** the public safety procedures and products and build capacity for organizations to respond faster. It is necessary to create and widely disseminate tsunami evacuation or flooding maps, and instructions on when to go, where to go, and how to go. Evacuation shelters and evacuation routes need to be clearly identified, and widely known by all segments of the coastal population.

6. **Strong buildings, safe structures, and prudent land-use policies which save lives and reduce property damage** that are implemented as pre-disaster mitigations. Tall, reinforce concrete buildings may be adequate places to which people can vertically evacuate if there is no time to reach higher ground inland. Long-term planning to avoid placing critical infrastructure and lifeline support facilities in inundation zones will reduce the time needed for services to be restored.

7. **Stakeholder coordination as the essential mechanism** that facilitates effective actions in warning and emergency response (Figure 6). Clear designation of the national or local authority from which the public will receive emergency information is critical to avoid public confusion, which would compromise public safety.

8. **High-level advocacy that ensures** a sustained commitment to prepare for infrequent, high-fatality natural disasters such as tsunami.

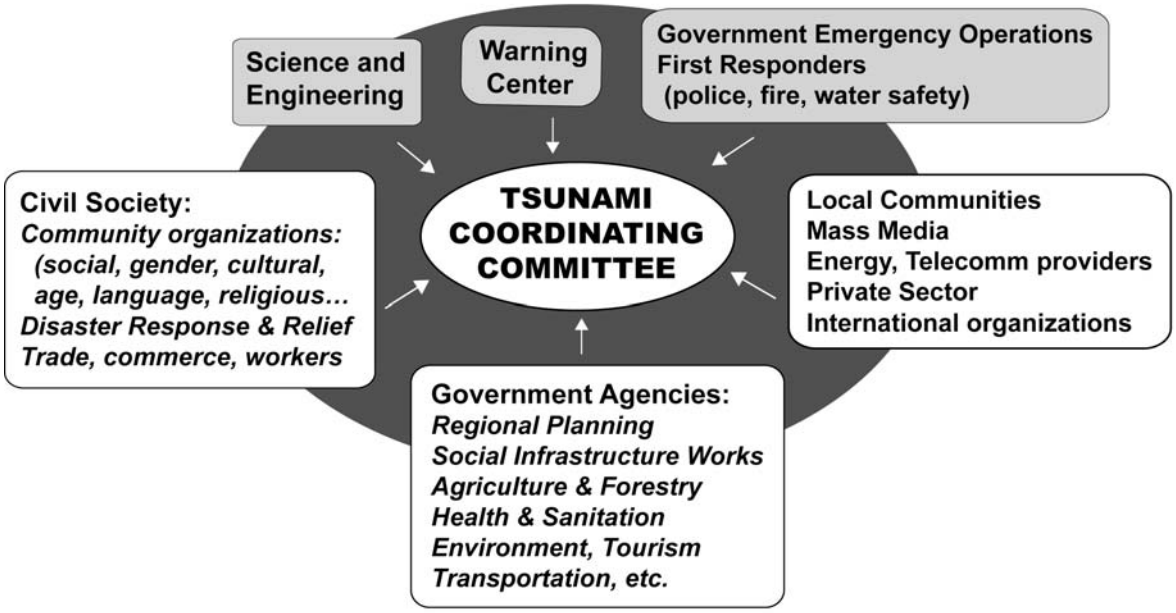

Figure 6. A Tsunami Coordinating Committee engages all stakeholders to develop and participate in comprehensively reducing the risk from tsunamis. All government and non-government agencies must work together in order to reach the population. Key contributors are the scientists and engineers who assess and evaluate the risk, the tsunami warning centre which is responsible for rapid alerts, and government emergency services which must move every person out of harm's way before the tsunami arrives. Source: ITIC

STAKEHOLDER COORDINATION IS CRITICAL

An effective tsunami early warning system is achieved when all persons in vulnerable coastal communities are prepared and respond in a timely manner upon recognition that a potential destructive tsunami may be approaching. While timely tsunami warnings issued by an officially-recognized regional tsunami warning centre using real-time seismic, sea level, and other geophysical data streams from throughout the monitoring region are an essential component of the system, it is absolutely critical that these scientifically-based warning messages are communicated to the public in an understandable manner that clearly and simply instructs ordinary citizens on the actions they should take to ensure their safety.

These actions include the evacuation of people situated in areas of potential flooding to safe zones or shelters, along with instructions on who should evacuate, where and how they should go, when to go, what to bring, and how they will know when it is safe to return. Consideration and planning should also to be given to special needs populations, such as the elderly, physically-handicapped, and groups of people who cannot read, hear, or understand conventional warning methods. In this regard, pre-disaster tsunami awareness and preparedness activities are essential for educating and familiarizing the public in advance so that they are able to respond immediately and knowledgeably during the actual emergency.

The success of any warning system lies in its ability to reach people, e.g., that the people with important specialized knowledge of the impending hazard are able to quickly and efficiently pass on usable information to all the people who are at risk. Although technology is essential for information analysis and delivery, successful early warning ultimately relies on the abilities of people to reach people.

National and Local Tsunami Coordination Committees (TCCs) are valuable mechanisms to build effective tsunami responses that will minimize loss of life and damage from this quick-impacting natural hazard. A TCC should be comprised of all stakeholders involved in the identification of the risk, the

warning guidance, and the pre- and post-disaster mitigation activities, and should meet regularly to collectively inform, decide, and share information.

THE KEY ROLES OF NATIONAL DISASTER MANAGEMENT ORGANIZATIONS AND CIVIL-MILITARY COORDINATION IN TSUNAMI PREPAREDNESS AND EMERGENCY RESPONSE

Coordination is essential, and in many countries, as part of the civil defence organizations of governments, the Disaster Management Organization (DMO) should play an essential role in the efficient and immediate actions to ensure public safety and, additionally, in leading efforts to increase government and community preparedness. To build stakeholder commitment for efficient response, each national DMO should consider sponsoring a Tsunami Coordination Committee to serve as the coordinating and implementing body for building a comprehensive and sustainable tsunami mitigation programme.

Specifically, the DMO can play a very important leadership role in:

- **Preparing the public** for all hazards, including tsunamis, through education and awareness, communication of risk to communities and involvement of communities in hazard mitigation activities through pre-disaster mitigation projects. It should act as the translator of science and technology to ordinary citizen-understandable concepts/language;

- **Identifying the hazards** and vulnerable communities (i.e. conducting risk evaluation), through cooperation with technical institutions locally and internationally, and then making the information known to the public in an understandable manner;

- **Ensuring information flow** from warning centres to the public for safety through coordination and timely dissemination of understandable and practicable information before and during the disaster, and afterward, informing the public when it is safe to return and commencing immediately search-and-rescue efforts and disaster recovery processes;

- **Building**:
    - **All-stakeholder coordination** (local and national) for effective emergency response;
    - **Community-level linkages** to implement people-centred early warning and mitigation; and
    - **High-level advocacy** to sustain tsunami preparedness for future generations.

Ensuring that an effective national tsunami warning and mitigation system is implemented in every nation with a tsunami threat is a considerable task, especially for Small Island Developing States. The 17 Member States of the South Pacific Applied Geosciences Commission, a regional organization that is involved in disaster risk management, have a population of only ~7 million, with 5 million in Papua New Guinea. The ~ 7 million people are scattered over a vast region 10,000 km from east to west and 5,000 km from north to south, with many small islands only minimally connected: Establishing reliable communications is a critical requirement for success.

To be effective, every island will have to know when a tsunami is approaching and be prepared to respond. In fact, there is heavy responsibility on national and local disaster management organizations to provide leadership in emergency response, search and rescue, and disaster recovery for their people. Facing this challenge will require a strong and effective national disaster management system, a well-designed strategy and close and effective cooperation and coordination between all stakeholders. Relevant legal and administrative arrangements will be required and the necessary human resources will need to be put in place, in addition to technical and scientific infrastructures. This is the challenge we must collectively address. We must work together to build tsunami-resilient communities.

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Dr. Kong has been the ITIC Director since 2001. She oversees a Centre that is an integral part of the IOC's efforts to deploy tsunami warning and mitigation systems globally. She also sits on the U.S. National Tsunami Hazard Mitigation Program's Steering Committee, and is the former Chair of the Hawaii State Earthquake Advisory Committee. She is a graduate of Brown University and received her doctorate in 1990 from the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution.