Tsunami Early Warning Systems in the Indian Ocean and Southeast Asia

Report on Regional Unmet Needs

UNITED NATIONS
ESCAP
Economic and Social Commission for Asia and the Pacific
Tsunami Regional Trust Fund

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About this Report

This Report provides an overview of priorities for tsunami early warning systems in the Indian Ocean and Southeast Asia. In particular, it will guide funding decisions by the ESCAP Multi-Donor Voluntary Trust Fund on Tsunami Early Warning Arrangements in the Indian Ocean and Southeast Asia, and was developed at the request of the Fund's Advisory Council.

ESCAP would like to thank the Governments of Thailand, Sweden, Turkey and Nepal, which have made financial contributions to the Fund, and the many other countries and partners that have made important contributions of their time and expertise.

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Acronyms and Abbreviations

AADMER	ASEAN Agreement on Disaster Management and Emergency Response
ADB	Asian Development Bank
ACDM	ASEAN Committee on Disaster Management
ADPC	Asian Disaster Preparedness Center
ADRC	Asian Disaster Reduction Center
ADRRN	Asian Disaster Response and Recovery Network
ASEAN	Association of Southeast Asian Nations
ATWS	Australian Tsunami Warning System
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
CCR	Coastal Community Resilience
DART	Deep-ocean Assessment and Reporting of Tsunamis
DRR	Disaster Risk Reduction
EOC	Emergency Operations Centre
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EWS	Early Warning System
GLOSS	Global Sea Level Observing System
GTS	Global Telecommunications System
HFA	Hyogo Framework for Action
ICG	Intergovernmental Coordination Group
ICT	information and communication technology
IFRC	International Federation of Red Cross and Red Crescent Societies
IO	Indian Ocean
IOC UNESCO	Intergovernmental Oceanographic Commission of UNESCO
IOTWS	Indian Ocean Tsunami Warning and Mitigation System
ISDR	International Strategy for Disaster Reduction
ITIC	International Tsunami Information Centre
JMA	Japan Meteorological Agency
JTIC	Jakarta Tsunami Information Centre
JCOMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
LoA	Letter of Agreement
MDGs	Millennium Development Goals
MoU	Memorandum of Understanding
NDWC	National Disaster Warning Centre
NEIC	National Earthquake Information Center

NGI	Norwegian Geotechnical Institute
NGOs	non-governmental organizations
NOAA	National Oceanic and Atmospheric Administration (United States)
NTWC	National Tsunami Watch Centre
OCHA	Office for the Coordination of Humanitarian Affairs
PAGER	Prompt Assessment of Global Earthquakes
PTWC	Pacific Tsunami Warning Center
PTWS	Pacific Tsunami Warning and Mitigation System
RISTEK	Indonesian State Ministry of Research and Technology
RTWP	Regional Tsunami Watch Provider
SAARC	South Asian Association for Regional Cooperation
SCMG	Sub-Committee on Meteorology and Geo-physics
SDMC	SAARC Disaster Management Centre
SEI	Stockholm Environment Institute
SEisComp	Seismological Communication Processor
SMS	Short Message Service
SOPs	Standard Operating Procedures
TEWS	Tsunami Early Warning System
TWFP	Tsunami Warning Focal Point
UNDP	United Nations Development Programme
UNDP-RCB	UNDP Regional Centre in Bangkok
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
USGS	US Geological Survey
WG	Working Group
WMO	World Meteorological Organization

Executive Summary

This Study contains an update of the original "Report on Regional Unmet Needs and Recommendations: Tsunami Early Warning Systems (TEWS) in the Indian Ocean and Southeast Asia". The Study aims to guide the policy and programming of the Fund as well as other initiatives in this area of work. This updated Study has been prepared in light of ongoing work and new developments in early warning systems in the region.

Since the Indian Ocean tsunami of 2004, intensive work has been carried out by a range of stakeholders to support development of all elements of the regional tsunami warning system in the Indian Ocean and Southeast Asia. There has been significant progress in particular in establishment of tsunami watch provider services in several countries in the region, and installation of networks of seismic and sea level stations on which these warnings depend. Important issues concern the long-term sustainability of the system (e.g., ongoing provisions for early warning in national, provincial and local budgets) and strengthening "end-to-end" warnings that reach people at risk and generate an appropriate response.

Nearly five years after the Indian Ocean tsunami, most funding for tsunami early warning is now being phased out. However, in almost every aspect of tsunami warning -- from operation of sea level sensors to institutional frameworks to community awareness initiatives -- tsunami warning is most effectively and sustainably addressed through a multi-hazard approach, together with other related hazards. Most initiatives to develop tsunami warning in the region have indeed been adopting such an approach. In this regard, early warning can be considered an important form of climate change adaptation, since climate change is expected to increase the frequency and severity of natural disasters.

The following paragraphs summarize the status of the different aspects of the regional tsunami warning system:

Governance and Institutional Arrangements

The Indian Ocean and Southeast Asian region is rich in institutions contributing to regional coordination on different aspects of disaster risk reduction (DRR). The regional tsunami warning system is coordinated by IOC UNESCO's Intergovernmental Coordination Group (ICG) for the Indian Ocean, with other countries in Southeast Asia covered by the ICG for the Pacific. Intensive work has been carried out by many countries to develop disaster management laws and institutions following the Indian Ocean tsunami. In many cases, additional work to develop implementing regulations and Standard Operating Procedures (SOPs) at different levels of Government is ongoing.

Monitoring and Warning

Seismic and sea level stations have been installed to fill gaps in the regional TEWS network. Countries face a challenge in terms of the needed expertise and providing allocated funding to manage and sustain the stations. Ongoing support for operation and maintenance will be needed to maintain the performance of the regional monitoring and warning network over the long-term. Six countries and one regional institution have expressed willingness to commence the transition process to become a RTWP, which three countries have already started.

Risk Knowledge

Risk assessment guidelines and an Indian Ocean tsunami hazard map based on current knowledge have been developed within the framework of ICG/IOTWS Working Group 3. The Guidelines, entitled "Tsunami risk assessment and mitigation for the Indian Ocean: knowing your tsunami risk – and what to do about it" were adopted by ICG/IOTWS -VI in April 2009. Even at the broadest level, the high-risk tsunami zones and the overall tsunami frequency in different parts of the region are still poorly known, with most recent research focusing on areas affected by the 2004 Indian Ocean tsunami. While intensive work has been carried out to improve risk knowledge, applying the information for planning and vulnerability assessments is a challenge, especially at the local level. Vulnerability mapping is a complex exercise with expanding but limited coverage. It may be difficult for Governments and disaster managers to access reliable and standardized data that are needed.

Communication and Dissemination of Warnings

There is a clear need to strengthen systems of dissemination and communication, in particular at the downstream level. Several countries are developing Standard Operating Procedures for tsunami warnings, but these are fully developed and tested only in a few countries. Significant gaps include effective and redundant channels of communication to the community level, and design of clear warning messages that are understandable to end users. To a large extent, the channels of communication available for disaster warnings may reflect the overall development of communications networks in a country.

Preparedness and Response Strategies

Intensive and innovative work on community preparedness and response strategies is carried out in many countries in selected areas. A comprehensive programme is not available in most cases. Many tsunami drills have been carried out in the region since the Indian Ocean tsunami, although there is no comprehensive regional programme for drills and other assessments of the status of the TEWS over the long-term. There are numerous actors involved in this area of work and also many gaps in education, awareness, and operating procedures.

Based on this assessment, 17 priorities for TEWS in the Indian Ocean and South China Sea have been identified (see Section 8).

Introduction

1.1 Report on Regional Unmet Needs

The original ESCAP study "Report on Regional Unmet Needs and Recommendations: Tsunami Early Warning Systems (TEWS) in the Indian Ocean and Southeast Asia", was prepared by Mr. Chow Kok Kee, Consultant, and published in August 2007. Its objectives were to identify gaps in the TEWS and to offer recommendations on priority areas for consideration by the ESCAP-administered *Multi-donor Voluntary Trust Fund on Tsunami Early Warning Arrangements in the Indian Ocean and Southeast Asia* (hereafter referred to as the "Fund"). The original Study aimed to serve as an input for policy and programming purposes to the Advisory Council of the Fund. It was also intended to provide advice to partners wishing to support efforts to fill identified gaps.

This updated Study has been prepared in light of additional information and a number of developments in early warning systems in the region at the regional, national and community level. The Study has been expanded to provide more analysis to users on national and local level gaps in addition to regional needs.

The structure of the report has been altered to correspond more closely to the considerations for development of an early warning system found in the "Checklist" developed as a product of the Third International Conference on Early Warning held in 2006.[1] The Conference concluded that people-centered early warning systems are critical *"to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life and damage to property and the environment"*.

The Checklist is structured around the four key elements of effective early warning systems. These elements are: Risk Knowledge, Technical Monitoring and Warning Service, Communication and Dissemination of Warnings, and Response Capability. The Checklist also covers Governance and Institutional Arrangements and outlines concerns on cross cutting issues such as a multi-hazard approach, involvement of local communities and consideration of gender perspectives and cultural diversity.

By covering these key elements and cross cutting issues, the study is enriched in several important ways:

1. Expansion of the concept of "end-to-end", which frequently emphasizes communications systems. The study also emphasizes legal and organizational systems and their connections to overall disaster risk reduction, risk knowledge issues, such as hazard mapping, data collection and analysis, as well as longer term mitigation efforts.
2. The study delves deeper into issues on a national and community level which significantly influence the efficacy of the end-to-end systems, for example, capacities to receive and respond to early warning.

[1] ISDR (2006) Third International Conference on Early Warning, Developing Early Warning Systems: A Checklist.

1.2 ESCAP Tsunami Regional Trust Fund

The destructive 2004 Indian Ocean tsunami demonstrated the need for an Indian Ocean Tsunami Warning and Mitigation System (IOTWS) to identify and mitigate risks posed by tsunamis. In 2005, ESCAP set up the Multi-Donor Voluntary Trust Fund on Tsunami Early Warning Arrangements in the Indian Ocean and Southeast Asia (hereinafter the "Fund"). The Fund has received contributions from the Governments of Thailand (US$ 10 million), Sweden (US$ 2.6 million), Turkey and Nepal.

The Fund aims to build and enhance tsunami early warning capabilities in accordance with the needs of Indian Ocean and Southeast Asian countries. The Fund is a resource mechanism to narrow the capacity gaps in the region, through building institutional, technical, system-wide and other types of capacity for the development of early warning systems for tsunamis in a multi-hazard context. The Fund works within the international framework of the ICG/IOTWS, coordinated by the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC UNESCO). In addition to IOC UNESCO, four other United Nations entities are partners in the Fund: the secretariat of the International Strategy for Disaster Reduction (ISDR), the Office for the Coordination of Humanitarian Affairs (OCHA), the United Nations Development Programme (UNDP) and the World Meteorological Organization (WMO).

As of the end of 2008, the Fund had conducted five rounds of funding; it had received 51 proposals from various regional, subregional and national organizations. Eleven projects had been approved, with a total budget of roughly US$ 9.2 million. Through these projects, the Fund balanced programming of different aspects of early warning arrangements, including monitoring and warning services, risk knowledge, dissemination and communications, and response capacity from the national to the subnational and community levels.

More information on the Fund can be found at: www.unescap.org/pmd/tsunami_index.asp.

1.3 Methodology

This study is based on desk research to outline the current status of regional TEWS projects and initiatives including a mapping of regional achievements and gaps (who is doing what, where, when, how, etc.), followed by analysis of unmet needs and gaps and possible ways to address them. The research was carried out by Sheila B. Reed, Consultant.

A review of existing documents was carried out, including:
- reports from IOC UNESCO (including ICG/IOTWS and its Working Group meetings);
- regional/national IOTWS plans and strategies;
- status and progress updates from regional and national TEWS initiatives (carried out by United Nations entities, bilateral donors, governments, regional organizations, global and regional disaster management and early warning centres, and civil society organizations), and relevant conference proceedings and presentations.

See Annex 1 for a list of the main resource documents used for this Study.

Background

2.1 TEWS Evolution

Tsunami early warning systems monitoring the Indian Ocean were not well developed prior to the occurrence of destructive Indian Ocean tsunami in December 2004. Furthermore, emergency communication systems failed and coastal populations and tourists were not educated and prepared to respond appropriately to tsunami warnings and calls for evacuations. As a result, all countries failed to respond effectively to the tsunami. Some of the countries affected by the tsunami had tsunami early warning systems monitoring their Pacific shores where the greatest threat was perceived. It was obvious that there was an urgent need to establish Tsunami Early Warning Systems (TEWS) in the Indian Ocean and Southeast Asia to significantly reduce the risk of future loss of lives, assets and livelihoods. Thus, IOC UNESCO together with WMO quickly identified national focal points and national centres to operate on a 24/7 basis for tsunami early warning. The Intergovernmental Coordination Group (ICG) for the Indian Ocean Tsunami Warning and Mitigation System (IOTWS) was formed in 2005, with secretariat support provided by IOC UNESCO.[2] Six meetings have been held to date, the most recent in April 2009. The Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) includes countries bordering the Pacific and marginal seas.[3] The ICG/PTWS was established in 1968 and coordinates international tsunami mitigation activities, including the dissemination of timely tsunami warnings, watches, and advisory bulletins throughout the Pacific.

At the outset of TEWS development, several challenges and limitations emerged. For example, capacities of countries for the establishment of national TEWS differed significantly. In some countries, like India, Indonesia, Malaysia and Thailand, networks of seismological stations and tide gauges were established quickly. These were ultimately configured for TEWS as well. On the other hand, countries such as Myanmar and Cambodia did not possess systematic seismic and tidal observations.

In 2005, members of IOC UNESCO held several rounds of international negotiation and finally reached consensus[4] on building a distributed, interconnected tsunami warning system. An Interim Advisory Service was set up for the Indian Ocean involving the provision of tsunami advisories and watch information from Pacific Tsunami Warning Center (PTWC) in Honolulu and Japan Meteorological Agency (JMA) in Tokyo directly to the National Tsunami Warning Centres (NTWC) of the ICG/IOTWS Member States. Eventually, this responsibility is planned to be taken over by a number of Regional Tsunami Watch Providers (RTWPs) located in the Indian Ocean region. At the national level, each ICG/IOTWS Member State is responsible

[2] ICG/IOTWS Member States: Australia, Bangladesh, Comoros, Djibouti, France, India, Indonesia, Iran, Kenya, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Myanmar, Oman, Pakistan, Seychelles, Singapore, Somalia, South Africa, Sri Lanka, Tanzania, Thailand, Timor-Leste, United Arab Emirates, United Kingdom and Yemen.
[3] ICG/PTWS Member States: Australia, Canada, Chile, China, Colombia, Cook Islands, Costa Rica, Democratic People's Republic of Korea, Ecuador, El Salvador, Fiji, France, Guatemala, Indonesia, Japan, Malaysia, Mexico, New Zealand, Nicaragua, Niue, Panama, Papua New Guinea, Peru, Philippines, Republic of Korea, Russian Federation, Samoa, Singapore, Thailand, Tonga, Tuvalu (provisional), United States of America and Viet Nam.
[4] IOC UNESCO Resolution XXIII-12.

for issuing warnings to its own citizens through its NTWC. These warnings are based either on the NTWC's own analysis, or on the advisory messages received from PTWC and JMA, or a combination of both. This decision was a significant step made by the region in the establishment of an IOTWS.

The spirit and desire for regional cooperation was further demonstrated by setting up five working groups under the ICG/IOTWS (four at the first meeting and the fifth at the second meeting) to identify gaps and to recommend approaches to be taken on issues such as seismicity, sea level networks, risk assessment, modeling and forecasting, and interoperability of tsunami advisory and warning centres. A sixth working group was adopted by the third meeting of the ICG/IOWTS (ICG/IOTWS-III) in Bali, Indonesia in August 2006 to deal with cross-cutting issues related to mitigation, preparedness and response.

Although the South China Sea has previously been considered as a low tsunami risk area, severe earthquakes along subduction zones, e.g. around the Philippines, could generate tsunamis that would affect the coastal areas of Philippines, China and Viet Nam, and possibly parts of Cambodia, Thailand and Malaysia. Other areas of concern are the countries near the Makran Subduction zone - Oman, Iran, Pakistan and India, among others - as little research has been conducted regarding the hazard potential of this fault, which last generated a major tsunami in 1945. Some countries do not have national funding for developing national tsunami warning systems and have indicated that they need technical assistance. Donor funds have tended to be concentrated in the countries that suffered greatest impact from the Indian Ocean tsunami of 2004.

At the ICG/IOTWS-III meeting in 2006, countries maintained their decision that the IOTWS should be made up of many, mostly national, early warning systems. The fourth ICG meeting (ICG/IOTWS-IV), held in Mombasa, Kenya in February 2007, agreed that national implementation of effective and sustainable end-to-end early warning and mitigation systems was of critical importance and Member States without sufficient capacity to develop tsunami early warning and mitigation systems should be given special support to accelerate their respective implementation. The ICG/IOTWS-IV meeting noted that several countries were developing Regional Tsunami Watch Provider (RTWP) capabilities. ICG/IOTWS-IV agreed to develop, by the end of 2007, an implementation plan for an interoperable system of RTWPs, including a transition from the Interim Advisory Service providers, for presentation at the next meeting of the ICG/IOTWS. At the ICG/IOTWS-V meeting in April 2008, an RTWP Implementation Plan was adopted and it was agreed that the transition process would commence in the latter half of 2008. In terms of the nomination of Tsunami Warning Focal Points and Tsunami National Contacts, 25 out of 28 countries had made complete (13) or partial (12) formal nominations.

2.2 Response to the 12 September 2007 Tsunami Event[5]

The tsunami generated on 12 September 2007 by a magnitude 8.4 earthquake southwest of Bengkulu, Sumatra, occurred after many components of the IOTWS had been installed and the Interim Advisory Service had been operational for over two years. An Indian Ocean-wide watch

[5] Summary excerpted from Indian Ocean Tsunami Warning and Mitigation System (IOTWS) "12 September 2007 Indian Ocean Tsunami Event – Post Assessment of IOTWS Performance", Intergovernmental Oceanographic commission Technical Series 77, UNESCO 2008.

bulletin was issued by PTWC and JMA for the first time since the Interim Advisory Service began in March 2005. The event presented an ideal opportunity to evaluate the performance of the IOTWS, to highlight both the strengths and weaknesses of the system, to identify areas that required further attention, and to provide a benchmark of the status of the system. The IOC Secretariat sent out a post-event survey questionnaire to the 25 Member States to find out whether the NTWCs received bulletins from the Interim Advisory Service in a timely manner, to determine what actions were taken by the NTWCs, and to learn whether the Member States had activated their emergency response plans based on the available information.

Overall, the survey produced many positive results indicating that progress had been made in the development and implementation of the IOTWS. Gaps and weaknesses were also identified, mainly at the downstream end of the system where national procedures for issuing tsunami warnings and evacuation orders required further attention. The seismic and coastal and deep water sea level networks demonstrated that they were capable of detecting and locating the earthquake source and confirming that a tsunami had been generated. As these core networks expand, it is anticipated that the time for both earthquake detection and tsunami confirmation will reduce and accuracy will increase further to within the targets set by the ICG/IOTWS. The survey produced national reports and a number of very detailed findings that are beyond the scope of this report to mention.

2.3 Key Components of the Regional TEWS

A complete and effective early warning system comprises four inter-related elements, spanning knowledge of hazards and vulnerabilities through to preparedness and capacity to respond.[6]

Risk knowledge	Monitoring and warning service	Dissemination and communication	Response capability
Systematically collect data and undertake risk assessments	*Develop hazard monitoring and early warning services*	*Communicate risk information and early warnings*	*Build national and community response capabilities*
Are the hazards and the vulnerabilities well known? What are the patterns and trends in these factors? Are risk maps and data widely available?	Are the right parameters being monitored? Is there a sound scientific basis for making forecasts? Can accurate and timely warnings be generated?	Do warnings reach all of those at risk? Are the risks and the warnings understood? Is the warning information clear and useable?	Are response plans up to date and tested? Are local capacities and knowledge made use of? Are people prepared and ready to react to warnings?

Figure 1: The Four Elements of Effective Early Warning Systems[7]

Good early warning systems have strong linkages between the four elements. The major players concerned with the different elements should meet regularly to ensure they understand all of the other components and what other parties need from them. Risk scenarios should be constructed and reviewed. Specific responsibilities throughout the chain should be agreed and

[6] ISDR (2006) Third International Conference on Early Warning, Developing Early Warning Systems: A Checklist.

[7] UN/ISDR Platform for the Promotion of Early Warning.

implemented. Past events should be studied and improvements should be made to the early warning system. Manuals and procedures should be agreed and published. Communities should be consulted and information should be disseminated. Operational procedures such as evacuations should be practiced and tested.[8]

Behind all of these activities should lie a solid base of political support, laws and regulations, institutional responsibility, and trained people. Through these, early warning systems are established and supported as a matter of policy and preparedness to respond is engrained in society.[8]

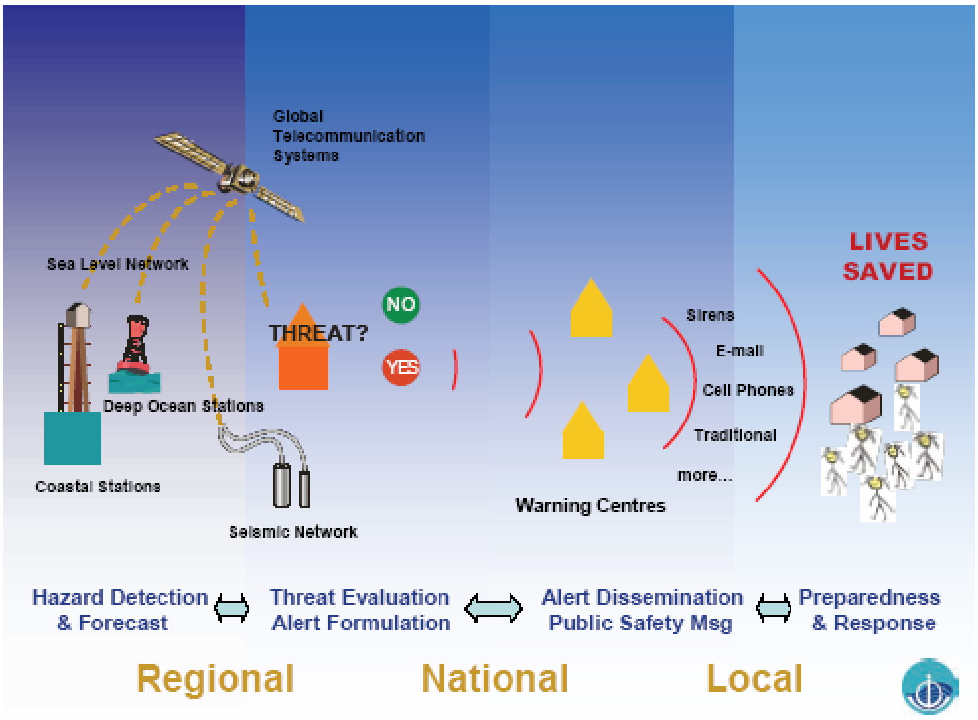

Figure 2: End-to-end components of TEWS

Rather than being carried out as a separate activity, most TEWS are part of a multi-hazard EWS that addresses hazards threatening the population and includes all actors who are responsible, in order to improve economies of scale, sustainability and efficiency and to consider all end users needs. It is likely that a multi-hazard EWS will be activated more often than a single-hazard warning system and therefore will provide better functionality and reliability which will support warning for dangerous and high intensity events, such as tsunamis, that occur infrequently. The TEWS is easier to support when linked to the same institutions, trained staff and technology that monitor other hazards. Multi-hazard systems also help the public understand the range of risks they face and can reinforce desired preparedness actions and warning response behaviours.[9]

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[8] UN/ISDR Platform for the Promotion of Early Warning.

[9] ISDR (2006) Third International Conference on Early Warning, Developing Early Warning Systems: A Checklist.

Governance and Institutional Arrangements

3.1 Summary

The Indian Ocean and Southeast Asian region is rich in institutions contributing to regional coordination on different aspects of disaster risk reduction (DRR). The regional tsunami warning system is coordinated by IOC UNESCO's Intergovernmental Coordination Group for the Indian Ocean, with other countries in Southeast Asia covered by the ICG for the Pacific. Intensive work has been carried out by many countries to develop disaster management laws and institutions following the Indian Ocean tsunami. In many cases, additional work to develop implementing regulations and Standard Operating Procedures (SOPs) at different levels of Government is ongoing.

3.2 Introduction

Well developed governance and institutional arrangements, both internationally and nationally, form the foundations for successful development and sustainability of sound early warning systems. Clear indicators of political commitment are the level of resources allocated and the efficiency of their use by stakeholders. Decentralization of authority, as well as building capacity and devoting resources at provincial and local levels are means to foster participation. Ultimately, the TEWS functions as part of the overall DRR system.

Key foundations of DRR and EWS are the laws and regulations which underpin the functioning of the systems, clarify roles and responsibilities and dedicate resources to warning, response and recovery. Since the Indian Ocean tsunami of 2004, countries like Sri Lanka, Indonesia and Thailand have passed national disaster management legislation.

3.3 International Coordination Mechanisms

3.3.1 Intergovernmental Coordination Group (ICG)

The Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) was formed in response to the 2004 Indian Ocean tsunami. The IOC Assembly, during its twenty-third Session (21-30 June 2005), formally established the ICG/IOTWS through Resolution IOC-XXIII-12. In 2006 and 2007, IOC UNESCO was mandated by the UN General Assembly to coordinate the implementation of the Indian Ocean Tsunami Warning and Mitigation System (UNGA Res/61/132 and UNGA Res/62/91).

ICG/IOTWS includes six Working Groups[10] (WGs) and some task teams within these groups. They are overseen by a Steering Group composed of ICG/IOTWS officers, Working Group chairs and vice chairs. It is IOC UNESCO's mandate to coordinate all activities, groups and NGOs involved in the ICG/IOTWS.

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[10] WG1: Seismic measurement, data collection and exchange, WG2: Sea level measurement, data collection and exchange, WG3: Risk assessment, WG4: Modeling, forecasting and scenario development, WG5: A System of Interoperable Advisory and Warning Centres; RTWP Task Force, WG6: Mitigation, preparedness and response. ICG Working Group members include: Indian Ocean countries (28), Observer States, UN agencies and NGOs.

WG meetings have effectively pushed forward the goals of the TEWS, based on consensus of the members. The rate of progress, however, is uneven among the Working Groups and is dependent on support at a national level. Group output is sometimes hampered by lack of consistent attendance by country representatives. Generally, a certain level of expertise in the relevant technologies and disciplines is required to participate in a Working Group. At the Fifth Session of the ICG/IOTWS, the Steering Group requested that the membership criteria for WGs be formalized to facilitate contact with members and help maintain the momentum at WG meetings. Further, financial issues have plagued some countries in terms of ability to send representatives, which limits the range of opinion on important issues in the meetings.

3.3.2 Other International Coordination Groups

ESCAP

ESCAP, at its 64th Session in April 2008, established a new intergovernmental Committee on Disaster Risk Reduction and programme of work on disaster risk reduction, and mandated ESCAP to further strengthen its capacity in this area. Issues to be addressed include policy options and strategies for multi-hazard disaster risk reduction and mitigation; regional cooperation mechanisms for disaster risk management, including space and other technical support systems; multi-hazard assessment, preparedness, early warning and response to disaster risks.

To enable transfer of valuable information and knowledge of disaster management across the region, ESCAP's DRR programme is advocating a synchronized platform for cooperation and knowledge sharing for the increasing number of networks and initiatives with specific focus on certain types of natural disasters, phases of disaster management and geographical locations.

The ESCAP Tsunami Regional Trust Fund promotes coordinated programming to support end-to-end early warning in ESCAP Indian Ocean and Southeast Asian countries, through a multi-hazard approach. Grants are provided to governments and intergovernmental and not-for profit organizations. IOC UNESCO, ISDR, OCHA, UNDP and WMO attend Advisory Council meetings as observers and appraise proposals to the Fund.

UN International Strategy for Disaster Reduction (ISDR)

Among other initiatives, ISDR has been coordinating a multi-partnered initiative "Building Resilience to Tsunamis in the Indian Ocean", which targets national focal points for development of early warning systems and national platforms for DRR in India, Indonesia, Maldives, and Sri Lanka. The initiative aims to advance research and analysis on risk and impact of disasters including socio-economic impact and gender aspects. In order to strengthen coherence between global and government policies, ISDR is building partnerships among ISDR system and regional partners. ISDR has also been coordinating global and regional platforms for disaster risk reduction (DRR), including regular Asian Ministerial Conferences on DRR.

The Indian Ocean (IO) Consortium

The Indian Ocean (IO) Consortium "Strengthening National Capacities for Tsunami Early Warning and Response Systems in the Indian Ocean" was established during the Third International Conference on Early Warning in Bonn, March 2006, and is composed of eight partners: ISDR, IOC UNESCO, UNDP, WMO, UNEP, IFRC, OCHA and the World Bank. Its purpose is to support the development of national components of the IOTWS and further the development of national coordination mechanisms among the governments and ISDR system partners. The IO Consortium is supporting implementation of national action plans for TEWS and linking ongoing regional TEWS activities. A review of national TEWS plans has been undertaken in order to identify critical areas of need that require support.

ASEAN [11]

The Association of Southeast Asian Nations (ASEAN) has developed an Agreement on Disaster Management and Emergency Response (AADMER). The aim of the agreement is to provide effective mechanisms for joint response and DRR and it sets out principles for regional cooperation. This Agreement has not entered into force, but efforts are ongoing to operationalize the components of the Agreement. It was employed following the Yogjakarta, Indonesia May 2006 earthquake and more recently in the response to Cyclone Nargis in Myanmar in May 2008.

SAARC

The members of the South Asian Association for Regional Cooperation (SAARC) include Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, and Pakistan and Sri Lanka. The SAARC Disaster Management Centre (SDMC) was set up in October 2006 in New Delhi, India.

BIMSTEC

The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) includes Bangladesh, Bhutan, India, Myanmar and Thailand. In its focal sector of Environment and Disaster Management, a decision was made to establish the BIMSTEC Centre for Weather and Climate. BIMSTEC plans to strengthen emergency preparedness for natural disasters, especially through early warning systems and networking with ADPC and SAARC.

ESCAP /WMO Typhoon Committee [12]

The Typhoon Committee was established to promote and coordinate the planning and implementation of measures required for minimizing the loss of life and material damage caused by typhoons in East and Southeast Asia.

ESCAP/WMO Panel on Tropical Cyclones [13]

The Panel on Tropical Cyclones is the equivalent organization to the Typhoon Committee serving the Indian Ocean.

South-South Cooperation

With support from ESCAP and the UNDP Special Unit on South-South Cooperation, an Asia-Pacific Regional South-South Cooperation Mechanism for Disaster Risk Reduction was established in late 2007, for which Indonesia serves as the interim secretariat.

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[11] ASEAN member states are: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

[12] The Typhoon Committee is currently composed of 14 Members: Cambodia; China; Democratic People's Republic of Korea; Hong Kong, China; Japan; Lao People's Democratic Republic; Macao, China; Malaysia; the Philippines; Republic of Korea; Singapore; Thailand; Viet Nam; and the United States of America.

[13] The Panel on Tropical Cyclones is currently composed of 8 Members: Bangladesh; India; Maldives; Myanmar; Oman; Pakistan; Sri Lanka; and Thailand.

Other regional actors
Several actors in the Asia-Pacific region offer stakeholders resources, and expertise in disaster risk reduction. These include:

- **Asian Disaster Preparedness Center (ADPC)**, in Bangkok, Thailand, develops sustainable institutional disaster risk management capacities and is working in the areas of climate risk management, community-based disaster risk management, disaster risk management systems, public health in emergencies, supplying training resources, and urban disaster risk management.
- **Asian Disaster Reduction Center (ADRC)** was established in Kobe, Japan, in 1998. The Center works to build disaster resilient communities and to establish networks among countries through many programmes including personnel exchanges.
- **Asian Disaster Response and Recovery Network (ADRRN)** was created in February 2002, when ADRC and OCHA, with the assistance of the ASEAN Foundation, brought together more than 30 NGOs from all over Asia in Kobe, Japan, to discuss the need for a network of NGOs for disaster reduction and response in Asia.

3.4 National Coordination Mechanisms

Coordination of TEWS at the national level takes place generally through the national disaster management bodies in each country, but arrangements differ considerably. Well defined relationships are important to avoid problems including: clashes between early warning providers as to who is the ultimate authority, confusing or contradictory messages to the public from various sources, and budgetary inefficiencies where monitoring centres and emergency operations centres (EOCs) are duplicated in each institution resulting in the possible marginalization of one or more of these institutions. In Thailand, for example, an attempt was made to address these issues by institutionally incorporating the Thailand National Disaster Warning Center (NDWC) into the Ministry of Information and Communication Technology, also the home of the Thailand Meteorological Department, to promote efficiency and to better clarify their respective roles.

3.4.1 Legal and Policy Frameworks

The strength of national legal and policy frameworks for Disaster Risk Reduction (DRR) is likely to affect the functioning of the regional TEWS. Regionally, there is considerable momentum to establish national disaster management laws and regulations. Generally the process to develop, vet and pass the laws requires a number of years and once passed, the laws are not fully operable without considerable work on related policy documents and operations plans as well as capacity building throughout the system. Major governance issues also concern whether management of the DRR system is decentralized, how well it is resourced, and how well it works to the community level. Weaknesses and gaps in any of these aspects precipitate issues that are described above particularly in relation to the national level of commitment to the TEWS and national roles in the TEWS.

Several initiatives have supported national efforts to develop appropriate legislation and tools to implement these laws. UNDP carried out studies on "Institutional and Legislative Systems for Early Warning and Disaster Risk Reduction" in Sri Lanka, Indonesia and Thailand. The preliminary findings of these studies were presented to a regional workshop in May 2008.

Some findings included:

- The recent passage of disaster management laws in all three countries is heralded as a significant milestone, however, the laws tend not to contain specific legal language on early warning systems and tend to focus on response.
- All countries are increasing emphasis on DRR in national development planning.
- Although a small degree of improvement has been seen partly through efforts to achieve the Millennium Development Goals (MDGs), women lack adequate political participation and voice in the legislature which seriously dilutes their impact on laws and policies for gender-balanced DRR; their participation is generally lowest at the smallest administrative level.

Other gains are being made in law, policy and planning for early warning as part of DRR. For instance, the Maldives Government has been finalizing a Disaster Risk Management Act and is developing a National Platform for Disaster Reduction.

Several initiatives have addressed the need for greater clarification of roles. A series of four SOP (Standard Operating Procedures) workshops[14] took place between October 2006 and May 2007 in Indonesia and focused on warning and information dissemination including the development of a dissemination strategy that includes interconnecting policies between national and local levels. The ESCAP Tsunami Regional Trust Fund is supporting a series of regional workshops implemented by IOC UNESCO to strengthen national capacity to develop SOPs, focusing in particular on Myanmar, Pakistan, Philippines and Viet Nam.

3.4.2 Sustainability issues and financial resources

Sustainability is a particular challenge for TEWS as tsunami disasters tend to be rare events. One major indicator for sustainability of TEWS is the level of ongoing financial support from national government budgets essential for its long-term effectiveness. Others include integration of TEWS in broader disaster management legal and institutional development for a multi-hazard approach and incorporation of early warning and prevention in development policies and plans.

Funds are continuously needed to support capacity development, participation in meetings, maintenance of hardware and software and databases, dissemination of information to the public and ongoing educational, media and DRR programmes covering various hazards including tsunamis. One issue is that there is a tendency to lump DRR budgets with emergency/relief budgets, with the end result that funds are used for relief assistance rather than development of a preventive system. Most major donors are tending to phase out TEWS funding after years of intensive effort; political will to protect the region needs to be maintained.

3.5 Civil Society and Community Coordination

Stakeholders in TEWS include the general public, media and civil society actors such as NGOs. Community-based organizations and networks are important actors in strengthening the TEWS.

General Public

The general public is the end user of the TEWS and each person/household essentially requires

[14] Sponsored by UNDP, USAID, GTZ and The Indonesian Red Cross/IFRC.

their own personal and family plans for response to early warning messages. There are significant regional disparities in terms of development, including disparities in income and education. Even in Indonesia where considerable work is underway to reach communities, it may be years before all are reached. Countrywide resources devoted to supporting community preparedness are generally small and insufficient compared to those dedicated to technical components of TEWS and central planning.

Media

The media has the potential to provide substantial support for TEWS. The media can have a high impact and inaccuracies in the information provided can lead to an inappropriate response by a large number of people. Therefore, media actors require investment in their capacity to report on disasters and support early warning. Actors experience confusion as to the roles and authorities of government agencies in the EWS and often lack real-time information and analysis.

3.6 Priorities/Recommendations

1. Provide support at the national level to put laws and regulations into operation through development of relevant policies and SOPs.
2. Promote sustainability and adequacy of funds to achieve TEWS objectives by linking project interventions with earmarked funds for TEWS in national budgets.
3. Promote efficiency through regional resource sharing arrangements and the multi-hazard approach.
4. Support links between institutional arrangements at different levels of government, from the regional to the national, provincial and community levels, including “end-to-end” SOPs.

Risk Knowledge

4.1 Summary

Risk assessment guidelines and an Indian Ocean tsunami hazard map based on current knowledge have been developed within the framework of ICG/IOTWS Working Group 3. The Guidelines, entitled "Tsunami risk assessment and mitigation for the Indian Ocean: knowing your tsunami risk – and what to do about it" were adopted by ICG/IOTWS -VI in April 2009. Even at the broadest level, the high-risk tsunami zones and the overall tsunami frequency in different parts of the region are still poorly known, with most recent research focusing on areas affected by the 2004 Indian Ocean tsunami. While intensive work has been carried out to improve risk knowledge, applying the information for planning and vulnerability assessments is a challenge, especially at the local level. Vulnerability mapping is a complex exercise with expanding but limited coverage. It may be difficult for Governments and disaster managers to access reliable and standardized data that are needed.

4.2 Introduction

Risks arise from the combination of hazards and vulnerabilities at a particular location. Assessments of risk require systematic collection and analysis of information and should consider the dynamic nature of hazards and vulnerabilities that arise from processes such as urbanization, rural land-use change, environmental degradation and climate change. Risk assessments and maps help to motivate people, to prioritise early warning system needs and guide preparations for disaster prevention and response.[15]

4.3 Organizational Arrangements

National and local risk assessments based on hazard data and vulnerability information should be available and include multi-hazard risk assessments for key sectors, such as education and land use management, and cost benefit analysis to determine where resources should be placed. Risk assessments allow decision makers and the public to understand the country's exposure to various hazards and its social, economic, environmental and physical vulnerabilities.

At the national level, tsunami hazard mapping and modeling is proceeding and the trend is increasing toward multi-hazard or integrated mapping. Frequently, a number of institutions are involved in mapping and modeling using a variety of technologies. National capacities to promote risk knowledge vary considerably depending on the availability of expertise, tools for analysis and data quality. In many countries there is insufficient data for modeling on national and local levels. In Indonesia, which is vulnerable in many respects to numerous hazards, efforts are being made by the government to standardize disaster risk mapping. In Thailand, the Department of Disaster Prevention and Mitigation is developing an integrated system that is intended to serve as a clearinghouse of disaster risk management information. In Maldives, detailed island level risk mapping is being completed by a UNDP-supported study within the Ministry of Planning and National Development.[16]

[15] ISDR (2006) Third International Conference on Early Warning, Developing Early Warning Systems: A Checklist.
[16] Disaster Risk Assessment Maldives (DRAM).

In many countries, regulations related to housing, building and land use planning are not unified under comprehensive policies and risk assessments may not be included in master plans for developing cities and rural areas. Land-use policies and environmental protection measures vary in terms of effectiveness and enforcement, some due to lack of clear mandates for designated institutions and the need for greater administrative capacity. Some laws are outdated relative to modern needs. Sub-standard building materials may be used particularly by the poor.

The ICG/IOTWS WG3 is supporting processes to promote comprehensive risk assessment and mitigation options. A number of countries are planning to prepare risk assessment case studies around topics such as use of environmental barriers (e.g., mangroves and sand dunes), use of artificial countermeasures such as tsunami breakwaters and sea walls, land cover and land use (tsunami-specific zoning), tsunami resistant infrastructure, evacuation plans (vertical evacuation and tsunami safe zones) and harnessing indigenous knowledge to reduce vulnerability.

4.4 Identification of Hazards

An IOC UNESCO Workshop[17] on "Indian Ocean Tsunami Hazard Assessment" took place in July 2007, which represented a first step towards developing an Indian Ocean tsunami hazard map based on assessment of earthquake sources and on modeling of deep-ocean propagation.[18] A Tsunami Hazard Map for the Indian Ocean region is being prepared by Geoscience Australia, with contributions from members of ICG/IOTWS Working Group 3. The map was presented at the ICG/IOTWS–VI meeting (7-9 April 2009), and will be made freely available to all Indian Ocean countries. In fact, two maps ("low risk" and "high risk") were prepared to highlight the uncertainty regarding the risk of major tsunamis from some subduction zones.

A recent study on "Risk Assessment and Mitigation Measures for Natural- and Conflict-Related Hazards in Asia-Pacific" commissioned by OCHA Regional Office for Asia and the Pacific Bangkok and carried out the Norwegian Geotechnical Institute (NGI), presented a first-pass assessment of the tsunami hazard and population exposure based on today's knowledge using a deterministic scenario approach.[19] The tsunami hazard map for Asia and the Pacific is shown in Figure 3, and the number of people exposed is listed in Table 1.

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[17] "IOC UNESCO Workshop on Indian Ocean Tsunami Hazard Assessment", Bandung, Indonesia, 17-18 July 2007, Final Report.

[18] Tsunamis can be generated when the seafloor is uplifted or down-dropped, pushing the entire water column up or down. The potential energy that results from pushing water above mean sea level is then transferred to horizontal movement of the tsunami wave propagation . (Source: USGS)

[19] "Risk Assessment and Mitigation Measures for Natural- and Conflict-Related Hazards in Asia-Pacific", OCHA Regional Office for Asia and the Pacific Bangkok, January 2009.

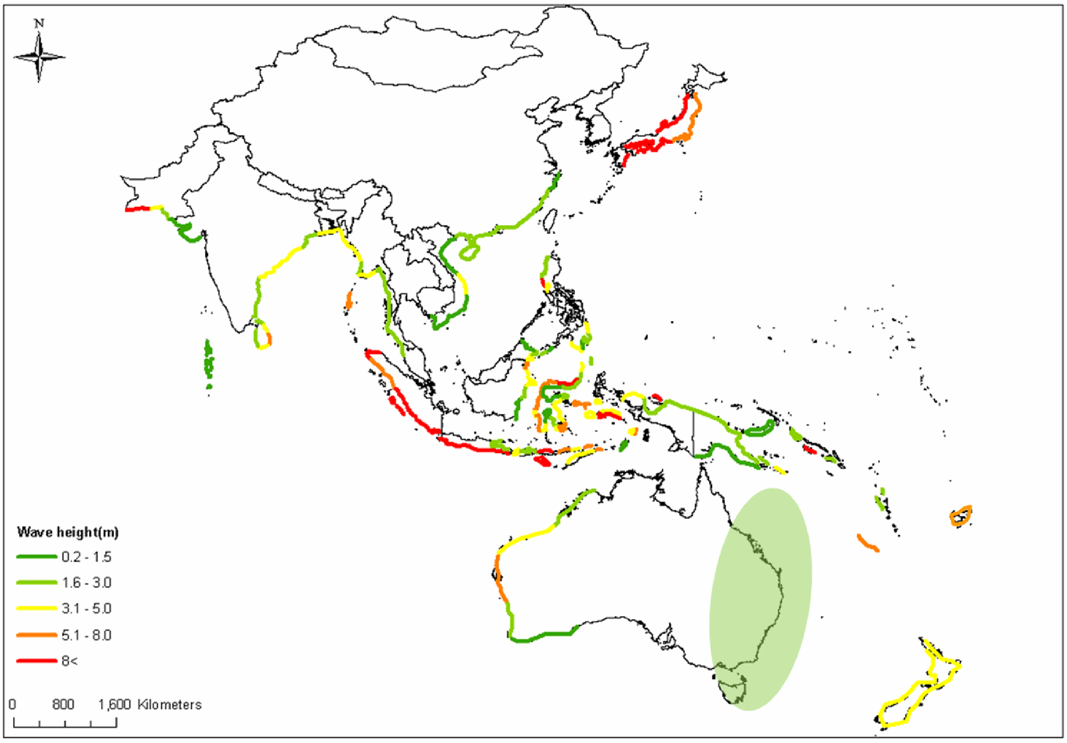


Figure 3: NGI "first pass" tsunami hazard map for Asia-Pacific. Note: The coastal areas without a level of tsunami hazard indicated on the map mostly represent areas where no data are available.

Maximum wave run-up of more than 10m was estimated along the coast of Pakistan. These waves are associated with short travel times, and there is hence little time for warning. In the neighbouring shorelines in India, the waves are an order of magnitude smaller. For the Bengal Bay and Andaman Sea coastlines, potentially destructive waves of 5-8m are found at Andaman, Nicobar, a small section of the Myanmar coastline and Sri Lanka. In India, Bangladesh and Myanmar almost 3 million people are exposed to tsunami hazard.[18]

Indonesia is the country exposed to the largest wave run-ups, ranging from 5 to 20m over large parts of the country. Short travel times are often associated with tsunami impact in Indonesia, which makes tsunami early warning difficult. The exposed population in Indonesia exceeds 1.5 million. Similarly, a large number of people could be exposed to large waves in the Philippines. Large population exposure is also found for Viet Nam and China, but in these countries the tsunami risk is lower, both because of the smaller waves expected and longer travel times and hence increased possibilities of early warning.[20]

[20] "Risk Assessment and Mitigation Measures for Natural- and Conflict-Related Hazards in Asia-Pacific", OCHA Regional Office for Asia and the Pacific Bangkok, January 2009.

Table 1: Exposed population to tsunami in Asia-Pacific

Country/Area	Exposed population in Year 2000	Percent of total population
Australia	13,300	0.07
Bangladesh	1,400,000	1.00
China	720,000	0.06
Fiji	28,000	3.5
French Polynesia	850	0.36
Indonesia	1,600,000	0.76
India	1,030,000	0.10
Japan	3,600,000	2.8
Maldives	22,000	8.0
Myanmar	650,000	1.4
New Caledonia	23,000	11
New Zealand	73,000	1.9
Pakistan	180,000	0.12
Philippines	1,150,000	1.5
Papua New Guinea	1,300	0.02
Solomon Islands	3,100	0.75
Sri Lanka	155,000	0.85
Thailand	11,500	0.02
Tonga	1100	1.1
Vietnam	430,000	0.54
Vanuatu	1,100	0.6
Western Samoa	1,400	0.8

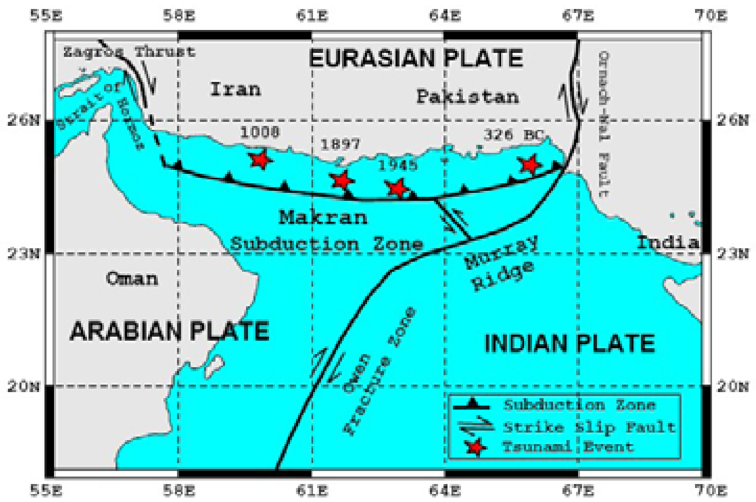
No probabilities are associated with the scenarios in the study and this is considered to be essential for an effective risk assessment. Probabilistic hazard assessments are urgently needed to guide tsunami hazard mitigation. It is clear, however, that hazard maps and assessments will be only as strong as the data on which they are based. Historical records of tsunami events are limited.

Research by Geoscience Australia has revealed approximately 26 teletsunamis[21,22] in the historical record, yet these records are incomplete in many places. Two recent studies showed that the 2004 Indian Ocean Tsunami had at least one likely precedent about 600 years ago.[23, 24] The findings could be used to put statistical weight behind estimates of future tsunamis and could contribute to policy decisions on tsunami preparedness. Earthquake and tsunami sources have been studied more extensively in Sumatra but other areas of high potential require more focus, particularly Andaman-Nicobar, Arakan, Java, Makran (see box on page 19) and the South China Sea.

21 Joint programme with Dale Dominey-Howe (Macquarie University), Historic records of teletsunami in the Indian Ocean and insights from numerical modeling, Natural Hazards, 2006.
22 A teletsunami can be defined as a tsunami that travels more than 1,000 kilometres from its origin before reaching land.
23 Medieval forewarning of the 2004 Indian Ocean tsunami in Thailand, Kruawun Jankaew, Nature Magazine 455, 1228 – 1231, 30 Oct 2008.
24 A 1,000-year sediment record of tsunami recurrence in northern Sumatra, Katrin Monecke, Nature Magazine 455, 1232 – 1234, 30 Oct 2008.

Makran - One of the subduction zones which requires more study

Sources: National Report submitted by the Islamic Republic of Iran to the ICG/IOTWS - V (also map below) and “IOC UNESCO Workshop on Indian Ocean Tsunami Hazard Assessment” Bandung, Indonesia, 17-18 July 2007, Final Report.



The northwestern Indian Ocean has experienced some deadly tsunamis but little research work has been devoted to tsunami hazard assessment in this region. In 1945 a fault rupture resulted in a large tsunami. Historical data has indicated that other tsunamis occurred in 326 BC, 1008, and 1897. It is thought that GPS observations are urgently needed along the Makran coast and more paleotsunami studies. A preliminary estimation of the hazard is calculated for each area of the coastline and numerical modeling is performed for each source scenario. The maximum tsunami wave heights along the coasts are then calculated to show the locations facing the greatest threats. The University of Tehran is working on developing three models, a generation model, a propagation model and an inundation model, to help predict potential tsunamis in the Gulf of Oman, in the Makran Subduction Zone.

4.5 Community Vulnerability Assessment

Vulnerability assessments are expanding but coverage is still low. In general, information on social, economic and environmental factors that increase vulnerability is inadequate. The vulnerability of groups who lack effective connections to the early warning systems such as rural poor, urban poor, ethnic minorities, handicapped persons, elderly, children, and foreigners such as refugees, migrant workers and tourists requires more analysis and inclusion of those groups in discussions of their vulnerability.

Coastal Community Resilience (CCR) is a general methodology for assessing the relative vulnerabilities of a community using an eight point scale including factors like national resource management, early warning and institutional frameworks for DRR. Building on local knowledge and needs, this initiative supported integrated and more standardized hazard awareness and mitigation efforts particularly by agencies working in local communities and helping them to prioritize DRR activities. With support of the ESCAP Tsunami Regional Trust Fund, ADPC has trained officials from Sri Lanka and Maldives in CCR assessment and carried out CCR assessments of pilot sites in both countries. In February 2008, ICG/IOTWS WG 6 organized a workshop on Approaches to CCR at its inter-sessional meeting. The workshop brought together various approaches to CCR and their role in developing integrated disaster risk management in the coastal communities around the Indian Ocean.

4.6 Risk Assessment

Prior to the Indian Ocean tsunami of 2004, there were very limited efforts in undertaking risk assessments in the countries affected. Risk information was largely based on limited historical records of events and most were inadequate to impress decision makers and the public to take the appropriate action to minimize these risks.

Since the 2004 tsunami, a number of tsunami risk assessments have been completed or are underway. In Thailand, a tsunami risk assessment was completed in 2007 using a scenario approach based on the 2004 event from a single source, i.e. Sumatra tsunamigenic earthquake. In Indonesia, a risk assessment is being undertaken with high local resolution. In Sri Lanka, at least one district has been a subject of a tsunami modeling study and several districts have had risk assessments using community participatory approaches. In southern coastal states of India, the government is scoping a risk assessment study that will attempt to map hazards of important concern in coastal communities. Meanwhile in Maldives, a national risk profile was completed and at least nine islands are being subjected to a detailed multi-hazard risk assessment study.

IOC UNESCO, in cooperation with the UNDP Regional Centre in Bangkok (UNDP RCB), and within the framework of ICG/IOTWS WG3, has developed standardized Guidelines for Tsunami Risk Assessment and Mitigation. The purpose of the Guidelines is to provide a description of basic and best-practice methodologies and case studies for conducting tsunami risk assessments and for developing effective mitigation solutions. The Guidelines were adopted by ICG/IOTWS - VI in April 2009, will be published as an IOC UNESCO Technical Publication and will be available to all IOC UNESCO Member States.

4.7 Information Storage and Accessibility

An overview of various national, regional and global data collection, storage and analysis methods was presented in the 2006 "Workshop to Improve the Compilation of Reliable Data on Disaster Occurrence and Impact" and served to reveal the wide variety of tools in use in the region. As is the case regionally, national level data collection, storage and access suffer from a lack of standardization, limited access to data and unreliable data.[25] A sustainable approach to database development would include development of comprehensive systems, ensuring that data is compatible among systems, and competent and motivated human resources to manage the systems.

Government policies may be lacking in regard to supporting the appropriate use of data and there may be different modes of access and storage. In the tsunami-affected countries, UNDP RCB is supporting governments to build capacity for utilizing the DesInventar methodology, which collects homogeneous data on disasters of all scales. Notable achievements to date

[25] Workshop to "Improve the Compilation of Reliable Data on Disaster Occurrence and Impact" April 2-4, 2006, jointly organized by the Centre for Research on the Epidemiology of Disasters (CRED) and UNDP Bangkok.

include the increasing use of the database and analysis by the Government focal organizations in Sri Lanka, Indonesia and in Tamil Nadu, India. These databases are currently being used to develop a report that analyzes the interface between disaster risks and poverty using a pioneering methodology. Databases in Iran, Nepal and Orissa State, India are also analyzed as the region's contribution to the upcoming ISDR System Global Assessment Report 2009. When completed, the analysis generated is expected to guide policy makers in using disaster risk reduction in poverty alleviation programmes.

4.8 Priorities/Recommendations

1. Support research on historical records of tsunami events. Special focus is required for areas of high potential risk that have not been studied extensively, particularly Andaman-Nicobar, Arakan, Java, Makran and the South China Sea.
2. Continue support to increase the coverage of vulnerability assessments, in particular at the local level.
3. Support development and application of standardized risk mapping and risk assessment guidelines.
4. Promote capacity development for standardized information storage, system compatibility, data accessibility and their use for disaster risk reduction.

Monitoring and Warning Service

5.1 Summary

Seismic and sea level stations have been installed to fill gaps in the regional TEWS network. Countries face a challenge in terms of the needed expertise and providing allocated funding to manage and sustain the stations. Ongoing support for operation and maintenance will be needed to maintain the performance of the regional monitoring and warning network over the long-term. Six countries and one regional institution have expressed willingness to commence the transition process to become a Regional Tsunami Watch Provider (RTWP), which three countries have already started.

5.2 Introduction

Monitoring and warning services form a critical component of the TEWS as there must be a sound scientific basis for predicting and forecasting hazards and a reliable forecasting and warning system that operates 24 hours a day. Continuous monitoring of hazard parameters and precursors is essential to generate accurate warnings in a timely fashion. Where possible, tsunami warning services should be coordinated with warning services for other hazards to gain the benefit of shared institutional, procedural and communication networks.[26]

5.3 Institutional Mechanisms

For regional watch advisories, ICG/IOTWS Member States have decided that having several Regional Tsunami Watch Providers (RTWPs) is the preferred mode of operation rather than a single provider. This may have advantages in terms of redundancy and for technical reasons, given the large number of tsunamigenic subduction zones in the Indian Ocean region. Essentially, the RTWPs will support an interoperable tsunami watch system for the Indian Ocean that aims to emulate the interim service provided by Pacific Tsunami Warning Centre (PTWC) and the Japan Meteorological Agency (JMA), with enhanced capability to help advise those countries most at threat. In the longer-term, it is envisaged that RTWPs will support the development and provision of enhanced tsunami warning services by National Tsunami Warning Centres (NTWCs). As more detailed bathymetry and coastal topography information becomes available to NTWCs, these centres will be able to undertake more detailed inundation studies to determine tsunami threat more accurately at the national level.[27]

The two-tier interoperable system of Regional Tsunami Watch Providers (RTWP) and National Tsunami Warning Centers (NTWCs) will be in place where:[28]

- Nations are responsible for issuing warnings within their own territories;
- Related relevant information will be freely available;

[26] ISDR (2006) Third International Conference on Early Warning, Developing Early Warning Systems: A Checklist.
[27] IOC UNESCO (2008) Indian Ocean Tsunami Warning and Mitigation System (IOTWS), Implementation Plan for Regional Tsunami Watch Providers, IOC Information Series No. 81.
[28] Indian Ocean Tsunami Warning and Mitigation System IOTWS. Implementation Plan, Third Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS-III), Bali, Indonesia, 31 July – 2 August 2006, IOC Technical Series No. 71, UNESCO 2006.

- Some nations will derive their own warnings from primary seismic and sea-level observations and seismic and ocean models;
- Other nations will receive watches based on bilateral arrangements with RTWPs that should assist them in preparing and issuing their own national warnings.

The roles and responsibilities of a RTWP are:[29]

- Determine and provide timely initial earthquake information (magnitude, location, depth, time, confidence levels);
- Determine more specific threat information using output from scenario databases produced by tsunami models, using earthquake source information and verified by sea level information;
- Provide timely tsunami watch information for use in preparation and issuing of national tsunami warnings by NTWCs;
- Provide timely standardized Situation Reports (SitReps) for use by other RTWPs and NTWCs;
- Share information with other RTWPs and NTWCs via, for example, GTS, web sites, RSS feeds, fax, emails, etc, in standard formats;
- Coordinate updates, cancellation and finalization advice with RTWPs;
- Regular testing and exercises to determine system performance (including communication channels to NTWCs, decision tools, etc.);
- Perform calibration and validation of detection and forecasting tools and models;
- Define their own region for provision of service, which may include the whole Indian Ocean, or a sub-region.

A two year transition period is envisaged for RTWPs to run in parallel with the PTWC and JMA, until the service can ultimately be taken over completely by the RTWPs.[29] The NTWCs, operating within their own legal frameworks, will be free to negotiate bilateral agreements with RTWP(s) from which they wish to access tsunami watch information.

For sustainability purposes, the timely development of RTWPs is critical yet the locations and countries of responsibility have not been completely determined. There are also some questions whether the RTWPs can provide the services needed by the most vulnerable NTWCs and what the conditions will be for providing the services. Several stakeholders have expressed willingness to commence the transition process, these are: Australia, India, Indonesia, Iran, Malaysia, Thailand and ADPC.[30] India has commenced the transition process in June 2008, Australia in August 2008 and Indonesia in January 2009.

The Governments of Bangladesh, Cambodia, China, Lao PDR, Maldives, Myanmar, Philippines, Sri Lanka, Thailand, and Viet Nam agreed in 2006[31] to establish an operational end-to-end multi-hazard early warning centre for the Indian Ocean and South China Sea. ADPC is establishing a regional facility for TEWS, based on that agreement. In light of the regional scope and likely economies of scale, the ESCAP Tsunami Regional Trust Fund is supporting development of the facility as well as its operation for two years. To enable national financial

[29] IOC UNESCO (2008) Indian Ocean Tsunami Warning and Mitigation System (IOTWS), Implementation Plan for Regional Tsunami Watch Providers, IOC Information Series No. 81.
[30] IOC UNESCO (2008) Fifth Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System, Kuala Lumpur, Malaysia.
[31] Meeting on Regional Cooperation on Early Warning Arrangements, Preparedness and Mitigation of Natural Hazards, 14 July 2006, Bangkok, Thailand.

systems to incorporate collaborating country support into their annual budgetary processes, the Maldives Meteorological Service is implementing a system sustainability plan. Collaborating countries' formal commitments to financially contribute to system sustainability are hoped to be made shortly. The sustainability of the ADPC regional facility will depend on the continued contributions from Member States.

When the RTWPs become operational, they will issue the following messages: 1) an Earthquake Alert message for potentially tsunamigenic under-sea earthquakes as soon as possible after the event's detection, followed by 2) a Tsunami Detection Alert message within 15 minutes of detection, and, 3) A Nil Tsunami Advisory providing confirmation.[32] Together with the NTWCs, they should adhere to internationally agreed-upon public messages in interoperable formats. Confusion among users will be minimized if these public messages are similar in name and content from one centre to the next.

At the national level, institutions, generally the NTWC, have been selected to take the lead on tsunami monitoring and warning, in many cases the national meteorological organization conducts monitoring activities and issues warnings in conjunction with the NTWC and/or Emergency Operations Centers. Most central institutions have monitoring staff on duty 24/7 to issue warnings on the appropriate levels but some may lack staff and resources to maintain 24/7 vigilance at more remote locations. This weakness forms one of the vulnerable links in the end-to-end chain.

5.4 Monitoring Systems

The post-event survey undertaken by the IOC Secretariat following the 12 September 2007 tsunami event indicated strengthened national monitoring systems. Of the 21 Member State respondents:

- Many (12) NTWCs undertook their own earthquake analysis.
- Most Member States (19) took some action after receiving the PTWC/JMA bulletin.
- Many (13) Member States monitored sea level.
- Some (8) Member States used numerical models in their analysis.[33]

Plans have been developed by ICG/IOTWS on seismic and sea level detection networks. Several elements of these plans to install and/or upgrade seismic and sea level stations have been addressed by UN (e.g. by IOC UNESCO and ESCAP's Tsunami Regional Trust Fund), regional, and national entities, including in the South China Sea and Bay of Bengal areas.

5.4.1 Seismic Data

There are two categories of seismic stations, some form part of the core regional network coordinated by IOC UNESCO, whereas others are additional stations for improved coverage primarily at the national level. To form the core network, seismic stations meeting certain qualifications have been selected to provide essential seismic data relevant to monitoring and

[32] Indian Ocean Tsunami Warning and Mitigation System IOTWS. Implementation Plan, Third Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS-III), Bali, Indonesia, 31 July – 2 August 2006, IOC Technical Series No. 71, UNESCO 2006.

[33] Indian Ocean Tsunami Warning and Mitigation System (IOTWS) "12 September 2007 Indian Ocean Tsunami Event – Post Assessment of IOTWS Performance", Intergovernmental Oceanographic Commission, Technical Series 77, UNESCO 2008.

detecting earthquakes that can trigger tsunamis, and some new sites have been proposed. In addition to the core network of the Indian Ocean, national seismic networks are necessary to address specific national requirements and constraints.[34]

As of April 2009, 73 of 80 core network seismic stations were in operation in the Indian Ocean region. Not all countries have the needed expertise and allocated funding to manage the stations and guidance documents have been made available by ICG/IOTWS to all Member States. Although it is considered to be critical by IOC UNESCO that seismic waveform data is shared in real-time, not all seismic stations are currently available in real-time.

National seismic networks are at various stages of development. These include stations that are part of the core regional network as well as additional stations tailored to specific national needs. Some examples:

- Australia has nearly completed installing its seismic stations.
- Singapore's network has been consistently improved since 2004, the goal is to have 7 stations.
- Indonesia plans to have a total of 160 seismic stations.
- India opened its national Early Warning System for Tsunamis and Storm Surges in October 2007 and has installed a network of seismic stations.

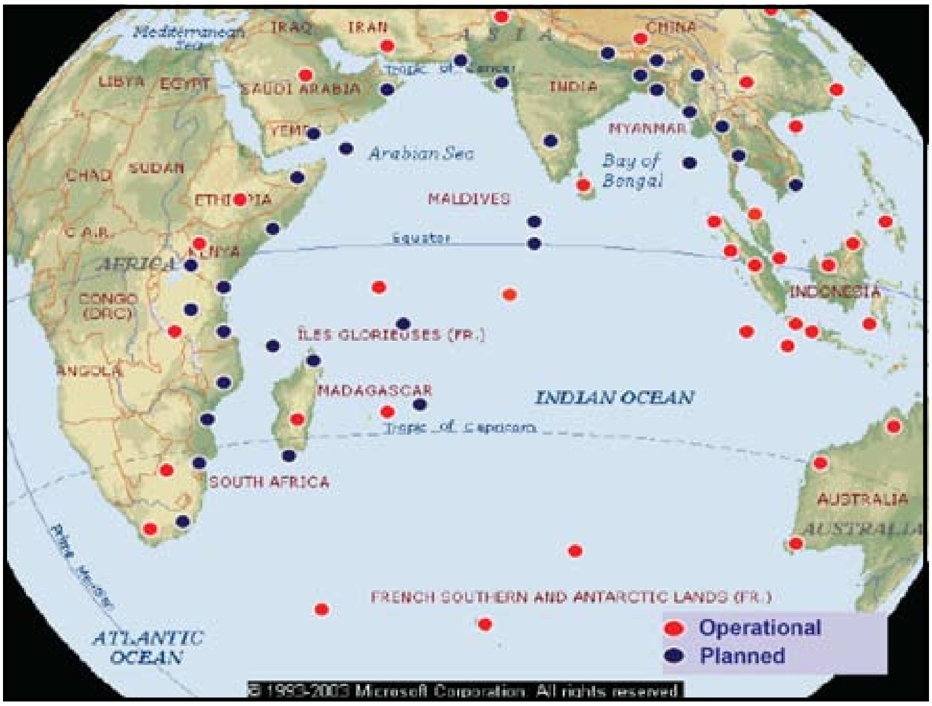


Figure 4: Core Regional Seismic Network for the Indian Ocean[34]

Most national seismic networks allow free access to their data and those currently not sharing have been asked to reconsider. The IOC UNESCO data sharing policy stipulates a free exchange of data between Member States and this will be extended to include real-time waveform data. The need for free exchange of real-time seismic waveform data is one of the six key recommendations of the Fifth Session of the ICG/IOTWS. To accomplish this goal, training of NTWC staff is critical. The potential RTWPs have been requested by the ICG/IOTWS to assist with the design of the required training material and to conduct the training.

[34] Indian Ocean Tsunami Warning and Mitigation System IOTWS, Implementation Plan, Third Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS-III), Bali, Indonesia, 31 July – 2 August 2006, IOC Technical Series No. 71, UNESCO 2006.

5.4.2 *Sea Level Data*

Real-time sea level observations are a key element in TEWS as these observations are used to help confirm the existence of a major tsunami or to cancel a tsunami watch or warning following an earthquake. Real-time sea level data together with numerical modeling output is important to provide improved tsunami forecasts. Two types of measurement systems are used to detect the presence and character of tsunami waves: coastal sea level stations, typically installed in harbors and at piers, and deep ocean stations using ocean-floor pressure sensors.[35]

The global network of coastal sea level stations established under the IOC UNESCO Global Sea Level Observing System (GLOSS) forms the basis of the initial sea level monitoring for the basin-wide IOTWS. These sites have been identified because of the proven quality, relevance, and long-time availability of the data. These stations are part of a multi-user/multi-purpose sea level observing network that serves both research and operational purposes (e.g., monitoring long-term sea level change, storm surge monitoring, and port operations). The multi-purpose nature of these stations maximizes the likelihood of ongoing maintenance and the continued functioning of the sea level network.[35]

Over 120 coastal stations are in place and 64 are transmitting real-time data using GTS.[36] The ESCAP Tsunami Regional Trust Fund has supported the installation of four sea level stations in Myanmar, Philippines and Vietnam. Five more station installations are planned by the end of 2010. All in all, there are a relatively small number of sea level stations to cover the region. This is due to funding priorities and/or technical difficulties in upgrading and sustaining some of the stations. A major challenge is to maintain and broaden the user base for these observing networks. Some countries have mechanisms, structures, and funds in place to carry this forward while others will need to develop them.[35]

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[35] Indian Ocean Tsunami Warning and Mitigation System IOTWS, Implementation Plan, Third Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS-III), Bali, Indonesia, 31 July – 2 August 2006, IOC Technical Series No. 71, UNESCO 2006.

[36] As defined in the WMO Technical Regulations (WMO Publication No. 49), the Global Telecommunication System (GTS) is the coordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange and distribution of observations and processed information within the framework of the World Weather Watch (WWW). It is implemented and operated by National Meteorological Services of WMO Members and also a few International Organizations (ECMWF, EUMETSAT). GTS consists of an integrated network of point-to-point circuits, and multi-point circuits, which interconnect meteorological telecommunication centres.

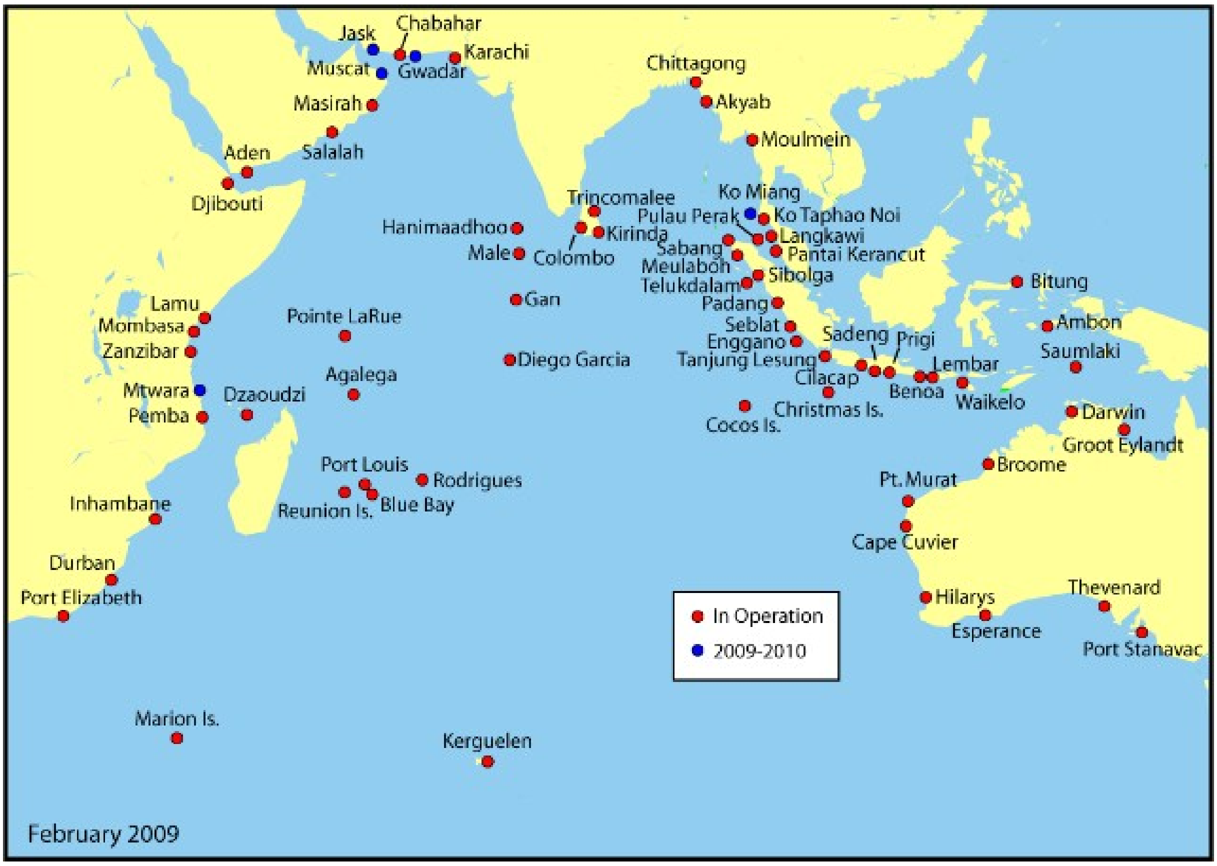

Figure 5: Current and planned sea level stations in the Indian Ocean.[37]

Sea level measurement at deep ocean stations ("tsunameters") is critical to improve the rapid detection and forecast of tsunamis, as they can be deployed offshore, near tsunamigenic areas. Apart from their value in early wave detection, they also provide "clean" open ocean wave signatures that can be correlated with forecast models.[38] The deep ocean network consists of 19 stations with a further 13 planned for deployment. A major issue plaguing the deep ocean network is vandalism and accidental damage, particularly arising from interaction with fishing activities. This increases the risk of non-transfer of data and weakens sustainability of the deep ocean system.

37 Map of sea level stations is provided by IOC UNESCO.
38 Indian Ocean Tsunami Warning and Mitigation System IOTWS, Implementation Plan, Third Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS-III), Bali, Indonesia, 31 July – 2 August 2006, IOC Technical Series No. 71, UNESCO 2006.

Figure 6: Indian Ocean Deep Ocean Sea Level Measurement Network.[39]

At the national level, several countries are making efforts to upgrade their sea level network, which is useful to monitor storm surges and flooding, often as part of a multi-hazard warning system approach. Collaborations have been established between countries like Australia, Germany, Indonesia, Malaysia, Thailand and USA including a range of technical collaborations and cooperation on contribution and deployment of tsunameter instruments.[40]

The need for free exchange of real-time sea level data among Member States is one of the six key recommendations of the ICG/IOTWS–V Conference. In addition, Member States are urged to promote awareness and explore possible means to reduce the intensive and ongoing vandalism on tsunameter buoys and to report to the ICG/IOTWS. Member States need to consider long-term financial and in-kind support to ensure sustainability of sea level instrumentation networks and their maintenance.

5.5 Forecasting and Warning Systems

Significant advances are being made worldwide in the detection of earthquakes. The US-based National Earthquake Information Center (NEIC) has access to about 1,000 seismic stations which has reduced the time needed to process information by early warning centers and disseminate a warning message to national/regional/local authorities globally to less than 20 minutes (and to only 5 minutes in the US).

[39] Map of Deep Ocean Sea Level Stations is provided by IOC UNESCO.
[40] Tsunameters are deep-ocean stations for sea level measurements.

Numerous new monitoring and forecasting tools have been developed and some have been shared in the region. These include:

- PAGER (Prompt Assessment of Global Earthquakes) which combines ShakeMaps[41] with population exposure to come up with estimates of numbers of people who were exposed to strong ground shaking. This will be made publicly available on the internet.
- SEisComp (Seismological Communication Processor) is free software developed by the German Research Center for GeoSciences – Helmholtz Center Potsdam (GFZ) and uses SeedLink[42] as a core protocol and has been running in Indonesia since May 2007.[43] It was tested on September 12, 2007 and the BMG (Indonesian Meteorological and Climatological Organization) made the tsunami warning in 5 minutes and the location was fixed in 4 minutes. SEisComp is also installed in several other countries.
- The National University of Singapore has developed a methodology for calculating magnitudes of large earthquakes, using a few reliable seismic stations and comparing results with the USGS; the computations can be completed in 15-20 minutes.
- The NEIC has developed PQLX, a software tool to evaluate seismic station performance, which sits on top of the station database – it can help with determining detection thresholds and time and location errors.

5.6 Priorities/Recommendations

1. Promote long-term financial and in-kind support to ensure sustainability of seismic and sea level instrumentation networks and their maintenance.
2. Promote use of the network of sea level and seismic stations for multi-hazard purposes to maximize the likelihood of ongoing maintenance and the continued functioning of the network.
3. Conduct a network-wide effectiveness review to analyze geographic coverage.
4. Promote national support for real-time, timely, free and open access to data, analysis, and other information products for (tsunami) warning purposes.

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[41] ShakeMap is a product of the USGS Earthquake Hazards Program in conjunction with regional seismic network operators. ShakeMap sites provide near-real-time maps of ground motion and shaking intensity following significant earthquakes.

[42] The SeedLink protocol is a robust data transmission intended for use on the Internet or private circuits that support TCP/IP. The protocol is robust in that clients may disconnect and reconnect without losing data, the transmission is started where it ended. All data packets are 512-byte Mini-SEED records.

[43] In Jakarta, the new version of the seismology software package "SeisComP3" replaces an older one that only worked automatically and did not include sufficient visual control and interaction. (GFZ website).

Communication and Dissemination of Warnings

6.1 Summary

There is a clear need to strengthen systems of dissemination and communication, in particular at the downstream level. Several countries are developing Standard Operating Procedures (SOPs) for tsunami warnings, but these are fully developed and tested only in a few countries. Significant gaps include effective and redundant channels of communication to the community level, and design of clear warning messages that are understandable to end users. To a large extent, the channels of communication available for disaster warnings may reflect the overall development of communications networks in a country.

6.2 Introduction

The purpose of dissemination and communications systems is to ensure that people and communities are warned in advance of impending tsunami and earthquake events. Warnings must reach those at risk and contain clear messages with simple useful information that will enable the appropriate responses to save lives and livelihoods. Regional, national and community level communication systems must be pre-identified with formal confirmation regarding authorities who will issue the messages. The use of multiple communication channels is important to ensure that as many people as possible are warned, to avoid failure of any one channel and to reinforce the warning message. The systems should facilitate national and regional coordination and information exchange.[44]

The post-event survey undertaken by the IOC Secretariat following the 12 September 2007 tsunami event indicated some positive changes in regard to dissemination and communications but there is a clear need to focus on strengthening systems at the downstream level. Most of the negative outcomes of the survey can be addressed both by the ICG/IOTWS and at the national level through a comprehensive capacity development process and regional cooperation. Post-event assessments can assist in this process by highlighting the strengths and weaknesses of the IOTWS at regional, national and local levels and by raising the awareness of how Member States responded, both individually and collectively.[45]

[44] ISDR (2006) Third International Conference on Early Warning, Developing Early Warning Systems: A Checklist.
[45] Indian Ocean Tsunami Warning and Mitigation System (IOTWS), "12 September 2007 Indian Ocean Tsunami Event – Post Assessment of IOTWS Performance", Intergovernmental Oceanographic Commission Technical Series 77, UNESCO 2008.

Table 2: Outcomes of the IOC UNESCO Survey

Positive outcomes	Negative outcomes
• All (21 out of 21 respondents) NTWCs received watch bulletins from PTWC/ JMA.	• Several Member States experienced delays in receiving watch bulletins from PTWC/JMA.
• 15 NTWCs received watch bulletin via the GTS.	• Some Member States experienced downstream communications problems.
• Indonesia located the earthquake hypocentre and issued a warning within 5 minutes of the event.	• Some Member States issued warnings after other Member States had cancelled their warnings.
	• In some Member States, evacuations were ordered when a closer analysis of the event may have indicated that the tsunami risk was low. The positive side of this is that it is good practice for the communities involved but the negative side is that it can build complacency.
	• In some Member States there was confusion over the need to evacuate and disconnection between national and local decision making.

This chapter contains some examples of issues and good practices based partially on the post-event survey national reports (undertaken by the IOC Secretariat following the 12 September 2007 tsunami event[46]) and reports supported by UNDP Regional Office in Bangkok on institutional and legislative systems for early warning in Indonesia, Sri Lanka and Thailand.

6.3 Organizational and Decision Making Processes

While progress has been significant in recent years with passage of legal instruments to support emergency management in many countries, procedures may require formalization for numerous aspects of dissemination and communication. There are many national actors who must be coordinated in terms of their responsibilities for informing the general public. These include government staff, from the President or Prime Minister and armed forces to regional centres, national centres, and local authorities including governors, mayors, and police. Others include public and private (such as amateur radio operators) media, tourist destinations, civil society and communities.

The people who support the warning system require training and education regarding the roles they should play, including the smaller administrative units and communities. Many of the stakeholders who could contribute significantly to effective warning have not received

[46] Indian Ocean Tsunami Warning and Mitigation System (IOTWS), "12 September 2007 Indian Ocean Tsunami Event – Post Assessment of IOTWS Performance", Intergovernmental Oceanographic Commission Technical Series 77, UNESCO 2008.

sufficient training or they are not fully engaged in dialogue on how to support the public. In some countries much work is carried out by Red Cross and Red Crescent volunteers while in others volunteers need to be brought more fully on board. Adequate budgets are vital in the provinces and districts to upgrade equipment and devices. There should be more signing of Memorandums of Understanding (MoUs) or Letters of Agreement (LoAs) for interagency collaboration and streamlining of the warning system.

SOPs may not be in place or sufficiently vetted to guide these actors or SOPs may be organization-centric and not unified. Some of these actors do not operate 24/7 so coordination will be critical to disseminate messages, particularly at night-time. People with authority must wait for the data to be analyzed in order to avoid false alarms. Authorities often express fear of issuing false alarms due to potential negative legal effects or public outcry and worry about the margin of error in analysis. Bureaucratic processes may cause delays in dissemination of information and action. Any confusion over government roles and authorities and inadequate collaboration among information providers reverberates with the media and the public who may be skeptical about the sources of messages and the messages themselves.

Several initiatives have addressed the need for greater clarification of roles. A series of four SOP workshops[47] took place between October 2006 and May 2007 in Indonesia and focused on warning and information dissemination including the development of a dissemination strategy that includes interconnecting policies between national and local levels, tools and equipment for warning dissemination, SOPs for warning dissemination at the local level, and message content that can be understood by communities. The ESCAP Tsunami Regional Trust Fund is supporting a series of regional and national workshops implemented by IOC UNESCO to strengthen national capacity to develop SOPs.

6.4 Effective Communication Systems and Equipment

The dissemination of data and early warning messages is undertaken in numerous ways including by telegraph, telephone (mobile, fixed), facsimile, TV, radio, cellular operators, mosques, churches, hitting bamboo or drums, and sirens. Electronic communications systems are subject to power outages and failure or overloading, so alternatives such as manual sirens and loudspeakers are important. Key actors in communication include the local police and disaster managers, among others, who must be capable of effectively communicating warning messages.

Warning towers have been installed extensively in the region; Sri Lanka's goal is to install over 200 while Thailand intends to reach nearly 150. A critical issue regarding the siren towers is that redundancy is important to back up the tower functions in order to effectively reach all at risk. Regulations need strengthening for tower operation and the operators and the public require training and education as to how the system works. Adequate funds are needed to maintain and inspect the towers.

In general, limited progress is being made on community-based early warning systems. Community leadership for early warning needs to be established as well as effective methods of communicating to people with limited access to technology. A programme currently

[47] Sponsored by UNDP, USAID, GTZ and The Indonesian Red Cross/IFRC.

underway by the Stockholm Environment Institute (SEI) Asia focuses on "Early Warning and Community Preparedness: Strengthening the Technology – Community Interface". A study within the programme "From knowledge to action: learning to go the last mile", aims to collect good practices to promote enabling circumstances for reaching people and results should be available at the end of 2008. The vision is to expand upon the results of the Last Mile Hazard Warning System developed by Sri Lankan organization Sarvodaya, which highlights use of addressable satellite radio (AREA) sets plus GSM/CDMA phones. The pilot system was put into action on the day of the September 12, 2007 Bengkulu tsunamigenic earthquake and regular alerts were successfully sent to Sarvodaya villages.

6.5 Warning Messages

Creating effective warning messages and disseminating them is extremely challenging. Even warning messages that are globally accepted may not provide sufficient guidance on response actions. Although messages may be clear, they may not flow downstream efficiently in order to reach everyone at risk. Two major access problems are 1) messages transmitted during the night do not reach people while they are sleeping; and 2) messages may not be transmitted in all of the appropriate languages to be understood, for example, by immigrants, migrant workers, or tourists.

Warning statements should not evoke curiosity or panicky behavior and rumor control action should be taken. A clear and phased formulation of warning messages should help to create public trust that warnings are well founded. For verbal language messages, the wording turns out to be very important - warning messages that lack clarity can cause public confusion. There may be limited feedback to the warning centers as to whether warnings have been successfully received and understood by relevant agencies and the public. The actual general warning format may not be well known by most local stakeholders involved in warning dissemination. Some communities have been confused by messages relayed by signal or siren towers. Efforts are currently underway by many organizations to understand how people comprehend the various messages.

A particular problem is the need for interpretation of news bulletins to the public, otherwise, for example, an earthquake of around 5 on the Richter scale may cause panic. The technical information has to be backed up with the human relationship aspects. The assistance of community leaders should be sought to help in explaining the threat and a warning should be followed by subsequent information and an all clear signal given when the threat of disaster has passed.

6.6 Priorities/Recommendations

1. Continue to support development of Standard Operating Procedures (SOPs) from the regional to the national, provincial and local levels.
2. Continue programmes to strengthen channels of communication for warning messages from the national to local levels, including strengthening of communications networks where feasible.
3. Strengthen the efficacy of warning messages, e.g. through regular user feedback, involving other stakeholders such as the media in their development, and training end users.

Response Capability

7.1 Summary

Intensive and innovative work on community preparedness and response strategies is carried out in many countries in selected areas. A comprehensive programme is not available in most cases. Many tsunami drills have been carried out in the region since the Indian Ocean tsunami, although there is no comprehensive regional programme for drills and other assessments of the status of the TEWS over the long-term. There are numerous actors involved in this area of work and also many gaps in education, awareness, and operating procedures.

7.2 Introduction

This chapter focuses on the activities that should occur when a warning or watch has been disseminated. The success of these activities is dependent on the quality of planning and capacity building that has taken place before the event, including all measures discussed in previous chapters, such as putting enabling policies and plans in place, building credibility of regional and national institutions, development of hazard maps and models, monitoring of seismicity and sea level, analyzing and building scientific and community capacity, and communication of information on hazards to the public. Response activities should feed back into the longer term strategy through sharing of lessons.

It is to be stressed that response capacity is an extremely broad area and that numerous actors are involved. To give full credit to the complexities of the response systems is beyond the scope of this study. Further, effective response is predicated upon the planning and strategic involvement of many stakeholders and experts, in areas including but not limited to climate change, natural resource management, gender, child protection, poverty reduction, infrastructure planning, military, police, and emergency and health services. Response capacity should include general disaster risk reduction (DRR) activities which would, for example, include zoning regulations to place schools and hospitals outside of tsunami inundation zones.

It is essential that communities understand their risks, respect the warning service and know how to react. Education and preparedness programmes play a key role. It is also essential that disaster management plans are in place, well practiced and tested. The community should be well informed on options for safe behaviour, available escape routes, and how best to avoid damage and loss of property.[48] Many people, in particular living close to subduction zones, do not have time to wait for an official warning and need to be trained to move to safe areas in response to earthquakes and other natural tsunami warning signs, as well as to understand and accept a high level of false alarms.

The media are invaluable partners in influencing and educating the public regarding TEWS. Another critical role for media is helping the government and the public deal with false alarms

[48] ISDR (2006) Third International Conference on Early Warning, Developing Early Warning Systems: A Checklist.

and to avoid panic. To do this, a protocol should be in place with media in terms of how to report why a disaster event did not take place as predicted to enhance public understanding. Local media are important actors to move messages among communities. The preparedness and warning messages need to be passed among schools, hotel security, and a range of other facilities, and various types of media can be used to do this.

ISDR indicators for measuring the implementation of the Hyogo Framework for Action and strengthening disaster preparedness for response include:

- Strong policy, technical and institutional capacities and mechanisms with a disaster risk reduction perspective are in place;
- Disaster preparedness plans and contingency plans are in place at all administrative levels and regular drills and rehearsals are held to test and develop disaster response programmes;
- Financial reserves and contingency mechanisms are in place to enable effective response and recovery;
- Procedures are in place to exchange relevant information during disasters and to undertake post-event reviews.

7.3 Reaction to Warnings

The tremors of the 12 September Bengkulu earthquake lasted for several minutes. Violent tremors were reported in Jakarta and several high rise buildings were evacuated. The earthquake also led to a power outage in Bengkulu, which crippled communications. Consequently, the extent of damage in areas near the epicenter was not immediately known. Ultimately, there were approximately 25 deaths and 100 injured. The impact in some communities was substantial, over 17,000 homes were destroyed or heavily damaged with the worst hit areas being West Sumatra and Bengkulu province, including Pesisir Selatan and Mentawai Islands districts and North Bengkulu District.[49]

The ICG/IOTWS Member States reported mixed response to the messages issued in the warnings. For example, in Bangladesh, where communities are well accustomed to evacuating ahead of storms and cyclones, an orderly evacuation was conducted along part of the coastline. In Thailand, the National Disaster Warning Center determined that a public alarm was not needed and sent out a confirmation of “no tsunami threat”. Progress achieved and issues encountered were reviewed in the USAID IOTWS Transition workshop in December 2007, by Indonesia, Thailand, Maldives and India. The country-based analyses indicated some similar needs among the countries. These include the following:

- Enhance evacuation planning, especially in densely populated areas;
- Enhance provision of accessible tsunami shelters;
- Augment numbers of warning and evacuation drills nationwide and conduct more simulations with special focus on schools and local communities.

[49] Data presented by Muslim Aid Indonesia to OCHA, December 2007.

Response to the Bengkulu Earthquake in Indonesia:
Significant Progress toward the End-to-End System; Much Work Yet to Be Done[50]

For a country whose northern Sumatra province was devastated in the 2004 tsunami, Indonesia's progress toward achieving an early warning system has been remarkable. The monitoring and dissemination phases of the 12 September warning beat all previous records. The alarms were triggered less than two minutes after the earthquake and a warning was sent approximately two minutes later. This message reached the general public by radio, television, SMS, and other local communication networks. In some areas, RANET units were also able to provide information. The Indonesia Red Cross (Palang Merah Indonesia - PMI) mobilized local volunteers immediately and began distributing stand-by stocks. Participating National Societies offered help immediately. UN assessment teams prepared to deploy. PMI ultimately assisted over 5,500 families.

The progress that had been achieved and issues needing further attention included the following:

Reaching the last kilometer through RANET. One hundred fifty RANET units have been distributed in Indonesia (136 were installed by the end of 2007). In one case, the RANET unit was turned off, so it did not receive the warning message.

Low rate of evacuation. Many local people did not understand the information disseminated in the warning messages issued by government agencies. In addition, September 12 was the first day of Ramadan and some people did not evacuate because of the ceremonies.

Development of SOPs. Work on development of SOPs particularly at the sub-national level has been slow due to the complexities in ensuring that they are appropriate to the context. SOPs must also be in line with national disaster management policies currently under development in relation to the Disaster Management Law which was finalized in 2007. The SOPs should include evacuation as well as how people's property will be protected. The national TEWS coordinator (RISTEK) is working closely with its sister agencies to facilitate local SOP development.

Safe evacuation. Several "safe areas" in densely populated areas were located quite far away. It was difficult to safely and quickly evacuate hundreds of thousands of people, so options for vertical evacuation are being explored by the local governments.

7.4 Disaster Preparedness and Response Plans

Disaster plans must be tailored to the individual needs of vulnerable communities, thus in addition to the national plan, communities must participate in planning based on hazard and vulnerability maps of their locations and then practice implementing the plans. The ESCAP Trust Fund is supporting "Strengthening National and Community Capacities for Effective Early Warning Dissemination and Response" in the Maldives. Community-based preparedness

[50] Synthesized from the US IOTWS Program Transition Workshop Proceedings, December 2007, presentation by BMG and GITEWS, pages 11-13.

activities included development of early warning and response plans on target islands. Early warning volunteer task forces have already been identified and trained on some of the islands. Both women and men are included in the task forces and training and the roles of women in disaster preparedness have been extensively discussed during awareness building activities.

7.5 Community Response Capacity

The local response actors require capacity development region-wide to strengthen their ability to meet large and smaller disaster response needs. From a human resources point of view, the needs for management skills are critical in order to effectively utilize the technology and equipment required for efficient response. There may also be shortages in human resources to manage the response resources. These human resource needs may be highlighted less by both local authorities and assistance actors than needs for material resources.

Empowering the volunteer network is seen as one effective means to create closer collaboration and a more efficient response system. The Sri Lankan Red Cross Society works through its network of volunteers and is implementing a large scale training programme through creation of a training center supported by the National Red Cross Society of the Republic of Korea. The Sri Lanka-Korea Disaster Management Centre will be used to train staff members, volunteers, and members of the public.

7.6 Public Awareness and Education

7.6.1 Public Awareness Strategies

The efficacy of early warning systems is deeply rooted in communities' knowledge of their own vulnerability and their capacity to protect themselves and their livelihoods. Country-wide public awareness strategies are important to stimulate a culture of disaster resilience, with outreach to urban and rural communities. Although scientific analysis regarding the tsunami hazard is still being developed, citizens need to be up to date with current knowledge so they can prepare themselves to react. It is unclear to what degree the coverage, depth and breadth of awareness-raising methods have been effective across the region.

Statistics do not exist on levels of risk awareness regionwide, but this information would be extremely useful. Awareness campaigns have been widely undertaken and some examples include the following:[51]

- Malaysia initiated several public awareness programmes in 2007 in the form of exhibitions, tsunami video displays and simulation exercises involving the public and government authorities.
- In Pakistan, an awareness campaign regarding tsunami, its possible occurrence, the probable loss of life and property and mitigation measures, has been undertaken through news and print media.
- In Australia, because tsunamis are infrequent events, long-term awareness programmes aim at reducing complacency, conducted together with strengthened emergency management training and exercise regimes. Since the inception of the Australian Tsunami Warning System (ATWS) project in June 2007, over 50 separate activities have been delivered to representatives from every state and territory.

[51] Examples taken from National Reports for the "Fifth Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System", Kuala Lumpur, 8-10 April 2008.

7.6.2 *Evacuation Drills*

In most countries affected by the 2004 tsunami evacuation drills have been conducted especially in tsunami-affected areas but most require fine tuning. Drills tend to be rather ad hoc and the high risk areas in most countries are not covered proportionately with hazard-specific drills and evacuation information. While warning response drills are increasing, coordination and resources for coverage are not adequate - some provinces and districts are not able to conduct drills due to budget constraints.

Ideally, drills and evacuation information need to be supported by regulations which stipulate frequency for drills, standards for success and procedures covering each area and hazard. Feedback/evaluation or measurement of the effectiveness of drills is still limited. The evacuation routes and location of safe places need to be clarified in a strategy or plan by area and hazard, such as locating key facilities outside of hazard zones and ensuring that police seal off evacuated areas. Key influential actors such as education institutions, teachers, village and religious leaders, and local government institutions, as well as NGOs, the private sector and community based organizations and networks should be involved.

Two highly publicized drills have served as examples to the entire region and the inclusion of a wide range of national and international stakeholders ensured that lessons and good practices would be retained. The first tsunami drill was conducted in Padang city in West Sumatra on the first anniversary of the December 2004 tsunami disaster and another at the end of 2006 in Bali, the most popular tourist destination in Indonesia. The exercise in Bali was carefully constructed as an end-to-end EWS simulation, involving institutions at all levels and communities. The Indonesian government has been conducting tsunami preparedness drills in various parts of the country every year on 26 December - the annual anniversary of the 2004 tsunami. In 2008 the drill was held in Gorontalo and the first Indian Ocean-wide drill is considered for 2009.

7.7 Priorities/Recommendations

1. Continue to support the massive task of supporting response capacity at the local level, recognizing that populations in many areas – in particular those close to subduction zones – will need to react before receiving an official warning message.
2. Support regulations that stipulate frequency for drills, standards for evaluation and procedures covering each area and hazard, and involving key influential actors.

Priorities/Recommendations

This section provides a consolidated list of the 17 priorities/recommendations proposed in this report.

Governance and Institutional Arrangements

1. Provide support at the national level to put laws and regulations into operation through development of relevant policies and SOPs.
2. Promote sustainability and adequacy of funds to achieve TEWS objectives by linking project interventions with earmarked funds for TEWS in national budgets.
3. Promote efficiency through regional resource sharing arrangements and the multi-hazard approach.
4. Support links between institutional arrangements at different levels of government, from the regional to the national, provincial and community levels, including "end-to-end" SOPs.

Risk Knowledge

5. Support research on historical records of tsunami events. Special focus is required for areas of high potential risk that have not been studied extensively, particularly Andaman-Nicobar, Arakan, Java, Makran and the South China Sea.
6. Continue support to increase the coverage of vulnerability assessments, in particular at the local level.
7. Support development and application of standardized risk mapping and risk assessment guidelines.
8. Promote capacity development for standardized information storage, system compatibility, data accessibility and their use for disaster risk reduction.

Monitoring and Warning Service

9. Promote long-term financial and in-kind support to ensure sustainability of seismic and sea level instrumentation networks and their maintenance.
10. Promote use of the network of sea level and seismic stations for multi-hazard purposes to maximize the likelihood of ongoing maintenance and the continued functioning of the network.
11. Conduct a network-wide effectiveness review to analyze geographic coverage.
12. Promote national support for real-time, timely, free and open access to data, analysis, and other information products for (tsunami) warning purposes.

Communication and Dissemination of Warnings

13. Continue to support development of Standard Operating Procedures (SOPs) from the regional to the national, provincial and local levels.

14. Continue programmes to strengthen channels of communication for warning messages from the national to local levels, including strengthening of communications networks where feasible.
15. Strengthen the efficacy of warning messages, e.g. through regular user feedback, involving other stakeholders such as the media in their development, and training end users.

Response Capability

16. Continue to support the massive task of supporting response capacity at the local level, recognizing that populations in many areas – in particular those close to subduction zones – will need to react before receiving an official warning message.
17. Support regulations that stipulate frequency for drills, standards for evaluation and procedures covering each area and hazard, and involving key influential actors.

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