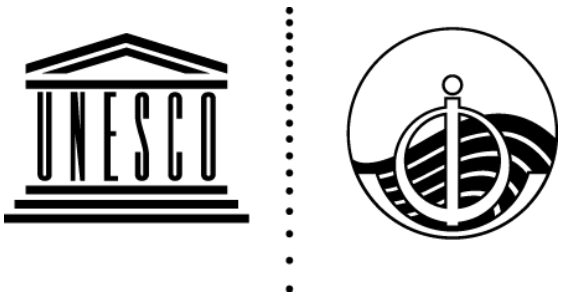
Intergovernmental Oceanographic Commission
technical series

108



MEDIUM-TERM STRATEGY

Pacific Tsunami Warning and Mitigation System (PTWS MTS)

2014–2021

UNESCO

Intergovernmental Oceanographic Commission
technical series

108

MEDIUM-TERM STRATEGY

Pacific Tsunami Warning and Mitigation System (PTWS MTS)

2014–2021

UNESCO 2013

IOC Technical Series, 108
Paris 2013
English only

For bibliographic purposes, this document should be cited as follows:

Intergovernmental Oceanographic Commission. 2013*. Pacific Tsunami Warning and Mitigation System (PTWS) Medium-Term Strategy, 2014−2021.* IOC Technical Series Nº108. Paris:UNESCO (English only)

Published in 2013
by United Nations Educational, Scientific
and Cultural Organization
7, Place de Fontenoy, 75352 Paris 07 SP

(IOC/2013/TS/108)

TABLE OF CONTENTS

1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

The PTWS Medium-Term Strategy (PTWS MTS) outlines the vision of a continuously improving Pacific Tsunami Warning and Mitigation System (PTWS) to meet stakeholder requirements during the period 2014–2021. This MTS is aligned with the eight year cycle of our parent body's Medium–Term Strategy. The Intergovernmental Oceanographic Commission (IOC) MTS (Resolution XXVII-2, part B) identifies early warning systems as an important part of its strategic vision and has aligned its MTS with the strategic planning cycle of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

The PTWS MTS focuses on describing general and essential strategic objectives to ensure an effective and efficient tsunami warning and mitigation system that is interoperable wherever possible with the other ocean basins and seas. The structure of the PTWS Working Group (WG) derives from the PTWS MTS and is described in the PTWS Working Group Structure document (ICG/PTWS-XXIII, Annex VI). Details of the methods of accomplishing these strategic objectives are defined in the PTWS Implementation Plan (version 2, 2001, draft document, IOC Technical Series No 86).

1.2 MISSION

The MTS envisions that PTWS is:

"A modern and effective tsunami warning and mitigation system based on Member State participation. As a result, PTWS Member States are aware of the tsunami threat, work to reduce risk, and are prepared to act to save lives".

1.3 CONTEXT

The Pacific Ocean basin is the largest, most diverse, and most tsunami-prone of any of the Earth's ocean basins. Pacific Ocean nations face and must be prepared for distant, and local tsunami threats. In the past, Member States (MS) depended primarily on Pacific Tsunami Warning Center (PTWC) and Northwest Pacific Tsunami Advisory Centre (NWPTAC) advice to inform National Tsunami Warning decisions. But a new awareness of local and regional threats demands that Member States commit to address these threats through improved and expanded national tsunami warning capacities and through formal regional collaboration. The result is an interoperable network of national and regional tsunami warning and advisory centres that complement the distant and regional tsunami advice provided by PTWC and NWPTAC. This MTS provides the framework for Member States to take responsibility and ownership for their national systems and to engage in the international coordination and collaboration process through the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS).

1.4 FRAMEWORK FOR TSUNAMI AND OTHER HAZARDS RELATED TO SEA-LEVEL WARNING AND MITIGATION SYSTEMS

The Pacific Tsunami Warning and Mitigation System operates as an important component within the Tsunamis and Other Hazards related to Sea-Level Warning and Mitigation Systems (TOWS). The governance of PTWS is provided through an Intergovernmental Coordination Group (ICG), under the Intergovernmental Oceanographic Commission (IOC) of UNESCO. The PTWS reflects the key principles of the Framework for the global Tsunamis and Other Hazards related to Sea-Level Warning and Mitigation Systems:

- Identifying warning and mitigation system requirements unique to the Pacific Ocean basin.
- Capitalising, to the extent practicable, on existing international groups with relevant responsibilities such as Global Sea-Level Observing System (GLOSS), WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), International Federation of Digital Seismograph Networks (FDSN) and the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO).
- Harmonising structure, standards, and practices among ICGs.
- Integrating with other international systems and organizations such as International Hydrographic Organization (IHO), particularly its Regional Hydrographic Commissions (South-East Pacific Hydrographic Commission [SEPHC]; South-West Pacific Hydrographic Commission [SWPHC], Meso American & Caribbean Sea Hydrographic Commission [MACHC] and East Asia Hydrographic Commission [EAHC]), World Meteorological Organization (WMO) and International Strategy for Disaster Reduction (ISDR).
- Collaborate on research and development across ICGs.

1.5 STRATEGIC PILLARS

Considering the important role that TOWS plays and the unique requirements of the Pacific Ocean basin, Medium-Term Strategy of the Pacific Tsunami Warning and Mitigation System is comprised of three pillars supported by four foundational elements.

The three pillars are:

- Risk Assessment and Reduction: Hazard and risk identification and risk reduction.
- Detection, Warning and Dissemination: Rapid detection and warning dissemination down to the last mile.
- Awareness and Response: Public education, emergency planning and response.

The supporting foundational elements are:

- Interoperability: Free, open and functional exchange of tsunami information.
- Research: Enhanced understanding and improved technologies and techniques.
- Capacity Building: Training, technology and knowledge transfer.
- Funding and Sustainability: Resources to sustain an effective PTWS.

1.6 DOCUMENT STRUCTURE

Section 2 provides an analysis of the current state of the PTWS. Section 3 describes the three pillars. Section 4 reviews the foundational elements, and Section 5 discusses Implementation.

2. ANALYSIS OF THE CURRENT STATE OF THE PACIFIC TSUNAMI WARNING AND MITIGATION SYSTEM

The current state of the PTWS can be summarised as follows:

- Whilst there has been significant progress, risk assessment and reduction are still incomplete for many areas.
- Whilst there has been a considerable expansion in the amount of seismic and sea-level data to detect tsunami threats, the data is not always interoperable or made

available in a timely manner to the warning centres. Exchanging observational data between neighbouring Member States (sometimes even within a single Member State) and across the regions remains a challenge.

- Pacific-wide and regional warning/advisory services provided by PTWC, West Coast and Alaska Tsunami Warning Center (WCATWC) and NWPTAC have been robustly operated with high reliability, and average warning times have reduced significantly. An important development over the last two years has been the move to enhance tsunami warning based on forecast models. The introduction and further development of these techniques and technologies in enhanced tsunami warning products will be a focus of the next three to five years.
- Some 24/7 robust National Tsunami Warning and Mitigation Systems (NTWS) have been developed and others are still under construction for determination of local, regional and ocean-wide tsunami threat. Establishing robust 24/7 national systems remains a challenge for many Member States.
- A positive tendency is that Member States' awareness of the urgent necessity for preparing countermeasures against tsunami threats has been increasing, especially after the 2004 Indian Ocean, the 2009 Samoan Islands, the 2010 Chile and 2011 Japan tsunami disasters. There is a need for more risk assessment, capacity building, disaster prevention education and preparedness activities to achieve further and sufficient tsunami preparedness and sustainability of operational systems.
- During recent years, internationally coordinated basin-wide tsunami exercises have been organized by PTWS although some of the lessons learned have still to be implemented. However, there is still room to improve the monitoring of system performance to underpin continuous improvement and ensure messages are delivered in a timely and accurate manner down to the "last mile".
- Member States are the main contributors to the PTWS. The budget for the ICG/PTWS (provided by the governing body, UNESCO/IOC, and donated by Member States) is not adequate to support all critical ICG/PTWS activities. Other PTWS activities depend largely on national regular budgets. For example, national and regional tsunami warning/advisory operational centres are not included in the PTWS budget, nor are extra budgetary contributions offered by concerned organizations such as ISDR, United Nations Development Programme (UNDP) and aid or technical agencies such as Australian Agency for International Development (AusAID), New Zealand Agency for International Development (NZAid), United States Agency for International Development (USAid), Japan International Cooperation Agency (JICA), Swiss Agency for Development and Cooperation (SDC) or the European Commission Humanitarian Aid Department's Disaster Preparedness Programme (DIPECHO).
- Whilst there has been improvement, coastal bathymetry information is still incomplete for many areas.

3. STRATEGIC PILLARS

3.1 INTRODUCTION

To formulate the PTWS Medium-Term Strategy, we consider the present situation described in section 2 and develop realistic strategic objectives that are achievable in five years. The driving question is "What can be done even with the present limited resources to enable enhanced tsunami risk mitigation in Member States?" The response to this question makes it possible to prioritize the activities for improving the various components of the entire PTWS. These priorities may also be considered by aid and technical cooperation agencies as guidance for their support to the PTWS.

The next sections describe the strategic objectives to be accomplished and the contents of each pillar as well as priority actions. Needless to say the ICG/PTWS and Member States will support the activities addressing these strategic objectives as much as possible. It is important to encourage Member States to take ownership as the main stakeholders and actors in these activities.

3.2 PILLAR 1: RISK ASSESSMENT AND REDUCTION

Understanding tsunami risk involves two components: hazard assessment (specifying tsunami sources and waves height along the coast), and risk assessment (estimating tsunami effects to the coasts or estimating damages). The aim is to know where the at-risk areas are and how strongly a tsunami could affect those areas. Risk and hazard assessment is to be conducted at and by each Member State, utilizing the recent and historical data completed by existing scenarios of Pacific-wide tsunamis and developing local scenarios as well. This assessment is an unavoidable starting point for efficient tsunami preparedness activities.

Following the experience of recent very large tsunami, such as the 2011 Japan event, the sources for these events are being reassessed by the science community. It is important that tsunami hazard and risk assessment take these new estimates of maximum credible tsunami into account. The TOWS-WG Inter-ICG Task Team on Hazard Assessment Related to Highest Potential Tsunami Source Areas is to report on this, while other groups such as these working on the Global Earthquake Model (GEM) provide a source of information, but PTWS must ensure this new knowledge is available to Member States.

Understanding tsunami risk assessment is fundamental to the other pillars. It is also required for disaster risk reduction activities that reduce community exposure to tsunami and other ocean-related threats.

Once an understanding of tsunami risks is available, Member States should do more to reduce the identified risks. Many of the activities required to achieve this are covered in the other pillars but research on land use planning and mitigation measures are included in this pillar.

Strategic objectives

- Member States will specify, periodically update, and detail their coasts.
- New hazard assessments will include recent updates by the science community on the maximum credible tsunami generated by mega-thrust events such as the Japan tsunami of 2011.
- Member States should develop risk reduction strategies through appropriate agencies and organizations to reduce, where possible, community exposure to threats from tsunamis and other ocean hazards.

Contents

Developing tsunami hazard maps based on recent and historical data and/or numerical simulation is the goal. These should include all credible tsunami from all known sources. Simple and rough estimation, like using altitude data of coastal topography as inundation criterion, can serve temporarily until more accurate mapping develops in the future including through paleotsunami research.

Suggested mechanisms

Steps for tsunami risk assessment in Member States include:

1 Specify tsunami sources capable of generating tsunamis that affect their own coastal areas. Local source or distant source? Which source is more likely to affect the coast?

- Specify them from the past tsunami records or consideration of tectonic circumstances. Data of past earthquakes and tsunamis are important, but past tsunami databases may lack the severest case(s). So it would be advisable to assume the largest scale of geophysically possible cases as well as referring to the past databases. Take into account recent re-evaluations of the maximum credible mega-thrust generated tsunami.
- Utilize maximum tsunami height distribution charts of wide areas by numerical simulation that can indicate tsunami energy direction. Within this context there is a need to compare and calibrate the various tsunami modelling tools in use.

2 Specify risk level at each coast or dangerous area:

- By numerical simulation, recent and past records and other available means.
- Post-tsunami reconnaissance surveys after recent or new event provide unique detailed data valuable for risk and hazard assessment. Such survey must be organized and carried out quickly and thoroughly after each tsunami occurs.

Since the work for the above steps includes technical and research capabilities, capacities and skills, it needs support from or cooperation with research communities. To be relevant and timely a compromise solution should be sought in terms of accuracy in the short term, improvement over time.

In the long term, it would be ideal to have the Member States' own experts who can deal with various technical matters. Such human resources development is essential for the sustainability of the system. It requires training courses, overseas or national opportunities for graduate or postgraduate education and scientific and technical networking.

3 Specify appropriate strategies and techniques for reducing Member State communities' exposure to tsunami and other ocean-related threats.

4 Standardize the quality and resolution requirement for bathymetric data as the starting point for achieving comparable and accurate tsunami propagation models.

3.3 PILLAR 2: DETECTION, WARNING AND DISSEMINATION

An effective tsunami warning system involves the rapid detection and quantification of the earthquake source, forecasting and verification of wave propagation and the likely threatened areas, development and dissemination to the "last mile" of information about the threat to enable communities to respond.

- Detection involves the implementation and development of seismic and sea-level observing systems that enable rapid assessment and verification of the threat.
- Warning involves the rapid detection of local earthquakes capable of generating local tsunamis, forecasting of wave propagation and potential impacts for regional and ocean wide tsunamis, and conveying that information in interoperable message formats.
- Dissemination involves the timely and accurate distribution of threat and warning information from and between warning centres, and from National Tsunami Warning Centres (NTWCs) to the community.

Since the Pacific is the world's largest ocean and has tsunami sources in widespread regions, it is appropriate to consider detection, warning and dissemination on three geographical levels:

(i) **National**

(ii) **Regional**

(iii) **Ocean-wide**

The following are descriptions of improvements needed with regards to detection, warning and dissemination at each level.

(i) **National warning**

National warning systems are the most crucial part in the entire end-to-end system for both local and distant source tsunamis due to the inalienable national responsibility for informing communities at risk and urging or ordering immediate evacuation.

National systems should be established or improved as the highest priority because such systems are needed to respond to all scales of tsunami threat (local, regional or ocean-wide).

Strategic objectives

- The development and continual improvement of sustainable national warning capabilities by each Member State;
- The improvement of national seismic and sea-level observation networks by each Member State and the free and open sharing of the data produced in near real time. Develop national capability with access to interoperable neighbouring seismic information for detecting local tsunami threats.
- As a core part of a local source tsunami warning strategy, ensure that coastal communities are able to recognise natural tsunami signs so that they can self-evacuate without waiting for official tsunami warning (see pillar 3).
- The building of optimized procedures covering all steps in the warning chain. Master the procedures by continuous practices including through full-scale evacuation exercises and drills down to the "last mile".
- Utilise new and available technologies and develop arrangements for the transmission and receipts of tsunami warnings alerts from international centres, and the dissemination of alerts to the "last mile" and public safety actions within countries.

Contents

Build (or improve) observational networks for seismic and sea-level data and online communication system(s) to rapidly collect these data. Establish or reinforce capabilities to analyse those data, evaluate tsunami effects, and issue tsunami warnings through improved communication networks for delivering warnings and information.

Suggested mechanisms:

- Improvement of seismic and sea-level observation networks requires considerable funding and human resources, so that it may be difficult for many countries to achieve this strategic objective without international donor support.
- Address improvements by better focusing on hazard assessment and building on efficient use of existing support mechanisms and international networks (such as CTBTO, FDSN and IRIS [Incorporated Research Institutions for Seismology] for seismic monitoring, and GLOSS for sea-level monitoring).
- While the precise production and definition of a tsunami warning requires specific capabilities, the delivery of warnings to the population is usually provided through other mechanisms by mandated agencies (Interior, Cabinet, Civil Defence, Hydro-meteorological and Weather Services). Early involvement of these bodies in the national tasks of the PTWS may help save time and money.
- Local source tsunami warning is very dependent on education so that coastal communities can recognise the natural tsunami warning signs. An effective education programme is therefore essential.

(ii) **Regional warning**

Regional systems are for protection from tsunamis that affect several Member States within the Pacific Ocean but do not have an impact over the whole ocean. In other words, regional systems are the systems whose area of responsibility (AoR) [1] is a part of the Pacific Ocean. There are already two established regional systems, which are operated by WCATWC and NWPTAC, respectively. Meanwhile, there are other regions where new regional systems may be required, particularly for the regions that are adjacent to tsunami generation source and have many nations within a small area. In such regions, cooperation among neighbouring Member States exchanging or integrating real time seismic and sea-level data is essential. In that regard, some regional systems should be considered with high priority just like local system establishment (e.g. the system in the Southwest Pacific region, where proper detection of earthquakes is difficult in a single country due to sparse distribution of small islands).

Strategic objectives

General:

- Ensure that all available sensor network data (seismic and sea-level) is available in near real time to the existing and developing regional warning centres.
- Development of cost efficient sea-level observing technologies to maximize the return from resources and underpin sustainability of the system.

Existent two regional systems:

- Maintain the present level of operational services provided by WCATWC and NWPTAC;
- Achieve further improvement to warning/advisory services provided by these Centres, including more specific information on the likely tsunami impacts in line with the overall PTWS objective, currently being implemented by PTWC, to provide likely

[1] AoR of regional systems depend on cases. Some are fairly wide so that the systems have characteristics of ocean-wide system, some others are smaller and the systems have characteristics of local systems to some extent. For example, WCATWC and NWPTAC are the former and Pacific side of Central America system would be the latter.

tsunami impact information in pre-defined coastal zones using forecast models rather than the non-specific warnings currently used.

Other new regional systems:

- Develop regional warning systems to provide warning service for regions as required. Target regions include the South China Sea, the South-West Pacific and the South-East Pacific.
- Utilise regional Working Groups to coordinate and share information on user requirements and communication issues and develop capacity on a regional basis.

Contents

General:

- Improve accuracy of earthquake location and size by making available all present and future seismic data collected by national and internationally coordinated networks (such as CTBTO, IRIS, FDSN).
- Coordinate and share information on the development of analysis techniques.
- Timely access for tsunami warning centres to all currently available and suitable sea-level station data in agreed standard format (CREX). Priority should be given to stations within 1 hour travel time from known sources.

Existent two regional systems:

- The USA and Japan continue their operational services in close cooperation to provide effective warning/advisory services consistent with the PTWC's warning/advisory service. This will include the introduction of similar capabilities to those being currently developed by PTWC (impact estimates in pre-defined coastal zones using calibrated forecast models).

Other new regional systems:

- Share real time seismic and sea-level data among Member States within the region.
- Establish regional warning centres if required, and ensure reliable warning services.

Suggested Mechanisms:

General:

- Use regional Working Groups to coordinate and share information on requirements and communication issues and develop capacity on a regional basis.

Existent two regional systems:

- The USA and Japan will continue their longstanding contributions to maintain stable operation and to improve their tsunami warning/advisory services. Now that a large amount of real time data is available, consideration should be given to extending the work of the existing centres to include more regions.

Other new regional systems:

- Promote cooperation and coordination through regional Working Groups of the ICG/PTWS, receiving and using information and advice from technical Working Groups.
- Funding is a challenge, but it should be on the countries' own expenses along with efforts to obtain support by international aid funds. Existing precedents suggest that

for regional warning centres to succeed a single Member State must take a leadership role such is the current case with USA and Japan.

Note: If all the Member States in the region have capabilities to individually analyse the shared observational data and evaluate the tsunami impact on their own coasts, establishing a regional centre that provides tsunami warning for the whole of the region may be unnecessary.

(iii) **Ocean-wide warning**

The Ocean-wide system deals with tsunami capable of expanding in a vast area of the Pacific Ocean, affecting a large number of countries. This system uses global observational networks of seismic and sea-level data, and also requires prompt and reliable communications means to deliver warnings to scattered countries around the Pacific Ocean. This warning information has the role of triggering the national warning procedures in each Member State.

Strategic objectives

- Maintain the present level of operational services provided by the PTWC, while implementing the use of forecast models to deliver estimates of tsunami impacts for pre-defined coastal zones.
- Continue to investigate technologies to improve warning/advisory services by the PTWC.
- Ensure that all available seismic and sea-level data is available to PTWC to improve earthquake characteristics and forecasts of tsunami impact.
- Utilise regional Working Groups to coordinate and share information on user requirements and communication issues and develop capacity on a regional basis.

Contents

- The USA continues its operational services in close cooperation with the regional centres, providing consistent and effective warning/advisory services. Any further improvement of the PTWS will be constructed on the basis of this present ocean-wide system and service.
- PTWC will target providing tsunami impact estimates for pre-defined coastal zones using forecast models calibrated with earthquake parameters (location, depth and magnitude) and sea-level observation.
- Ensure that existing and new seismic and sea-level station data are made available to PTWC and the regional warning centres.
- Keeping the Tsunami Warning Focal Point (TWFP) list up to date and as complete and reliable as possible is very important for effective warning.

Suggested mechanisms

- The USA will continue their longstanding contributions to maintain stable operation and to improve their tsunami warning/advisory services. Training support is required during the implementation of the changes in warning messages and products.
- Through the regional Working Groups ensure all available seismic and sea-level data is made available to PTWC and the regional warning centres.
- The ICG/PTWS will reinforce its mechanisms for obtaining and updating the TWFP list.

Note: What is most important for tsunami warning systems of any scale described above (i, ii and iii) is to guarantee stability, reliability and sustainability in the end-to-end operation, from receiving/delivering warning at centres down to the communities, and the system should always be ready (24/7) for the occurrence of this quite rare natural phenomenon. In other words, the primary aim for a warning system should be to maintain the system as a whole and keep the necessary reliability after its construction, or to develop such system as to be easy to maintain and to assure reliability.

From that standpoint state-of-the-art, technologies should be carefully assessed before bringing these into operational systems. It is essential to evaluate the newest, promising technologies from the viewpoints of not only effectiveness or attractive prospects but also operational reliability and robustness, when considering introducing them into the warning system.

3.4 PILLAR 3: AWARENESS AND RESPONSE

It is essential that the communities that are vulnerable to the effects of tsunami are made aware of the effects and how to respond when tsunami happens through simple cost-effective and cultural sensitive awareness programmes. Such programmes would include developing and disseminating information through the media, workshops/seminars, awareness materials, Internet, signage and billboards. If not already in existence, tsunami related curriculum programmes should be developed to build that inherent capability in young adults and children.

Due to the nature of tsunami, Member States must be able to respond and this will require putting in place plans and processes to enable effective response coordination. These plans and processes would include response management structures, responsibilities, evacuation arrangements and communication systems.

Member States should also plan and conduct exercises on a regular basis to test early warning systems and emergency evacuation.

To ensure that governments, non-governmental organizations (NGOs), private sector and community representatives are able to provide the required response, sustainable capacity building programmes should be developed and delivered.

Strategic objectives

- Strengthen public awareness of tsunami and associated hazards and how to prepare to respond. It is particularly important that this includes education on natural tsunami warning signs so that these can be recognised and self-evacuation of coastal communities can begin as soon as possible without waiting for official warnings.
- Develop and conduct exercises to test early warning systems and evacuation mechanisms.
- Establish rapid and effective evacuation mechanisms given the risk assessment guidance and data. Ideally this would include full evacuation zone maps and route plans.
- Develop and deliver suitable and sustainable capacity building programmes to facilitate effective and efficient response and coordination.
- Establish and/or strengthen appropriate response structures to facilitate effective coordination.
- Develop tsunami related curriculum programmes for all levels of education to build an inherent capability and raise the interest of young people in the disaster management

field providing a source of career development and support to the Member States in the future to plan, respond to and recover from tsunamis.

- Mainstream awareness and response programmes into Member States development strategies and sector plans to facilitate acquiring of resources to enable implementation of required response infrastructures/mechanisms.

Contents

- Communities need to be aware of the threats tsunami pose and how to respond when events happen. Government agencies need to have response plans and work together to ensure the plans work well by conducting regular exercises.
- Effective school level and public education is a key part of the national programmes of Member States.
- Awareness and response programmes will become a part of Member States development strategies.

Suggested mechanisms

- Provide training to responsible officials of government.
- Make available existing, further develop, and translate training, educational and awareness resources.
- Review or develop tsunami response plans.
- Develop evacuation zone, mapping and signing methodology.
- Conduct exercises and drills as preparedness tools to test warning systems, response and evacuation plans.

4. FOUNDATIONAL ELEMENTS

4.1 INTEROPERABILITY

Taken together, the TOWS and PTWS MTS require three kinds of interoperability:

First, national tsunami warning and mitigation systems must be interoperable among PTWS Member States and with the PTWC and NWPTAC to ensure full and open access to tsunami-relevant observational data, analysis, advisory and warning information, operational techniques and technologies, and best practices. More effective national tsunami warning and mitigation systems will result.

Second, the PTWS must be interoperable with other ocean hazards warning and mitigation systems to use and share data, analyses, and awareness and preparedness, and other common elements of such systems. Synergies will result that will increase the effectiveness of national tsunami warning and mitigation systems, regional warning centre operations, and drive down the costs of operating and maintaining ocean hazard and mitigation systems.

Third, the PTWS must be interoperable with other ICGs in the context of the TOWS framework. Again, improvements in effectiveness and efficiency will result for Member States, both individually and collectively.

For enhancing such interoperability, IOC created the TOWS-WG to coordinate activities of the ICGs and of relevant organizations dealing with other ocean hazards. Recognizing that the ICG/PTWS (and its predecessor International Coordination Group for the Tsunami Warning System in the Pacific, ICG/ITSU) has been continuously operated and successfully

contributed to tsunami disaster mitigation in the Pacific for more than forty years, the ICG/PTWS should share its experiences and knowledge within TOWS-WG and learn from new developments in other regions.

4.2 RESEARCH

Each of the three pillars requires on-going research and development to advance all elements of the PTWS. Investigations of the tsunami phenomena, including tsunami caused by landslides, volcanoes, and other sources and new developments, whether in tsunami detection, tsunameter technology or innovative GPS applications, new threat-based forecast systems, developments in operations and communications technologies, or innovative approaches to community preparedness need to be monitored, evaluated, and publicised to Member States.

There are many new research programmes and technologies being conducted and developed. Of particular note is the realisation in recent years that mega-thrust earthquakes are capable of producing very large tsunami, and this fact must now be built into tsunami hazards estimates. Since these are leading edge activities, many of them provide interesting and relevant results in theory, but they need to be validated in experimental stage in order to be put into practical use. Therefore we have to pre-assess new research results or technologies from various viewpoints such as relevance, effectiveness, efficiency, robustness, ease of maintenance and sustainability before officially introducing them into operational systems.

PTWS must promote closer cooperation with relevant research communities and request research communities to conduct or develop methodology or technology necessary for improving tsunami warning and mitigation in particular in relation to problems highlighted by our system.

4.3 CAPACITY BUILDING

An effective tsunami warning and mitigation system requires ongoing capacity building and training to support all three strategic pillars. Capacity building activities must be carried out continuously and forever in the three strategic pillars. Each Member State must be able to understand its risk and know ways in which they can mitigate the hazard, provide warning to its populations in a timely manner, and be able to carry out awareness and preparedness activities to sustain knowledge and ability-to-respond across generations.

The building of national human resource capacities that can develop, guide and lead these activities in each country is essential. Substantial experience, knowledge, and best practices have been accumulated over the years by Member States and this should be shared widely through trainings and workshops. Training courses and national, cross-sector and inter-regional workshops are excellent ways in which to build these skill sets and at the same time, support networking between countries during a real event.

As these skills are developed over time, trainings should be regularly conducted, and also be continually refreshed as new methods, technologies, and practices are identified. An example of regular training already available within the PTWS is the ICG/ITSU Training Programme organised by ITIC for PTWS Member States since the 1970s; such a programme (and others) can be expanded and/or customized to encompass and meet the needs of all countries.

4.4 FUNDING AND SYSTEM SUSTAINABILITY

Like any system, a robust and effective PTWS requires appropriate funding to be viable and evolve to meet new needs and incorporate new technologies. There is a need for renewed Member State commitment to invest in national tsunami warning and mitigation systems and to contribute, in whatever way possible, to the operation of the PTWS. In addition, there is a need to engage donor agencies and organizations to support all elements of the end-to-end tsunami warning and mitigation system in the Pacific Ocean.

Implementing this Medium-Term Strategy will require additional investment from within and outside the PTWS Member States. A separate supporting funding and sustainability strategy is needed to realize these investments.

5. IMPLEMENTATION

The PTWS Steering Committee will coordinate and monitor the implementation of the PTWS Medium-Term Strategy.

ANNEX I

LIST OF ACRONYMS

AoR	Area of Responsibility
AusAID	Australian Agency for International Development
CTBTO	Comprehensive Nuclear-Test-Ban Treaty Organization
DIPECHO	European Commission Humanitarian Aid Department's Disaster Preparedness Programme
EAHC	East Asia Hydrographic Commission
FDSN	International Federation of Digital Seismograph Networks
GEM	Global Earthquake Model
GLOSS	Global Sea-Level Observing System
ICG	Intergovernmental Coordination Group
ICG/ITSU	International Coordination Group for the Tsunami Warning System in the Pacific
ICG/PTWS	Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System
IHO	International Hydrographic Organization
IOC	Intergovernmental Oceanographic Commission
IRIS	Incorporated Research Institutions for Seismology
ISDR	International Strategy for Disaster Reduction
JCOMM	WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology
JICA	Japan International Cooperation Agency
MACHC	Meso American & Caribbean Sea Hydrographic Commission
MTS	Medium-Term Strategy
NTWS	National Tsunami Warning and Mitigation Systems
NWPTAC	Northwest Pacific Tsunami Advisory Centre
NZAid	New Zealand Agency for International Development
PTWC	Pacific Tsunami Warning Center
PTWS	Pacific Tsunami Warning and Mitigation System

SDC	Swiss Agency for Development and Cooperation
SEPHC	South-East Pacific Hydrographic Commission
SWPHC	South-West Pacific Hydrographic Commission
TOWS	Tsunamis and Other Hazards related to Sea-Level Warning and Mitigation Systems
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAid	United States Agency for International Development
WCATWC	West Coast and Alaska Tsunami Warning Center
WG	Working Group
WMO	World Meteorological Organization

IOC Technical Series

No.	Title	Languages
1	Manual on International Oceanographic Data Exchange. 1965	(out of stock)
2	Intergovernmental Oceanographic Commission (Five years of work). 1966	(out of stock)
3	Radio Communication Requirements of Oceanography. 1967	(out of stock)
4	Manual on International Oceanographic Data Exchange - Second revised edition. 1967	(out of stock)
5	Legal Problems Associated with Ocean Data Acquisition Systems (ODAS). 1969	(out of stock)
6	Perspectives in Oceanography, 1968	(out of stock)
7	Comprehensive Outline of the Scope of the Long-term and Expanded Programme of Oceanic Exploration and Research. 1970	(out of stock)
8	IGOSS (Integrated Global Ocean Station System) - General Plan Implementation Programme for Phase I. 1971	(out of stock)
9	Manual on International Oceanographic Data Exchange - Third Revised Edition. 1973	(out of stock)
10	Bruun Memorial Lectures, 1971	E, F, S, R
11	Bruun Memorial Lectures, 1973	(out of stock)
12	Oceanographic Products and Methods of Analysis and Prediction. 1977	E only
13	International Decade of Ocean Exploration (IDOE), 1971-1980. 1974	(out of stock)
14	A Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment and Baseline Study Guidelines. 1976	E, F, S, R
15	Bruun Memorial Lectures, 1975 - Co-operative Study of the Kuroshio and Adjacent Regions. 1976	(out of stock)
16	Integrated Ocean Global Station System (IGOSS) General Plan and Implementation Programme 1977-1982. 1977	E, F, S, R
17	Oceanographic Components of the Global Atmospheric Research Programme (GARP) . 1977	(out of stock)
18	Global Ocean Pollution: An Overview. 1977	(out of stock)
19	Bruun Memorial Lectures - The Importance and Application of Satellite and Remotely Sensed Data to Oceanography. 1977	(out of stock)
20	A Focus for Ocean Research: The Intergovernmental Oceanographic Commission - History, Functions, Achievements. 1979	(out of stock)
21	Bruun Memorial Lectures, 1979: Marine Environment and Ocean Resources. 1986	E, F, S, R
22	Scientific Report of the Interealibration Exercise of the IOC-WMO-UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open Ocean Waters. 1982	(out of stock)
23	Operational Sea-Level Stations. 1983	E, F, S, R
24	Time-Series of Ocean Measurements. Vol.1. 1983	E, F, S, R
25	A Framework for the Implementation of the Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment. 1984	(out of stock)
26	The Determination of Polychlorinated Biphenyls in Open-ocean Waters. 1984	E only
27	Ocean Observing System Development Programme. 1984	E, F, S, R
28	Bruun Memorial Lectures, 1982: Ocean Science for the Year 2000. 1984	E, F, S, R
29	Catalogue of Tide Gauges in the Pacific. 1985	E only
30	Time-Series of Ocean Measurements. Vol. 2. 1984	E only
31	Time-Series of Ocean Measurements. Vol. 3. 1986	E only
32	Summary of Radiometric Ages from the Pacific. 1987	E only
33	Time-Series of Ocean Measurements. Vol. 4. 1988	E only

(continued)

No.	Title	Languages
34	Bruun Memorial Lectures, 1987: Recent Advances in Selected Areas of Ocean Sciences in the Regions of the Caribbean, Indian Ocean and the Western Pacific. 1988	Composite E, F, S
35	Global Sea-Level Observing System (GLOSS) Implementation Plan. 1990	E only
36	Bruun Memorial Lectures 1989: Impact of New Technology on Marine Scientific Research. 1991	Composite E, F, S
37	Tsunami Glossary - A Glossary of Terms and Acronyms Used in the Tsunami Literature. 1991	E only
38	The Oceans and Climate: A Guide to Present Needs. 1991	E only
39	Bruun Memorial Lectures, 1991: Modelling and Prediction in Marine Science. 1992	E only
40	Oceanic Interdecadal Climate Variability. 1992	E only
41	Marine Debris: Solid Waste Management Action for the Wider Caribbean. 1994	E only
42	Calculation of New Depth Equations for Expendable Bathymerographs Using a Temperature-Error-Free Method (Application to Sippican/TSK T-7, T-6 and T-4 XBTS. 1994	E only
43	IGOSS Plan and Implementation Programme 1996-2003. 1996	E, F, S, R
44	Design and Implementation of some Harmful Algal Monitoring Systems. 1996	E only
45	Use of Standards and Reference Materials in the Measurement of Chlorinated Hydrocarbon Residues. 1996	E only
46	Equatorial Segment of the Mid-Atlantic Ridge. 1996	E only
47	Peace in the Oceans: Ocean Governance and the Agenda for Peace; the Proceedings of *Pacem in Maribus* XXIII, Costa Rica, 1995. 1997	E only
48	Neotectonics and fluid flow through seafloor sediments in the Eastern Mediterranean and Black Seas - Parts I and II. 1997	E only
49	Global Temperature Salinity Profile Programme: Overview and Future. 1998	E only
50	Global Sea-Level Observing System (GLOSS) Implementation Plan-1997. 1997	E only
51	L'état actuel de 1'exploitation des pêcheries maritimes au Cameroun et leur gestion intégrée dans la sous-région du Golfe de Guinée *(cancelled)*	F only
52	Cold water carbonate mounds and sediment transport on the Northeast Atlantic Margin. 1998	E only
53	The Baltic Floating University: Training Through Research in the Baltic, Barents and White Seas - 1997. 1998	E only
54	Geological Processes on the Northeast Atlantic Margin (8^{th} training-through-research cruise, June-August 1998). 1999	E only
55	Bruun Memorial Lectures, 1999: Ocean Predictability. 2000	E only
56	Multidisciplinary Study of Geological Processes on the North East Atlantic and Western Mediterranean Margins (9^{th} training-through-research cruise, June-July 1999). 2000	E only
57	Ad hoc Benthic Indicator Group - Results of Initial Planning Meeting, Paris, France, 6-9 December 1999. 2000	E only
58	Bruun Memorial Lectures, 2001: Operational Oceanography – a perspective from the private sector. 2001	E only
59	Monitoring and Management Strategies for Harmful Algal Blooms in Coastal Waters. 2001	E only
60	Interdisciplinary Approaches to Geoscience on the North East Atlantic Margin and Mid-Atlantic Ridge (10^{th} training-through-research cruise, July-August 2000). 2001	E only
61	Forecasting Ocean Science? Pros and Cons, Potsdam Lecture, 1999. 2002	E only

No.	Title	Languages
62	Geological Processes in the Mediterranean and Black Seas and North East Atlantic (11th training-through-research cruise, July- September 2001). 2002	E only
63	Improved Global Bathymetry – Final Report of SCOR Working Group 107. 2002	E only
64	R. Revelle Memorial Lecture, 2006: Global Sea Levels, Past, Present and Future. 2007	E only
65	Bruun Memorial Lectures, 2003: Gas Hydrates – a potential source of energy from the oceans. 2003	E only
66	Bruun Memorial Lectures, 2003: Energy from the Sea: the potential and realities of Ocean Thermal Energy Conversion (OTEC). 2003	E only
67	Interdisciplinary Geoscience Research on the North East Atlantic Margin, Mediterranean Sea and Mid-Atlantic Ridge (12th training-through-research cruise, June-August 2002). 2003	E only
68	Interdisciplinary Studies of North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes (13th training-through-research cruise, July-September 2003). 2004	E only
69	Biodiversity and Distribution of the Megafauna / Biodiversité et distribution de la mégafaune. 2006 Vol.1 The polymetallic nodule ecosystem of the Eastern Equatorial Pacific Ocean / Ecosystème de nodules polymétalliques de l'océan Pacifique Est équatorial Vol.2 Annotated photographic Atlas of the echinoderms of the Clarion-Clipperton fracture zone / Atlas photographique annoté des échinodermes de la zone de fractures de Clarion et de Clipperton Vol.3 Options for the management and conservation of the biodiversity — The nodule ecosystem in the Clarion Clipperton fracture zone: scientific, legal and institutional aspects	E F
70	Interdisciplinary geoscience studies of the Gulf of Cadiz and Western Mediterranean Basin (14th training-through-research cruise, July-September 2004). 2006	E only
71	Indian Ocean Tsunami Warning and Mitigation System, IOTWS. Implementation Plan, 7–9 April 2009 (2nd Revision). 2009	E only
72	Deep-water Cold Seeps, Sedimentary Environments and Ecosystems of the Black and Tyrrhenian Seas and the Gulf of Cadiz (15th training-through-research cruise, June–August 2005). 2007	E only
73	Implementation Plan for the Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas (NEAMTWS), 2007–2011. 2007 *(electronic only)*	E only
74	Bruun Memorial Lectures, 2005: The Ecology and Oceanography of Harmful Algal Blooms – Multidisciplinary approaches to research and management. 2007	E only
75	National Ocean Policy. The Basic Texts from: Australia, Brazil, Canada, China, Colombia, Japan, Norway, Portugal, Russian Federation, United States of America. (Also Law of Sea Dossier 1). 2008	E only
76	Deep-water Depositional Systems and Cold Seeps of the Western Mediterranean, Gulf of Cadiz and Norwegian Continental margins (16th training-through-research cruise, May–July 2006). 2008	E only
77	Indian Ocean Tsunami Warning and Mitigation System (IOTWS) – 12 September 2007 Indian Ocean Tsunami Event. Post-Event Assessment of IOTWS Performance. 2008	E only
78	Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS) – Implementation Plan 2013–2017 (Version 2.0). 2013	E only

(continued)

No.	Title	Languages
79	Filling Gaps in Large Marine Ecosystem Nitrogen Loadings Forecast for 64 LMEs – GEF/LME global project Promoting Ecosystem-based Approaches to Fisheries Conservation and Large Marine Ecosystems. 2008	E only
80	Models of the World's Large Marine Ecosystems. GEF/LME Global Project Promoting Ecosystem-based Approaches to Fisheries Conservation and Large Marine Ecosystems. 2008	E only
81	Indian Ocean Tsunami Warning and Mitigation System (IOTWS) – Implementation Plan for Regional Tsunami Watch Providers (RTWP). 2008	E only
82	Exercise Pacific Wave 08 – A Pacific-wide Tsunami Warning and Communication Exercise, 28–30 October 2008. 2008	E only
83.	*Cancelled*	
84.	Global Open Oceans and Deep Seabed (GOODS) Bio-geographic Classification. 2009	E only
85.	Tsunami Glossary	E, F, S
86	Pacific Tsunami Warning System (PTWS) Implementation Plan *(under preparation)*	
87.	Operational Users Guide for the Pacific Tsunami Warning and Mitigation System (PTWS) – Second Edition. 2011	E only
88.	Exercise Indian Ocean Wave 2009 (IOWave09) – An Indian Ocean-wide Tsunami Warning and Communication Exercise – 14 October 2009. 2009	E only
89.	Ship-based Repeat Hydrography: A Strategy for a Sustained Global Programme. 2009	E only
90.	12 January 2010 Haiti Earthquake and Tsunami Event Post-Event Assessment of CARIBE EWS Performance. 2010	E only
91.	Compendium of Definitions and Terminology on Hazards, Disasters, Vulnerability and Risks in a coastal context	*Under preparation*
92.	27 February 2010 Chile Earthquake and Tsunami Event – Post-Event Assessment of PTWS Performance (Pacific Tsunami Warning System). 2010	E only
93.	Exercise CARIBE WAVE 11 / LANTEX 11—A Caribbean Tsunami Warning Exercise, 23 March 2011	
	Vol. 1 Participant Handbook / Exercise CARIBE WAVE 11 —Exercice d'alerte au tsunami dans les Caraïbes, 23 mars 2011. Manuel du participant / Ejercicio Caribe Wave 11. Un ejercicio de alerta de tsunami en el Caribe, 23 de marzo de 2011. Manual del participante. 2010	E/F/S
	Vol. 2 Report. 2011	E only
	Vol. 3 Supplement: Media Reports. 2011	E/F/S
94.	Cold seeps, coral mounds and deep-water depositional systems of the Alboran Sea, Gulf of Cadiz and Norwegian continental margin (17th training-through-research cruise, June–July 2008)	*Under preparation*
95.	International Post-Tsunami Survey for the 25 October 2010 Mentawai, Indonesia Tsunami	*Under preparation*
96.	Pacific Tsunami Warning System (PTWS) 11 March 2011 Off Pacific coast of Tohoku, Japan, Earthquake and Tsunami Event. Post-Event Assessment of PTWS Performance	*Under preparation*
97.	Exercise PACIFIC WAVE 11: A Pacific-wide Tsunami Warning and Communication Exercise, 9–10 November 2011	
	Vol. 1 Exercise Manual. 2011	E only
	Vol. 2 Report. 2013	E only
98.	Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and connected seas. First Enlarged Communication Test Exercise (ECTE1). Exercise Manual and Evaluation Report. 2011	E only

No.	Title	Languages
99.	Exercise INDIAN OCEAN WAVE 2011 – An Indian Ocean-wide Tsunami Warning and Communication Exercise, 12 October 2011 Vol. 1 Exercise Manual. 2011 Supplement: Bulletins from the Regional Tsunami Service Providers Vol. 2 Exercise Report. 2013	E only
100.	Global Sea Level Observing System (GLOSS) Implementation Plan – 2012. 2012	E only
101.	Exercise Caribe Wave/Lantex 13. A Caribbean Tsunami Warning Exercise, 20 March 2013. Volume 1: Participant Handbook. 2012	E only
102.	*(In preparation)*	
103.	Exercise NEAMWAVE 12. A Tsunami Warning and Communication Exercise for the North-eastern Atlantic, the Mediterranean, and Connected Seas Region, 27–28 November 2012, Volume I: Exercise Manual. 2012	E only
104.	Seísmo y tsunami del 27 de agosto de 2012 en la costa del Pacífico frente a El Salvador, y seísmo del 5 de septiembre de 2012 en la costa del Pacífico frente a Costa Rica. Evaluación subsiguiente sobre el funcionamiento del Sistema de Alerta contra los Tsunamis y Atenuación de sus Efectos en el Pacífico. 2012	Español solamente (resumen en inglés y francés)
105.	Users Guide for the Pacific Tsunami Warning Center Enhanced Products for the Pacific Tsunami Warning System. 2013	E, S
106.	Exercise Pacific Wave 13. A Pacific-wide Tsunami Warning and Enhanced Products Exercise, 1–14 May 2013. Vol. 1 Exercise Manual. 2013 Vol. 2 Summary Report. 2013	E only
107.	Tsunami Public Awareness and Educations Strategy for the Caribbean and Adjacent Regions. 2013	E only
108.	Pacific Tsunami Warning and Mitigation System (PTWS) Medium-Term Strategy, 2014−2021. 2013	E only