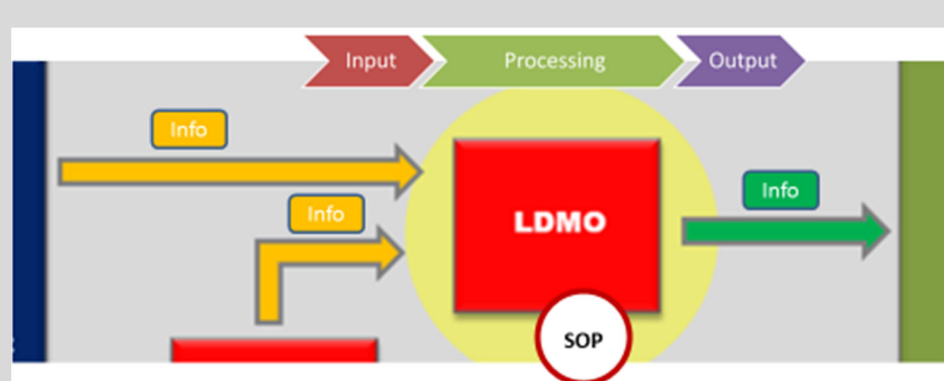
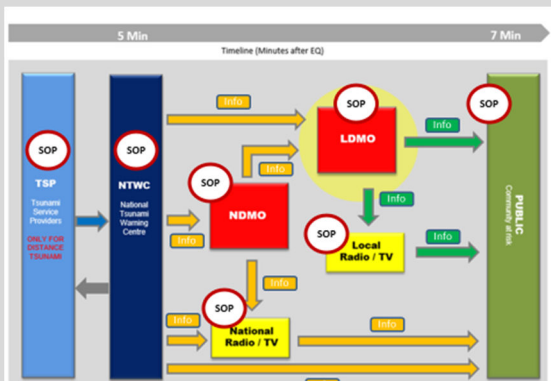


# Tsunami Warning Chains & Standard Operating Procedures for Tsunami Early Warning in ICG/IOTWMS Member States

## Status and Recommendations

March 2024



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## Abbreviations

<b>DMO</b>	Disaster Management Office / Organization
<b>EOC</b>	Emergency Operations Centre
<b>EQ</b>	Earthquake
<b>ESCAP</b>	Economic and Social Commission for Asia and the Pacific
<b>EIO</b>	Eastern Indian Ocean
<b>ETA</b>	Estimated Time of Arrival
<b>ICG</b>	Intergovernmental Coordination Group
<b>ICG/IOTWMS</b>	Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System
<b>IOC</b>	Intergovernmental Oceanographic Commission
<b>IOTIC</b>	Indian Ocean Tsunami Information Centre
<b>IOTR</b>	Indian Ocean Tsunami Ready
<b>IOTWMS</b>	Indian Ocean Tsunami Warning and Mitigation System
<b>IOWave</b>	Indian Ocean Tsunami Exercise
<b>LDMO</b>	Local Disaster Management Organization
<b>MSZ</b>	Makran Subduction Zone
<b>NDMO</b>	National Disaster Management Organisation
<b>NTWC</b>	National Tsunami Warning Centre
<b>NWG</b>	National Working Group
<b>NWIO</b>	North Western Indian Ocean
<b>SOP</b>	Standard Operating Procedure
<b>TEWS</b>	Tsunami Early Warning Systems
<b>TSP</b>	Tsunami Service Providers
<b>TTF</b>	Trust Fund for Tsunami, Disaster and Climate Preparedness
<b>UNESCO</b>	United Nations Educational, Scientific and Cultural Organization
<b>WIO</b>	Western Indian Ocean

## 1. Introduction

Effective tsunami warning requires rapid and reliable processes for detection and monitoring, the decision to warn, the generation of a warning by the national warning provider and its dissemination along a functioning warning chain, to reach people in risk areas in a timely manner. Integrated and timeline driven Standard Operating Procedures (SOPs) at all levels for actors involved are essential to achieve this.

The UNESCO-IOC Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning & Mitigation System (ICG/IOTWMS) supports Indian Ocean Member States in developing the necessary capacity to operate such warning processes in their countries by providing guidelines, training, advice, exchange of experience, and regular exercises.

At the 13th Session of the ICG/IOTWMS during 28th November - 2nd December 2022, in Bali, Indonesia, it was decided to hold two SOP training workshops in the inter-sessional period: one workshop for Western Indian Ocean (WIO) Member States (Comoros, France Indian Ocean Territories, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa, and Tanzania) and one workshop for Eastern Indian Ocean (EIO) Member States (Australia, Bangladesh, Indonesia, Malaysia, Maldives, Myanmar, Singapore, Sri Lanka, Thailand, and Timor-Leste).

During hybrid four-day SOP training workshops latest information regarding the development and status of SOPs along the tsunami warning chain at all levels in each of the Member States was shared and conceptual input provided. Further, the workshops were used to discuss critical issues and exchange experiences as well as to identify areas where improvements are still needed. The hybrid SOP training workshops were implemented during 3-6 July 2023 for WIO Member States and 10-13 July 2023 for EIO Member States.

As North-West Indian Ocean (NWIO) Member States (India, Iran, Pakistan, Oman, and United Arab Emirates) had recently already received extensive SOP training as part of the UNESCAP funded project "Strengthening tsunami warning in the North-West Indian Ocean through regional cooperation", a separate hybrid two-day SOP workshop to review progress and help prepare for UNESCO-IOC Exercise IOWave23 in October 2023 was implemented during 7-8 August 2023. The workshop also extended to Yemen.

Based on the results of the three workshops, this report summarises the status of tsunami warning chains and related standard operating procedures for tsunami early warning in the ICG/IOTWMS member states and provides strategic recommendations for further action.

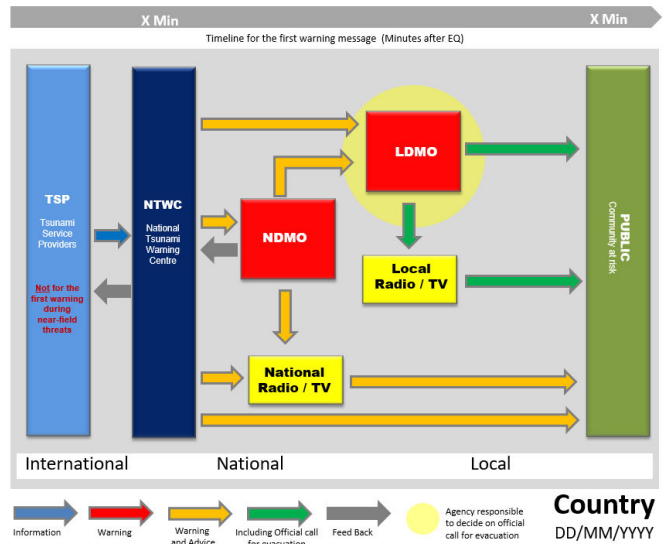
## 2. Methodological Approach

Developing and improving tsunami warning chains involves a number of issues to be considered:

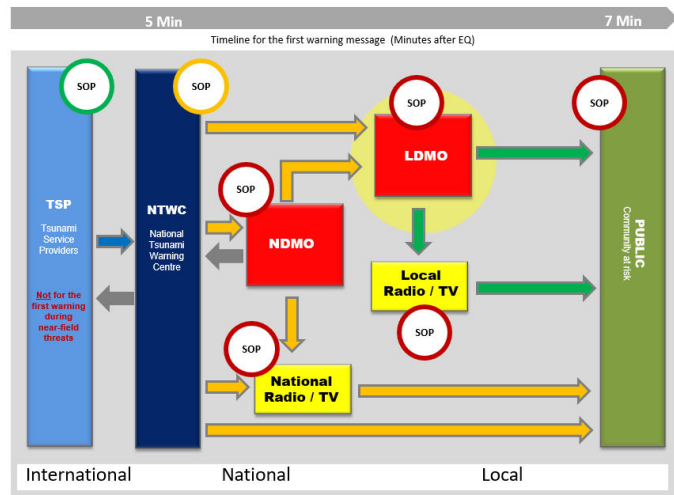
- Institutions on multiple levels involved: from international to national, regional and local levels. Public Media play an important role in warning dissemination.
- Roles & mandates: the involved institutions usually have different roles and mandates, which is reflected in the contents of their warning products. To call for evacuation (and triggering sirens) is usually bound to a specific decision making body (in some cases at local level).
- Warning & Guidance: communities at risk and the public in general do not only need a warning but also guidance what to do, which is generally supplemented by official calls for evacuation.
- Time pressure: tsunami warning chains, especially for near field threats, must reliably transmit warnings in a very short time frame (often only minutes)

- Redundancy: robust warning chains include parallel flows of warnings to assure redundancy in case of failure at one point.
- Coherence of warning message contents from different sources must be assured. This includes a clear understanding what the siren means (warning or evacuation?)

A visual-based approach to support multi-stakeholder work processes to strengthen tsunami warning chains had already been introduced and applied in most of the participating countries. At the heart of the approach is a simplified graphical representation of the end-to-end warning chain, including all key players. Specific colour codes are used to visualise different warning contents along the warning chain. The tool supports the creation of a common understanding of the warning process for all institutions involved, from the international to the national, regional and local levels, and documents it in a schematic diagram. It also helps in clarifying roles and mandates of the participating institutions, especially on decision making to call for evacuation and triggering sirens. The graphical visualization serves as a tool for a joint discussion about necessary adjustments of the warning chain to ensure redundancy and shorten the warning time according to the limited warning time available.



As the warning chain graphic displays the linkages between institutions in a systematic way, it can serve as a reference for the institutional SOPs along the warning chain. SOPs are needed at institutional levels. They must be integrated and timeline-driven. The warning chain graphic can be used to visualise the status of SOPs along the warning chain by including symbols that represent the status of SOP development. It helps to monitor the functionality of the warning chain and shows where action for improvement is needed. A simple set of colour codes provides a quick overview.



In order to make the SOP training workshops as effective as possible, it was considered important that the underlying national tsunami warning chains are sound and agreed by all stakeholders. Therefore, the national tsunami warning chains had been reviewed during preparatory meeting and feedback was provided to the Member States, so that any outstanding issues can be addressed prior to the SOP training workshops implemented in July 2023.

- Existing SOP and functional
- Existing SOP, which needs still to be improved
- SOP not yet existing

During the preparatory meeting Member States were asked to review their warning chains according to the following criteria:

- Consistency? Are the flows consistent? Decision making? Colour codes?
- Can the chain be shortened? Tsunami warning chains should be as short as possible. Each step in the warning chain takes time and is a possible point of failure.
- Redundancy? Robust warning chains include parallel flows of warnings to assure redundancy in case of failure at one point. Does the community at risk receives the warning from multiple sources? Are the contents of messages from different sources well aligned?
- In line with time? Is the proposed time line well aligned with information inputs (i.e. from TSPs and minimum ETAs? Does the time line allows enough time for community response?
- Can this be realistically implemented in practice? Is the proposed flow of the warning chain feasible in the time available? Are all institutions 24/7? Do they have sufficient human resources to operate the warning chain?
- Agreed and understood by all actors involved?

The four day training workshops for WIO and EIO Member States have been held in a hybrid format. The first two days were regional and held online. The objective was to build a common understanding on the importance of national tsunami warning chains and how a time-driven warning process can be made effective and operational with the support of tried and tested SOPs. Further, best practice, templates, and tools for SOP development were shared. On day 3, Member States gathered representatives from all the relevant organisations, either face-to-face or online, to work together to review national status. The fourth day was again held regionally and online to hear of the results of the national meetings including a presentation of the latest versions of the national warning chains and the status of SOP development.

The training for NWIO countries was implemented as a two day hybrid workshop. The first day was regional and online to review the status of the national tsunami warning chains and SOPs and to provide information on the availability and use of tsunami threat information provided by IOTWMS Tsunami Service Providers (TSPs), including new products for tsunamis generated by non-seismic sources such as volcanoes. The second day Member States were asked to gather representatives from all the relevant organisations, either face-to-face or online, to work together on open warning chain and SOP issues and prepare for UNESCO-IOC Exercise IOWave23

Following the workshops, the international consultant provided detailed feedback on each of the latest versions of the warning chain graphics presented, which was then sent individually to each Member State.

The following description of the status of national tsunami warning chains and related SOPs in the Indian Ocean Region is based on the presentations and discussions during the three regional training workshops and the subsequent analysis of the warning chains and available documentation on SOPs by the consultant.

### 3. Status of Warning Chains and related SOPs

#### 3.1. Western Indian Ocean

Western Indian Ocean Member States comprise Comoros, France Indian Ocean Territories, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa, and Tanzania. Somalia also belong to this region, but has not yet been become involved.

Warning Chains graphics have been developed in all WIO Member States, except Somalia. They provide a good overview of the current set-up and at the same time also allow to identify issues which still need to be followed-up.

The warning chains and the respective SOPs to operate must be in line with the available warning time. WIO Member States face mainly far-field tsunami threats from the Makran Subduction Zone (MSZ) and the Sunda Trench. Estimated arrival times (ETA) for the first wave are usually in the range of 5 to 8 hours. Few countries have shorter or longer ETA. This puts them in the group with the “longer” warning times in the Indian Ocean. But even these relatively longer warning times still pose a major challenge for the warning process.

ETA - MSZ						
Somalia		Kenya Seychelles	Comoros Madagascar Mozambique Tanzania	Mauritius Réunion		South Africa
3h	4h	5h	6h	7h	8h	9h +
				Mauritius Réunion Seychelles Somalia	Comoros Kenya Madagascar Mozambique	Tanzania South Africa
ETA - Sunda Trench						

Only half of the Member States have included a timeline in their warning chain graphics, and these are all worth discussing as they could be better aligned with the flow of monitoring and warning information provided by the TSP. The other half should still define and represent the timeline in the graphics.

During the presentation and discussion of the warning chains at the training workshop, it became apparent that the roles and responsibilities of some of the actors involved in the warning process still need to be further clarified in six of the nine Member States.

As far as the redundancy of the warning chain is concerned, no critical problems have been identified, but it could be enhanced in some Member States. While in almost all WIO Member States the decision to evacuate is the responsibility of the national disaster management organisation, only three have established direct communication links between them and the community. For the others, communication takes place via the local authorities.

Except one, all NTWCs of the WIO Member States have defined and shared their SOPs. When it comes to DMO SOPs, there are only a few examples which mainly represent the time-line driven information flow as defined during the IOWave20 exercise. These do not yet represent solid SOPs at institutional level, which would actually be necessary.

The warning chains and SOPs have so far been designed exclusively for seismically induced tsunamis. Possible non-seismic events still need to be taken into account.

Warning chain graphics are a powerful communication tool and should therefore be self-explanatory, that’s why it is important to assure that flows and colour codes are consistent. Except for 2 Member States, in all other cases there is room for improvement in the visualization of the warning chains graphics with regard to the colour codes used and logical consistency of the flows.

### 3.1. Eastern Indian Ocean

Eastern Indian Ocean Member States comprise Australia, Bangladesh, Indonesia, Malaysia, Maldives, Myanmar, Singapore, Sri Lanka, Thailand, and Timor-Leste.

Warning Chains graphics have been developed in all EIO Member States. Most of them have been updated during the SOP training in 2023. They provide a good overview of the current set-up and at the same time also allow to identify issues which still need to be followed-up.

Most of the EIO Member States face near-field threats with ETA < 3 hours from the Sunda Trench, while travel times from the Makran Subduction Zone (MSZ) are > 7 hours. Sri Lanka and Maldives have ETA between 3-4 hours from both source regions. This means all EIO member states must be able to deal with both scenarios, the near-field and the far-field tsunami threat. Indonesia, Myanmar and Timor Leste are facing the biggest challenge in terms of warning times with ETA < 1 hour.

ETA - Sunda Trench							
Indonesia Myanmar Timor-Leste	Australia Bangladesh Malaysia Singapore Thailand	Sri Lanka	Maldives				
<1h	2h	3h	4h	5h	6h	7h +	
		Maldives	Sri Lanka				Australia? Bangladesh Indonesia Malaysia Myanmar Thailand
ETA - MSZ							

Seven out of ten EIO Member States have shown a timeline in their warning chain graphics, except one all of them look solid. Three Member States should still work on the timeline in the graphics.

During the presentation and discussion of the warning chains during the training workshop, it became apparent that the roles and responsibilities of some of the actors involved in the warning process still need to be further clarified in four of the ten EIO Member States. The graphics show that there is a good level of redundancy built into the majority of warning chains. In two cases, warning information flows among the actors and to the community need further clarification.

The decision to evacuate still needs to be clarified in three Member States. In the other cases, it is mostly the responsibility of the NDMO, while two Member States have delegated it to the LDMO. Three of the NDMOs designated for decision making do not have direct communication links with the community and rely on the local authorities to relay information.

All NTWCs of the EIO Member States have defined and shared their SOPs. The DMO SOPs presented are all very general in nature and contain mainly information on the respective legal framework, general roles & responsibilities, organisational structures or contact data. These do not yet represent solid SOPs at institutional level, which would actually be necessary. There are two exceptions where Member States have shared DMO SOPs with more detailed process flow diagrams, including at the local level. However, it should be borne in mind that the presentation of an example of a local SOP does not mean that such SOPs have been introduced throughout the country.

The warning chains and SOPs have so far been designed exclusively for seismically induced tsunamis. Possible non-seismic events still need to be taken into account.

With the exception of 4 Member States, in all other cases there is room for improvement in the visualisation of the warning chain graphics in terms of the colour codes used and the logical consistency of the communication flows.

### **3.1. North West Indian Ocean**

During the past years, North-West Indian Ocean Member States (India, Iran, Pakistan, Oman, and United Arab Emirates) have received extensive support and training to further develop their national tsunami warning chains and SOPs as part of the UNESCAP funded project “Strengthening tsunami warning in the North-West Indian Ocean through regional cooperation” (TTF-31). Yemen also belong to this region, but has not yet been become involved.

The most important threat for all NWIO Member States comes from the Makran Subduction Zone, often with ETA < 1 hour. This requires that warning chains and SOPs are designed so that warnings can be issued and reach the population within a few minutes after a tsunamigenic earthquake.

Warning chains in all NWIO Member States can be considered solid, except Yemen. But there is still a need for improvement in the SOPs in most NWIO Member States, particularly on the part of the DMOs and the media, as well as on the part of the population. An important reference for the SOP development is the proposed harmonized approach to warning levels and NTWC products in the NWIO region, which has been developed in 2020.

The status of warning chains and SOPs for Tsunami Early Warning in the NWIO Region has been documented in a detailed report at the end of the TTF-31 Project Phase 2 in December 2022 (see Reference).

## 4. Strategic Recommendations

The following recommendations are addressed to the ICG-IOTWMS, the associated Secretariat and IOTIC:

**Strengthening the framework conditions for effective warnings through high-level political dialogue** | Such dialogues shall promote national steering, coordination and governance mechanism for existing warning systems with an end-to-end perspective and the required multi-stakeholder coordination and working processes for further development and improvements of tsunami warning chains and related SOPs.

**Strengthening regional cooperation** | Experiences from the UNESCAP funded project “Strengthening tsunami warning in the North-West Indian Ocean through regional cooperation” in the NWIO Region clearly show the benefits and synergy potentials of regional cooperation. Exchanging experiences, developing joint approaches and tools as well as joint learning processes facing shared challenges is not only leading to regional appropriate solutions but also strengthens the motivation in the partner countries to improve their systems. The recently implemented SOP training for regional groups of Member States (EIO, WIO, and NWIO) is a good model for this.

**Facilitate continuous and collective learning** | The provision of specific technical knowledge and references as well as sharing good practices among Member States how to develop effective warning chains and SOPs are key elements to continuously improve warning processes and public response to tsunami threats. Continue to provide training opportunities using hybrid working methods, combining regional exchanges via online platforms and national working processes as face-to-face meetings, which have proven to be effective and cost-effective and also lead to greater ownership of improvement processes by Member States.

**Focusing more strongly on the DMO SOPs** | Main challenges in the operation of warning chains at the present time are related to missing or weak procedures of the DMO and especially those at the local level. The experience gained from the recent trainings shows that the conceptual understanding of SOPs for tsunami warning by the DMOs is still diverse and often not adequate. This is certainly also due to the fact that to date there are virtually no really useful examples of such SOPs available that could serve as a reference for training and joint learning. It is recommended that good examples be developed for a variety of practical cases, representing typical near- and far-field threat situations. This would also be helpful for capacity development within the framework of IOTR.

**Stronger focus on SOPs in IOWave exercises** | The regular IOWave exercises provide a good opportunity for testing and improving SOPs along the warning chain. However, it is often not clear whether the existing SOPs are actually followed during the exercises or whether the activities are based more on the given scenario, the warning information already known and the reactions discussed in advance. It is recommended to emphasize that Member States should focus on real testing of their written SOPs including decision making processes and to take greater account of this in the exercise evaluation. To introduce this, it could be supported by dedicated observers.

**Enhancement of the IOC Post-Tsunami Survey Guidelines by including assessment of downstream processes** | Evaluations after tsunami incidents are unique and important opportunities for joint learning and providing factual evidence which can help to improve warning processes. Currently, post-tsunami surveys mainly focus on the assessment of tsunami impacts in the affected areas, but do not systematically evaluate the performance of the warning chain and response by local authorities and communities. Therefore it is recommend to develop an assessment framework which focuses on the end-to-end warning chain and community response issues and to promote it as a complementary tool as part of the existing IOC Guidelines.

## References

Project Report: Standard Operating Procedures for Tsunami Early Warning in the NWIO Region - Status at the end of TTF-31 Project “Strengthening tsunami early warning in the North West Indian Ocean region through regional cooperation”, December 2022

Workshop concept notes and documentation for the two regional preparation meetings prior to the SOP trainings:

- EIO, 01 June 2023: <https://oceanexpert.org/event/3926>
- WIO, 01 June 2023: <https://oceanexpert.org/event/3927>

Workshop concept notes and documentation for the three regional SOP trainings:

- WIO, 03-06 July 2023: <https://oceanexpert.org/event/3935>
- EIO, 10-13 July 2023: <https://oceanexpert.org/event/3940>
- NWIO, 07-08 August 2023: <https://oceanexpert.org/event/3956>

## Annexes

As annex to this report three PPT files are submitted which contain the latest version of the warning chain graphics and the status of SOP development as presented by the Member States during the training workshops as well as individual comments and observations by the consultant to each it.

- Warning Chains in WIO by 2023-07-13.ppt
- Warning Chains in EIO by 2023-07-13.ppt
- Warning Chains in NWIO by August 2023.ppt