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International Tsunami Survey Team (ITST) Post-Tsunami Survey Field Guide

2nd Edition, 2014

UNESCO

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TABLE OF CONTENTS

ANNEXES

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FOREWORD

Tsunamis have occurred in the past and they will continue to occur in the future. In order to improve our understanding of tsunamis and to develop tools and programmes to mitigate their effects, it is vital to learn from past events. This guide has been prepared to assist Member States, scientists, authorities and community leaders in organising and conducting post-tsunami field survey reconnaissance investigations.

The First Edition of this Guide was published in 1998. This Second Edition represents a thorough revision in recognition of the developments that have taken place in the tsunami field since 1998, as well as the expansion of International Tsunami Survey Team efforts into disciplines not covered in the First Edition.

The revision of the guide began in a sub-committee of the IUGG Joint Tsunami Commission. As such, this guide also represents a productive collaboration between the tsunami science community and the community of decision and policy-makers involved in the tsunami warning and mitigation systems.

It is a pleasure to acknowledge the work of the editors and contributors. It is also a pleasure to acknowledge the review by the technical working groups under each of the Intergovernmental Coordination Groups for the four regional tsunami warning systems, and the endorsement provided by both the Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG) and the IOC Executive Council.

I trust this guide will be useful in preparing future tsunami field surveys.

Wendy Watson Wright
Executive Secretary, IOC

EXECUTIVE SUMMARY

The 1998 Post-Tsunami Field Guide (Manual & Guides No. 37) was published by the Intergovernmental Oceanographic Commission (IOC) to provide guidance for International Tsunami Survey Teams (ITSTs) conducting post event reconnaissance studies. This revision of the First Guide addresses developments in the tsunami field since 1998, and the expansion of ITST efforts into disciplines not covered in the first Guide. It also attempts to align ITST efforts within the United Nations and UNESCO natural hazards and risk reduction framework. The Guide provides a flexible framework for undertaking post-tsunami surveys, their guiding principles, and protocols, and a set of best practices and templates for individuals and groups considering forming, or participating, in post-tsunami surveys.

The Field Guide is divided into three chapters:

Chapter 1 – Introduction to the Field Guide. This part outlines the rationale, purpose, and value of conducting field surveys. It describes the structure of the Guide, notes the modifications from the First Edition and importantly, recognizes the need for different ‘types’ of survey team structures to reflect varying research needs.

Chapter 2 – Conducting post-tsunami field surveys. This part deals with the mechanics of conducting post-tsunami field surveys and is divided into three subsections that outline the issues to be addressed *before*, *during* and *after* the survey is conducted.

Chapter 3 – Data types, equipment, methods and best practice. This part outlines the types of data that can be collected, the types of equipment needed to gather that data, the methods available to researchers and where appropriate, recognizes best practices. Data types and disciplines covered include:

- Tsunami characteristics including inundation, runup, and flow speed/depth/direction
- Tsunami impacts on the built environment
- Geology and tectonics including subsidence/uplift, scour, and deposits
- Ecosystem and biological impacts on both terrestrial and marine environments
- Eyewitness accounts and surveys, and
- Social, human and economic impacts.

Annexes are listed at the end of the Guide to provide more detail in discipline-specific areas, including examples and templates for researchers to use as appropriate.

1 Introduction

The 1998 Post-Tsunami Field Guide (Manual & Guides No. 37) was published by the Intergovernmental Oceanographic Commission (IOC) to provide guidance for International Tsunami Survey Teams (ITSTs) conducting post event reconnaissance studies. This Second Edition of the Field Guide addresses developments in the tsunami field since 1998, and the expansion of ITST efforts into disciplines not covered in the first Guide. It also attempts to align ITST efforts within the United Nations and UNESCO natural hazards and risk reduction framework. The Guide provides a flexible framework for undertaking post-tsunami surveys, their guiding principles, and protocols, and a set of best practices and templates for individuals and groups considering forming, or participating, in post-tsunami surveys.

This Field Guide is intended to facilitate the acquisition of critical data in the immediate aftermath of tsunamis. It will be of use to a variety of people and organizations, who may either participate in, assist in coordinating of or host, post-tsunami field surveys.

For researchers planning, or interested in taking part in a survey, this Guide will provide an outline of accepted field practices in a variety of disciplines, the expectations and responsibilities of team members, and the issues that need to be considered when working in a disaster affected country. For groups involved with coordinating ITSTs, this Guide will give an overview of the types of research investigations likely to be a part of post-event reconnaissance and a framework for communicating with and facilitating field teams. For host countries, this Guide provides an overview of the ITST process and how information from survey teams can be of use to government organizations in responding to a tsunami.

It is hoped that this Guide will promote pre-event planning in countries at risk of tsunamis to reduce the stresses of developing organizational logistics in the post-emergency response phase and make the process of conducting an ITST easier and more productive for both participating researchers and host country organizations.

1.1 Rationale, purpose and value of post-tsunami surveys

Post-tsunami field surveys are essential to understanding tsunamis and developing the tools and programmes necessary to mitigate their effects. Researchers participate in field surveys to better understand the impact of tsunamis and to apply this new knowledge to long-term tsunami disaster risk reduction efforts (Synolakis and Okal, 2005; Kong, 2011). The ultimate goal of these efforts is to save lives, reduce losses, preserve and enhance resilience, and reduce vulnerability both in the affected country and other vulnerable regions.

Post-tsunami surveys, particularly following high-profile, destructive events, attract experts from a number of disciplines including but not limited to physical, social, environmental sciences, economics, and engineering. Researchers collect perishable data such as evidence of the tsunami characteristics and impacts and document the factors that contribute to vulnerability and resilience (Goff and Dominey-Howes, 2011; van Zijll de Jong *et al.,* 2011). These data can also be of use to government decision-makers to better organize and deploy the often-limited resources to heavily affected areas in the aftermath of an event. The survey results can assist in the long-term for recovery planning that will help to mitigate losses from future tsunamis. The availability of survey data to the tsunami research community can help address a wide number of socio-economic and scientific research questions.

Following a tsunami disaster, local jurisdictions are likely to be overwhelmed responding to the immediate needs of the injured and displaced; not to mention the demands of government agencies, non-governmental organizations and the media. The influx of researchers puts additional stress on these jurisdictions and may interfere and conflict with emergency response activities. It is therefore important to coordinate with government emergency response operations in order to ensure the timely collection of perishable data. This data may otherwise be logistically difficult to obtain before natural environmental processes or clean-up efforts modify the landscape.

By following the principles outlined in this Field Guide, researchers can effectively participate in post-tsunami survey teams and collect valuable data in an integrated approach that captures the full extent of the event. At the same time, by coordinating their efforts with host country governments, teams can gain logistical assistance, a better understanding of the cultural issues in the affected country, and provide information that can be used to better manage recovery and the reduction of future impacts.

1.2 Structure of this Field Guide

This Field Guide is divided into three Chapters:

Chapter 1 – Introduction to the Field Guide. This chapter outlines the rationale and describes the purpose and value of conducting field surveys. It describes the structure of this Guide, notes the modifications from the First Edition and importantly, recognizes the need for different 'types' of survey team structures, and how field reconnaissance efforts align with United Nations and UNESCO natural hazards and disaster risk reduction efforts.

Chapter 2 – Conducting post-tsunami field surveys. This part deals with the mechanics of conducting post-tsunami field surveys and is divided into three subsections that outline the issues to be addressed *before*, *during* and *after* the survey is conducted.

Chapter 3 – Data types, data collection equipment, methods and best practice. This part outlines the types of data that can be collected, the equipment needed to gather that data, the methods available to researchers and where appropriate, recognizes best practice.

The main text of this manual is intended to be a concise summary not just for researchers planning to conduct an ITST but also for the governments who will be hosting ITSTs. More detail, examples and templates for researchers are provided in the Annexes, listed at the end of the manual. The Annexes may be printed separately as necessary for conducting surveys at different sites, and may also be translated into relevant local languages where necessary.

1.3 Modification of this Field Guide from the First Edition

The purpose of this Field Guide is to: (1) update the first Intergovernmental Oceanographic Commission (IOC) Post-tsunami Survey Guide (1998) in order to incorporate advances in the understanding of tsunamis; (2) improve data quality and acquisition; (3) facilitate coordination both within the research community and with host countries; and (4) contribute data to assist in the process of effective tsunami disaster risk reduction.

While post-tsunami field surveys have been undertaken for many years, the formal designation of an *International Tsunami Survey Team* (ITST) was first used after the 2nd September 1992 Nicaragua tsunami (Synolakis and Okal, 2005). As of the publication date of this Guide, ITSTs have responded to 31 events (see Annex I). Past ITSTs have ranged from an individual team studying a small region, to multiple teams that have covered both near and far field tsunami impacts. Annex I provides details about previous ITSTs.

Early ITSTs were driven by the hydrodynamic modelling community who needed water height and inundation measurements to benchmark the accuracy of model outputs. A team was necessary in order to quickly record the tsunami characteristics over potentially large areas. While generally focused on collecting water height data, most early ITSTs recognized the importance of interdisciplinary approaches to tsunami research and made an effort to share the information they collected with the people and officials in the affected country. In 1998, an ad-hoc working group headed by Salvador Ferreras compiled the first edition of the Post-tsunami

Survey Field Guide (UNESCO, 1998) as a response to the need for uniformity in collecting data.

A number of factors have led to this 2nd Edition of the Field Guide. In the 1990s, the number of tsunami researchers was relatively small and most events involved at most one or two teams and a handful of researchers. Two events changed this. In 1998 a moderate earthquake produced a major tsunami in Papua New Guinea. A number of researchers interpreted the tsunami as triggered by a submarine sediment slide. This generated interest in tsunami hazards in many parts of the world not previously considered at high risk of earthquake-generated tsunamis.

A major change in perception of tsunami hazards and in the scale of post-tsunami surveys followed the 26 December 2004 Indian Ocean disaster. The size of the event, both in terms of geographic spread and impact, was unprecedented in modern times. Dozens of teams and hundreds of researchers worked in the 11 affected countries over the following year. Not only was the amount of data collected much larger than in previous ITST efforts, it included numerous types of data measured in various ways by different groups. With the increase in data volume came concerns about how to archive and process the data, and quality issues including collection methodology, terminology, base levels, and ambient tidal conditions. The 2004 Indian Ocean tsunami made it clear that the ad hoc, informal way of conducting post-tsunami surveys was no longer adequate. The 11 March 2011 Japan tsunami disaster has further increased the volume and quality issues with vast amounts of data being collected, some types of which were unknown in 1998.

Tsunami research has changed since 1998. Advances in hydrodynamic modelling, the availability of space-based technologies including satellite imagery and global positioning satellite navigation, and methods of recording impacts such as the proliferation of amateur digital video and still imagery, require new sections to be added to the Field Guide. The 1998 Guide devoted one paragraph to describing tsunami sediment deposits. Since 1998, tsunami geology has become a major research discipline requiring careful techniques in collection and analysis of samples (Scheffers and Kelletat (2003), Tappin (2007), Shiki *et al.,* 2008; Chagué-Goff *et al.,* 2011).

In addition to advances in technique, many more disciplines have become involved in post-tsunami surveys including the social and economic sciences, ecology, and structural engineering. Post-tsunami surveys have moved beyond traditional approaches of measuring maximum inundation, runup and flow depth to include a detailed, varied, rich and contextual understanding of the effects of tsunamis at different places including upon people and their communities, infrastructure, agricultural systems, ecology, geomorphological systems, engineered structures and so on. Post-tsunami surveys now often take a much more ‘systems’ approach (Goff and Dominey-Howes, 2011). This Second Edition of the Guide seeks to address this rapidly developing integrative research framework.

When the First Edition of the Post-tsunami Survey Guide was published, the primary focus of tsunami hazard assessment and research was the Pacific. Tsunamis are now much more widely recognized as a global hazard that could impact any coastline. This edition of the Guide will provide government agencies in countries that may have had little awareness of tsunami impact with an overview of the phenomena researchers will be interested in studying and why they are important. By illustrating how ITSTs are conducted and the potential benefits a country may receive from their findings, it is hoped that more countries will be willing to work with the international tsunami community in facilitating post-tsunami surveys.

This Field Guide is intended to provide a flexible framework for undertaking post-tsunami surveys, their guiding principles, and protocols, and a set of best practices and templates for individuals and groups considering forming, or participating, in post-tsunami surveys. It represents best efforts at this moment in time and it attempts to take account of state-of-the-art knowledge, and it is intended to be revised regularly.

1.4 Recognizing the need for 'flexible' Post-tsunami Survey Teams

This Guide recognizes that there is a need to collect important data that may perish or be lost soon after a tsunami has occurred. Indicators of peak tsunami heights and flow directions may be quickly erased by weather and clean-up efforts. Damaged structures may be quickly bull-dozed away. People's memories of what occurred may be distorted by other factors.

Each tsunami is unique in terms of physical and cultural context. Consequently, there may be a need for different types of post-event survey teams depending upon the particular event. While this Guide focuses on tsunamis, it does recognize that an event may also involve significant non-tsunami impacts such as earthquake or volcano damage, public health or safety issues such as those occurring at the Fukushima nuclear power station following the 2011 Japan earthquake-tsunami disaster, and that reconnaissance teams from other disciplines may also be involved in research efforts. Some teams may have multiple roles fulfilling both ITST objectives as well as looking at other multi-hazard impacts. It is not the intent of this Guide to prescribe operating procedures for these other teams. It does encourage cooperation and exchange of ideas wherever possible. The types of teams and constraints on operation will be dictated by the specifics of the event.

1.5 Working with national research professionals

Countries affected by tsunamis have a broad range of domestic scientific and research capabilities and in-country resources. The most effective ITST is a shared enterprise involving international and local personnel that can exchange information and perspectives. This Guide emphasizes that ITSTs must involve the full collaboration of national and international researchers and that lessons learned during the survey are shared with host country agencies.

1.6 Tsunami terminology and alignment with United Nations and UNESCO natural hazards and disaster risk reduction definitions and efforts

A number of technical terms are used by tsunami researchers to describe data, methods, and analyses. Many fundamental terms used by the tsunami research community (for example, *hazard, risk, resilience, vulnerability, disaster,* etc.) are used in slightly different ways by experts from different discipline fields. It is critical that researchers working in the field of tsunami science consistently use established terms and meanings when reporting their results. This will help to ensure wider understanding of what is being reported and transferability of results between studies.

The terms used in this Guide are described in the IOC *Tsunami Glossary* (UNESCO, 2013) in various languages (see http://unesdoc.unesco.org/ulis/cgi-bin/ulis.pl?lin=1&catno=188226) and in the *Compendium of Definitions and Terminology on Sea-level-Related Hazards, Disasters, Vulnerability and Risks in a Coastal Context* (UNESCO, 2011). These documents draw on similar documents developed by UN/ISDR (see the UN/ISDR glossary of terms at http://www.unisdr.org/).

All researchers working in the field of tsunami science are advised to become acquainted with the meaning and use of these core terms.

2 Key Elements of the Survey

This Chapter outlines the key elements of ITST post-tsunami surveys and the issues that will need to be considered by the ITST, *before*, *during* and *after* deployment to affected areas. Post-tsunami survey teams may operate at a national and/or international level depending on the scale of the tsunami and the interests and capacity of national and international tsunami professionals and team volunteers. This Guide addresses only international teams but recommends that countries building a national capacity develop plans that are compatible with the international framework presented here for any proposed domestic teams.

The intent of this Guide is to be flexible and not prescriptive. The size and composition of a particular team will indicate which elements of this Guide are most relevant and important.

2.1 Before the Field Survey

ITSTs require careful pre-field work planning to be successful. This section summarizes the process of developing research priorities and co-ordination with the host country, team composition, logistical issues and the training of team members.

2.1.1 Tsunami National Contact

It is important that ITSTs work collaboratively with officials and professionals in the affected country. Effective operation of ITSTs can be greatly facilitated through the official Tsunami National Contact. IOC-UNESCO has established Tsunami National Contacts for all countries involved in the Regional Tsunami Warning Systems. This person is designated by his/her government to represent his/her country in the coordination of international tsunami warning and mitigation activities (http://www.ioc-tsunami.org/).

The Tsunami National Contact can assist with the development of appropriate Terms of Reference for the survey (see Section 2.1.3), ensure participation of local expertise on ITSTs, co-ordinate with national reconnaissance efforts, provide ITSTs with cultural awareness and knowledge, and make international researchers aware of relevant research and other data that will improve the ITSTs efforts. The Tsunami National Contact also acts as a liaison with IOC-UNESCO and the international tsunami community before events occur.

2.1.2 Host Country Co-ordination Committee, Decision-making procedure

After a tsunami has occurred, a host country Co-ordination Committee may be assembled in order to develop appropriate Terms of Reference and co-ordinate national and incoming ITSTs. Membership of the Co-ordination Committee could include:

- Tsunami National Contact person from the affected (host) country
- IOC-UNESCO staff member
- Host government representative (may be ministry and/or scientific staff member)
- Relevant scientist/technical expert(s) from host country university and/or research organization
- Others as relevant.

This Co-ordination Committee has the responsibility for the Terms of Reference and serves as liaison between incoming ITSTs and the host country government. Host country members who understand emergency response issues and the day-to-day technical challenges on the ground can provide valuable input to the decision-making process. The Co-ordination Committee may wish to identify an individual to act as the primary liaison between incoming ITSTs and host government officials. All relevant decisions (e.g., timing of surveys, team size, Terms of Reference, logistics required, etc.) can then be discussed and communicated.

The Co-ordination Committee will keep track of the type of data being collected by ITSTs and the geographic areas that they have worked in. It may encourage incoming ITSTs to work in areas that have not been covered by previous groups to avoid duplication of effort and ensure maximum knowledge gain.

2.1.3 Terms of Reference

It is recommended that ITSTs define the goals of their field reconnaissance efforts within a framework of the concerns of the host country and the needs of the research community. This framework is embodied in Terms of Reference that are developed by representatives of the affected community, IOC-UNESCO, and the tsunami research community. The Terms of Reference for a specific event should attempt to strike a balance between addressing specific questions of the affected country, and the research questions and expertise of the ITST volunteers.

Effective collaboration between ITSTs and the host country requires that both groups benefit. A perception that visiting experts are only interested in collecting data to advance their personal careers will make governments less interested in facilitating ITSTs or welcoming research efforts. When working well, this collaboration can meet the needs of affected communities and ease the efforts of participating ITST members by providing critical logistical assistance to them.

It may be appropriate for a small, highly mobile, team of experienced tsunami researchers to be deployed rapidly into affected regions to gather limited, significant, perishable data (e.g., water marks, flow direction indicators, geological deposits, etc.) soon after the event. Such teams would likely have a limited Terms of Reference. The results of their survey work should be shared and used to guide, larger, multi-sectoral, interdisciplinary teams with broader, more complex Terms of Reference and research tasks.

The specific Terms of Reference depend on the scale and characteristics of the event. Terms of Reference for recent events have included the following:

(1) ***Measure maximum inundation and maximum flood runup and flow depth above ground surface*** at as many sites as possible – such measurements are useful for many purposes including improving forecast inundation models and understanding impacts of tsunami inundation on building damage as well as contributing to a more complete historical database, which will eventually enable improved probabilistic approaches. It is recommended that complete inundation lines along with topographic and tsunami height profiles from the shoreline to the inundation limit be collected for the most important locations;

(2) ***Describe and collect geological samples of sediments left by the tsunami*** – such samples help with the characterization of tsunami deposits providing highly valuable analogues to compare with suspected palaeotsunami deposits;

(3) ***Measure the type and severity of damage to different types of buildings and other coastal structures*** and record what factors affected damage levels – such data are valuable for helping revise building codes and design standards and for informing land use zoning and planning decision making;

(4) ***Collect and measure information about the environmental and biophysical system impacts*** of the tsunami in different places – such work is helpful for exploring many aspects of conservation, ecosystem function analysis and environmental change and management;

(5) ***Collect information about survivor experiences*** through interviews – such eye-witness accounts can provide observations of tsunami characteristics, evacuation and preparedness issues and the full impacts of the event on people;

(6) ***Explore the human and community vulnerability and resilience factors*** at work in different places – what made a particular community resilient or vulnerable, what are the

differential experiences of different types of people who experienced the tsunami? – such data are critical for understanding how to develop appropriate education and hazard awareness programmes, for revising early warning approaches and alike;

(7) ***Make recommendations*** – use the results from tasks 1 to 6 to draw up recommendations to assist local and national government authorities to increase community resilience, improve disaster preparedness and planning and increase community awareness and education and help identify gaps for future field research.

Additional research objectives may be included in specific ITSTs Terms of Reference depending on the characteristics of a particular tsunami.

2.1.4 ITST Leadership (Co-ordination) and composition

There is no prescribed composition to an ITST, because such teams are self-organized, self-funded and composed of 'volunteers' coming from other countries. However, to facilitate functioning of the ITST in country, to be aware of cultural norms and practices, to take account of in-country expertise and knowledge and to facilitate skills and knowledge transfer, it is critical that whenever possible, ITSTs include a mix of host country experts and international participants.

ITSTs are typically composed of a mix of experts from different disciplines and coming from academic institutions and governmental organizations. In some cases it is appropriate to encourage the participation of practitioners such as warning centre staff, emergency management and response officials and planners. Some ITSTs have included journalists and film-makers and have successfully used the ITST survey as a vehicle for outreach and public education activities. In such cases, it is important that media ground rules be carefully developed and agreed to in advance.

Regardless of the composition of the ITST, it is always preferable that some of the team members have previous ITST post-tsunami reconnaissance experience. Ideally, ITSTs would also include graduate students or young professionals where possible so that expertise is gained and transferred to the next generation of researchers.

For some events, it may be necessary to restrict the size of an ITST depending on the nature of the impacts of the tsunami at specific places and the capacity of the host region to accommodate incoming teams. Size and exact composition should be negotiated between the incoming ITSTs via their Leader and the host country Co-ordination Committee.

Significant tsunamis generate interest from a wide range of disciplines, level of professional expertise, and previous field experience. There may also be interest from persons who are primarily interested in seeing the scope of the damage but do not have the background to readily contribute to the ITST effort. In putting together an ITST, it is important to consider how members will work together and contribute to the data-collection goals of the group. Establishing symposia/field trips at some suitable interval after the event can accommodate the interests of people who are primarily interested in touring damage sites.

Those thinking of participating on an ITST are advised to seriously consider their motivation and expectation for participation. Post-event surveys are undertaken in disaster-affected regions under difficult conditions. They typically involve intense physical exertion and psychological stress. ITSTs are not easy; they may be uncomfortable, and they can be distressing.

2.1.5 Leadership

Definition of leadership role(s) is important. The ITST leader should work with the host country Co-ordination Committee to define the ITSTs research contributions under the Terms of

Reference, and to communicate team travel plans to the host country. This person will also co-ordinate logistics and make sure that all team members understand their roles and responsibilities. For a small group, a single person may take on all of these roles. For larger ITSTs, it is recommended that responsibilities be designated to several individuals.

2.1.6 Disciplines involved in ITST surveys

The goal of ITSTs is to capture the broadest possible picture of the tsunami. ITSTs can do this either by incorporating different disciplines within the same ITST, or by having multiple ITSTs that focus on particular (and different) aspects of the tsunami. A large ITST may wish to consider dividing into sub-groups. The types of data recent ITSTs have investigated include:

- Inundation, runup, and flow depth/direction
- Building and infrastructure damage
- Geology and tectonics (subsidence/uplift, scour, sediments)
- Ecosystem and biological impacts (both terrestrial and marine – natural and agricultural)
- Eyewitness accounts and preparedness
- Social, human and economic impacts.

This list is not exhaustive. Future ITSTs may explore the possibility of developing new research areas, technologies, data collection techniques and methods not listed here.

Interdisciplinary teams help to provide detailed, contextual information about the tsunami that cover the breadth of the coupled human-environment system. They also have the added benefit of providing participants with a window into disciplines and research methods they may not have been previously aware of. The result is that the sum of such analyses may be much greater than its individual parts.

2.1.7 Logistics

Planning an ITST requires careful consideration of numerous logistical issues and challenges in order to carry out the intended research plan of the group. The Host Country Co-ordination Committee can provide guidance as to particular logistical issues at play in the affected country.

Schedule

The first decision is when to go to the field. A balance must be struck between the desire and enthusiasm of potential participants in an ITST to go in to affected areas to collect perishable data as quickly as possible, and the needs of emergency authorities, host governments and affected communities to complete essential activities in the immediate, critical, post-disaster emergency response phase. Annex II provides information for ITST Leaders and team members to consider when scheduling the survey.

Travel, accommodation, food and money

It is the responsibility of individual ITSTs to arrange funding and book travel and accommodation. The availability of lodging, rental cars and other transportation may be severely limited because of the impacts of the event and the needs of response personnel. It will be the responsibility of ITST members themselves to ensure they can feed themselves and have sufficient funds in the local currency to purchase necessary services. Be aware that credit card facilities may not be available, and if they are then they may only be available in the currency of the host country. It is best not to assume that safe drinking water will be available in the field.

Consideration should be given to the idea of the ITST working from a single 'base camp' or co-ordination centre or whether the ITST (or sub-groups) require multiple bases throughout the survey. The latter will most likely be the case for large events impacting a wide area.

Access, translation and guide services, communication needs
Access to affected areas may be controlled or limited by authorities. Participating in the ITST co-ordination process can facilitate access by providing information on how to apply for official access permission, and providing identification badges. Further details are provided in Annex II.

In many countries it is necessary to engage the services of translators and/or guides to enter affected areas. The Host Country Co-ordination Committee may be able to provide relevant information. The inclusion of host country experts as members of ITSTs can significantly improve the capacity for communication with local people in local languages helping off set such translator and guide service costs.

ITST participants are responsible for ensuring their own telecommunication and power needs. It should not be assumed that ITSTs will have access to stable telephone or mobile systems or regular power supply. The internet may not be available in a tsunami affected area.

Safety, health and insurance
The highest priority of any ITST is the safety of its members. This includes identifying and planning for a wide range of physical risks such as water safety, immunization, severe weather, earthquake aftershocks, and potential psychological risks. Working in places affected by disasters is extremely dangerous. The Host Country Co-ordination Committee may be able to help identify risks for a particular event.

It is recommended that ITSTs develop a safety plan before entering the field and ensure that all team members are aware of and know how to take action to reduce risks. ITST participants should check with their own organization regarding the protocols and health and safety risk assessment documentation required to enable them to participate in the field survey. ITST members are also advised to seek safety advice from their own government prior to travelling into the field.

The ITST Leader is advised to liaise with the Host Country Co-ordination Committee to ascertain ‘broad’ risk management issues and should communicate these to potential ITST members as early as possible to enable potential participants to decide if they can join the field survey. ITST participants are responsible for their own safety and security including injuries incurred in the field.

Individual participants are advised to ensure they have adequate health and travel insurance coverage from their home organization or employer. Participants are advised to bring their own health and safety equipment including medications and mosquito nets if required. If a participant takes regular medication they should ensure they have adequate supplies for the duration of the ITST (plus further supplies to allow for a safety buffer). Participants should advise others in the ITST and the ITST Leader if they have any medical conditions that might need a response from other team members – e.g., epileptic fits, allergies, etc.

Communication
Successful ITSTs face a variety of communication issues including internal communications between ITST members, externally between the ITST and host country representatives, and with people in the country met by ITST volunteers during the field survey. Section 2.2 focuses on some of the essential communication issues. Annex II provides further details on those issues related to communication.

2.1.8 *Relevant Background Information*

Section 3.1 describes background data that can be collected before going into the field. These data include satellite and remote sensing imagery, relevant research efforts in the affected area, and preliminary reconnaissance reports conducted by earlier ITSTs or researchers in related fields. Such data can assist an ITST in planning so as to optimize data collection and avoid duplication.

2.1.9 *Training*

All individuals participating in an ITST survey need to be as well prepared and properly trained as possible for the specific task they undertake. It is the responsibility of the ITST Leader to ensure all team members are trained to complete the tasks they will be expected to undertake in the field. Further details are provided in Annex II.

2.1.10 *Cultural awareness, country specific regulations and practices and human research ethics*

ITSTs undertake rapid assessments and generally cover as much ground as quickly as possible. When working in mixed or cross-cultural settings, it is very easy to inadvertently cause offense to host country team members and/or members of communities that the team is visiting or working in (van Zijll de Jong *et al.,* 2011). Understanding cultural constraints and behaviour in a culturally sensitive way will help reduce stress, improve group dynamics, facilitate mutual respect and ensure ITST work is focused and delivers results appropriate for enhancing community resilience to future tsunamis.

Care should be taken to understand and abide by cultural practices and norms (e.g., appropriate dress requirements, interview protocol, acceptable working days) and to be familiar with basic practices (greeting people, how to behave when invited in to someone's home, etc.) in the area where the work is to be undertaken. ITST members are advised to look up basic cultural practices of the area they are visiting prior to arrival.

The Tsunami National Contact person or the Host Country Co-ordination Committee may be able to compile and provide guidance materials on key/common cultural issues and protocols for ITSTs and the information can be communicated to all ITSTs and their members prior to the survey. Poor, culturally insensitive behaviour in the field can have serious repercussions including the cancelling of host government approval for ITST work, cancelling of research visas, withdrawal of logistical support and embarrassment to all agencies and organizations involved.

ITSTs and their members are expected to seek and obtain all relevant approvals for ethics and human research from their own organization prior to arrival in the affected regions.

2.1.11 *Legal requirements, visas and import/export permits*

ITST members are expected to abide by the legal rules and codes relevant to the study area. Partnering with host country experts will help to ensure that situations where team members might inadvertently fall on the wrong side of legal practice can be reduced to a minimum.

It is recommended that the ITST Leader seek general advice from the Host Country Co-ordination Committee about 'key' legal requirements for incoming ITST volunteers. ITSTs should seek appropriate visas and import/export permits to be allowed to undertake fieldwork and research in each country visited, and ensure they have the correct permits for importing equipment and exporting samples.

2.2 During the Field Survey

This section summarizes operational issues for ITSTs to consider while working in the affected country. It is divided into subsections associated with initial entry, conducting the survey, exit issues, and special considerations such as dealing with the media. The bulk of this section deals with communication – both internal among ITST members and external between the ITST and host country representatives and the Host Country Co-ordination Committee and with people met during the field survey. Good communication is vital to the success of ITSTs no matter how large or small they are or what disciplines are represented.

2.2.1 Entering the host country

Before an ITST enters the host country, the Host Country Co-ordination Committee and the Tsunami National Contact will have identified an entry briefing process. For a small team and/or localized event, the process may be informal and conducted by email or telephone. For a significant event, the process is likely to be more formalized. The Host Country Co-ordination Committee will advise of the expectations for the particular event.

For large teams or multiple ITSTs, the ITST Leader is likely to be requested to attend a 'check-in briefing' with the Tsunami National Contact and/or relevant government officers/ministries on arrival in the host country. This initial briefing provides an opportunity for the host government to raise relevant issues of concern and for the ITST Leader to reaffirm the commitments and intensions of the ITST so that the government officials understand how the ITST survey fits into the Terms of Reference. Reporting requirements for the ITST should also be clarified such as the nature and frequency of briefings and what is expected in a final report.

The ITST Leader needs to also communicate with the Host Country Co-ordination Committee to seek the latest advice about conditions in the field that could affect survey work, team safety and performance, and for information on other field reconnaissance efforts that pertain to the group's survey work. In some cases, the Host Country Co-ordination Committee may be able to provide a briefing on research issues and the findings from earlier teams.

After the initial check-in briefing with the government representative, the ITST Leader should hold a meeting/briefing with their ITST members **before field work commences**. This meeting should include:

- An overview of the host country check-in briefing and any updates from the Co-ordination Committee including what facilities and logistics are available to support the ITST and for how long;
- A summary of relevant logistical considerations such as where to change money, appropriate dress in public, obtaining food and water, pertinent safety information, local telephone services, etc.;
- Recent results, advice, and ancillary information, including recommendations on survey sites;
- Responsibilities of team members such as cultural sensitivity issues, field reports and handling of data, care and supervision of equipment;
- Advice about in-field safety issues and procedures such as the potential for aftershocks and evacuation in the case of potential further tsunami events;
- Communication plans for the group including frequency of meetings/briefings, how changes in plans and field efforts will be communicated and so on.

Open communication among ITST members is essential for the success of the ITST survey. Explanations should be provided if for any reason, plans are changed and if logistical support has to be redirected.

2.2.2 Conducting the field survey

The primary purpose of the ITST is to collect survey data in the area of expertise of the team members. Chapter 3 of this manual provides summaries of the types of data and acquisition considerations for a variety of data typically collected by ITSTs. This section focuses on the operational factors that affect ITSTs. Communication requirements during the period of the survey will depend on a number of factors including the Terms of Reference developed for the event, the size and makeup of the ITST and any subgroups, and logistical considerations such as whether the group is located at a single base camp site or multiple sites. ITST survey plans should include mechanisms to facilitate communication both within the ITST, with the Host Country Co-ordination Committee, and with the host government if requested. The following should be included in the plan:

Communicating with the host government
No matter what the size and scope of the ITST, it is important that the host government or designated agency be kept informed of how the survey work is progressing. Different host governments will require different levels, forms and types of briefings. The ITST Leader will be informed of the host government reporting requirements at the entry briefing. If daily briefings are requested, it is the ITST Leader’s responsibility to make sure they are provided and to advise the host government at the earliest opportunity if there is likely to be a delay.

Communicating with the Co-ordination Committee
It is important for the Host Country Co-ordination Committee to be kept aware of the survey progress. If the ITST learns of particular research or logistical issues while in the field, the Host Country Co-ordination Committee should be informed. Likewise the Host Country Co-ordination Committee may learn of issues that could impact the ITST and needs to be able to contact the ITST Leader.

Communicating within the ITST group
In order to ensure smooth functioning of the ITST, it is important to undertake frequent briefings with all ITST members. For a large group, a daily briefing can facilitate the exchange of research information, identify logistical problems or issues, engender a sense of team spirit and improve morale. They also give the chance to allow all team members to share their developing knowledge and express any questions or concerns they have on how the survey work is going. All team members should be given the chance to speak if they wish.

Talking with people during the field survey
All ITST participants will need to talk to people affected by the tsunami at some point during their survey work. In some cases these interviews may be peripheral to the central purpose of the ITST effort, and in others they may be the primary focus (see Annex X).

There is no area of ITST survey work where the possibility of causing cultural offense or getting biased data is as great as with interviews. For researchers not experienced in interview techniques and human behavioural research, talking to people can be challenging. Survivors have just experienced a traumatic event and may have lost loved ones and possessions. It is important to be aware of cultural issues when talking to people. These issues may cover a large range of behaviours including how to greet people, wearing of hats and sunglasses and whether it is appropriate for men to interview women and vice versa. Permission to record/videotape an interview or taking photographs must be given by the interviewee. It is essential to communicate with host country representatives about sensitive cultural issues before talking to people.

Keeping track of local contacts and obligations
It is likely that a number of local individuals and/or agencies will contribute to the success of a survey. Keep track of these persons and groups and consider collecting contact information so that they can be thanked later and/or properly acknowledged in publications or subsequent work. ITST participants may offer to send information or materials to persons met during the survey and it is important to carry through on any obligations made.

2.2.3 Exiting the country

An agreed-upon exit procedure for the ITST should be part of the discussions with the Host Country Co-ordination Committee at the initial briefing with host government officials. As a minimum, the exit process should include a verbal report on the activities of the ITST survey and preliminary findings. For many ITSTs, the exit process may be the only opportunity for the host country to learn from the team's effort. Exit procedures should include:

Exit briefing with host country officials and Co-ordination Committee
Prior to the ITST departing, a senior level meeting should occur at a time and place convenient to the host government, including members of the host government and its relevant contact points (Tsunami National Contact). At that meeting, the ITST Leader should provide a preliminary summary report of the ITST work, make a presentation in an appropriate format/style and engage in a question and answer session for the host government and its relevant staff. The summary report should include a description of the data collected and the preliminary results of the work. If the survey work has implications for preparedness and mitigation in the host country, the briefing should also include recommendations and priorities for risk reduction strategies and activities to improve tsunami resilience.

It is strongly recommended that ITSTs compile a written preliminary report of findings before leaving the country. The report can be presented to the host country and is tangible evidence of benefit for having facilitated the survey work. For busy researchers, completing a report before leaving has an added benefit. It may allow them to capture ideas and summarize findings before becoming distracted by other demands and projects in their home countries.

Check-out procedure for ITST members
The exact nature of the check-out procedure will reflect the complexity and style of the overall ITST and the actual process may vary for each member. As each member of the ITST departs, they should receive basic information on planned next steps for work including post processing of data, report writing and publication. Their full contact details should be confirmed to the ITST Leader. Individuals should agree what post-departure tasks they are willing to undertake and the time frame of those activities. Each individual should be thanked for their efforts.

Assessment
Consideration should be given to establishing some form of feedback on the survey from individual ITST members to the IOC-UNESCO and the ITST Leader. Such an assessment might reflect on what worked and went well, what did not work and why, and what could be improved next time. This could help form a template for improving ITSTs and this guidance in the future.

2.2.4 Special Considerations

Media

Most ITSTs are likely to have some contact with the media – either in the host country or their home country. Meaningful interaction with media may be beneficial but can be tricky to negotiate and could have political consequences. Media coverage can help to facilitate access to regions that might not otherwise be available to ITSTs, and it can provide an important education and outreach tool. Regardless of the interest of the ITST members in interacting with the media, it is important to discuss how it will be handled. Communication with the host country media should be considered as part of ITST service to host countries and communities.

Teams should think about who should represent them to the media – their skill, comfort level, language capacity and cultural sensitivity. The ITST Leader might not be the best person. The whole team should consider discussing those issues they would like covered in media interviews and careful consideration should be given to the consistency of information provided.

It may be appropriate for the ITST to brief the host country and international media daily or at regular intervals. It is recommended that the ITST Leader discuss with the host government and the Co-ordination Committee the nature, frequency and type of briefings that can/should be provided. This is important so that the host government is a partner in the type of information being provided to the public.

Some of the ITST's data and findings might be politically sensitive. The needs of the host government should be carefully considered and if possible discussed in advance before releasing information to the media or allowing them to be present at briefings. If the host government does not want media presence, it may be possible to have a separate follow-up meeting to present results that have been approved by the host government.

Social Media

Some recent ITSTs have included daily blogging, and Facebook and Twitter postings as part of their field procedures. These social media have the advantage of reaching large numbers of people and can serve as an important outreach tool by engaging the public in the process of conducting a survey. Social media postings are in the public domain and therefore should be treated with the same care as in dealing with professional media. The ITST Leader and the Host Country Co-ordination Committee should be kept fully aware of your posting plans to minimise the chance of posts being misinterpreted by people not familiar with the field.

Presentations to host country audiences

Many ITSTs have included public meetings and/or presentations to scientific or other host country organizations at the start, during or near the end of their field survey work. Such presentations range from providing introductory information on what the team intends to do based on previous experience and background information on earthquakes and tsunamis, to more specialized presentations to an audience of professionals already familiar with much of the subject matter. Similar care should be taken into consideration at presentations with the media. With appropriate planning, such presentations provide an additional ITST service to the host country.

2.3 After the Field Survey

An ITST is not complete nor can it be considered successful until the data gathered in the survey has been reported in a form that can be used by the host country and the international research community. Post-ITST data processing and publication is the responsibility of individual team members and data dissemination may be constrained by the requirements of funders who provided the financial support for the survey and by the needs of individuals to get professional recognition for their research efforts. This section of the manual summarizes mechanisms to facilitate publication and sharing of information.

2.3.1 Reports and publications arising from the ITST

After data has been collected in the field, there are a variety of dissemination mechanisms including ITST reports, professional presentations at conferences and workshops, informal community meetings geared towards the public and peer-reviewed publications.

ITST Interim and Final Reports
It is expected that the ITST Leader will present a preliminary report of the survey activities before leaving the host country and teams are strongly encouraged to leave a written version of the report with the host country representatives. The Terms of Reference and/or discussions with host country representatives may also include the expectation of a Final ITST Report and/or copies of other publications. The date for the production and delivery of the Final Report or publications needs to be negotiated with the host country. The date will vary according to the detail and scale of the ITST and the time required to post-process the data collected. Depending on the size and complexity of the ITST, it may be necessary for the ITST Leader to delegate writing tasks to different authors. Waiting for publications to appear in print may be more than a year after the completion of the survey thus potentially delaying production of the final report by an extended period of time, and this needs to be agreed to and understood by the host government. All reports and publications should acknowledge the assistance of government agencies and individuals who provided assistance to the field team and copies disseminated to the Host Country Co-ordination Committee.

Conferences and professional workshops
ITST members are encouraged to present the results (preliminary and final) at relevant conferences and professional workshops. Members of the ITST – together with host government officers/relevant staff may wish to convene special sessions at relevant scientific conferences. ITST members who present conference papers/presentations should communicate full details of these to the overall ITST Leader so that they can provide summaries to the host government and IOC-UNESCO for official records. Workshops which reflect on lessons learned by ITST survey teams can be very valuable for future efforts.

Anniversary workshops and symposia can provide a forum to focus dissemination of the results of a variety of ITST field efforts and put them in a context of post-disaster response and recovery efforts within affected countries. When coupled with field excursions to the impacted area, they can provide a vehicle for professionals not directly involved with an ITST to better understand the event.

Community meetings and presentations geared to the public
Once ITST members have returned to their home countries, their experiences and knowledge gained may be of interest to non-professional audiences and the general public. ITST members are encouraged to participate in Community forums, service club talks, displays and other outreach activities that foster tsunami preparedness. Further, researchers may liaise with official regional emergency preparedness agencies to ensure horizontal learning.

Peer-reviewed publications
Every discipline has a variety of peer-reviewed publications that may be appropriate to present the results of the ITST survey. For major tsunamis, opportunity usually arises for a special issue of an international refereed journal to take papers related to a specific

event. The ITST Leader, together with IOC-UNESCO may negotiate directly with editorial boards to support such proposals. All ITST team members should be included as co-authors on at least one summative paper about various aspects of the ITST, in recognition of their efforts. Any special issue publication should be provided to the host government as appropriate (and may be presented as the 'Final Report').

2.3.2 Gathering, Processing, Sharing and Distribution of Data

To be of the greatest use to the international tsunami community and to serve the function of reducing vulnerability, data collected during post-tsunami field surveys should be posted to a data repository and eventually assimilated into a long-term tsunami data archive. Some tsunami data, such as tide gauge recordings, are already routinely processed in this way (Dunbar *et al.,* 2011). However, the majority of survey data describing the full extent and severity of a tsunami (e.g. maximum wave height, inundation, socio-economic effects), are often not included in data archives. These data are most often stored by individual field investigators, making access by others difficult. All of these data are essential for tsunami hazard assessment, forecast and warning, inundation modelling validation, preparedness, mitigation, education, and research. ITST participants are encouraged to consider posting their final data to a data archive.

Some ITSTs collect a large volume of samples such as tsunami and soil deposits. The samples are analysed according to the interests of the researchers and accepted field methods of the time. Preservation of at least some of these samples is encouraged (archived). There are two reasons for sample preservation. The first is that samples are limited and researchers in other disciplines may be interested in examining them when the primary purpose for collecting the materials has been completed. The second is that technology changes and there may be an interest in applying new techniques on samples from older events.

Annex III provides further information about possible data sharing options.

3 Data types, data collection equipment, methods and best practice

The primary objective of an ITST is collecting field survey data relevant to the disciplines and expertise of the members of the team. This Guide recognizes that ITSTs are typically composed of discipline-specific experts who understand the requirements of their disciplines. However, researchers from different countries may have developed variations in the handling and processing of data or, when working in an inter-disciplinary field team, find themselves working with measurements, data and observations that go beyond their previous experience. The purpose of this section of the Guide is to give an overview of the types of data that are typically collected by ITSTs and where appropriate, recognize currently accepted best practices so that data collection is consistent and the results can be shared and applied as widely as possible. More detailed information about the specific needs of different ITST areas is given in Annexes V – XI.

All ITSTs need to be aware of the uncertainties and statistical variations in their data collection. It is often not feasible to sample in a statistically rigorous way due to time constraints and access issues involved with ITSTs. However, participants should be aware of the uncertainty issues involved with their particular discipline and convey this uncertainty in reports and published articles.

This section is organized into subsections that look at the types of relevant data and information that should be collected before field-work begins, and during the ITST. While it may be informative for ITST members to understand data issues outside of their areas of expertise, it is only necessary for a team to collect the data relevant to the questions and problems it seeks to understand and tackle and in relation to the agreed ITST Terms of Reference.

3.1 Before Going into the Field

Collecting data *before* going into the field is important for understanding the event, the current situation on the ground and for helping to make decisions about where to conduct post-tsunami surveys. Teams also need to collect the information and equipment relevant to their specific field efforts. Pre-survey data and information falls into four general areas:

- Data useful for understanding the general aspects of the event;
- Data that will aid in locating and conducting field surveys;
- Information about logistics and safety that is important for determining field sites; and
- Discipline-specific information for conducting the work a particular ITST intends to do.

3.1.1 General understanding of the tsunami event

The earliest information available about a tsunami typically pertains to the source characteristics (such as earthquake size/mechanism), tsunami water levels, travel time, and general impacts. Of particular interest to tsunami researchers is water level data. Annex IV describes real-time and archived sites for water level information for both coastal tide gauge locations and deep-water sites available at the time of the publication of this guide.

Historical information about the impacts of past tsunamis in a region can be accessed at the National Oceanic and Atmospheric Administrations (NOAA) World Data Center Global Historical Tsunami Database (http://www.ngdc.noaa.gov/hazard/tsu_db.shtml). The database includes runup and water levels from instruments, field surveys and eyewitness accounts, impacts, and bibliographic references.

It is also important to monitor impacts and conditions on the ground as the event unfolds. Situation reports by government and non-governmental agencies are posted on the United Nation's Relief Web site (http://reliefweb.int/). In the future, other relevant web sites carrying such information are likely to emerge.

National agencies, professional organizations and individual researchers may set up special events pages with links to information as it becomes available. A good way to keep track of early developments is through the IOC-UNESCO International Tsunami Information Center's Tsunami Bulletin Board. The Bulletin Board will also disseminate information about whether ITSTs will be invited to participate in post-event reconnaissance and the status of teams as they are developed and deployed. To subscribe to the Bulletin Board, please contact the ITIC (itic.tsunami@noaa.gov).

3.1.2 Locating field survey sites

Once a decision has been made to deploy an ITST, there are several useful tools for deciding on possible field sites:

Numerical modelling
Numerical models of the tsunami generation, propagation, and predicted water heights are routinely produced by national agencies and researchers soon after a tsunami occurs. Initial models may be limited by the available bathymetric data and understanding of the source characteristics, but can provide a general picture of where impacts are likely to have been the greatest. See Annex V for further information.

Geospatial information
A vast array of geospatial information including satellite imagery, geographic information systems databases, and aerial photography can assist in determining areas to be studied in the field. This information will help to identify impacted areas and land use and

demographic factors. Maps and satellite imagery are often available from Google Earth (http://earth.google.com), Relief Web (http://www.reliefweb.int), or the Centre for Satellite Based Crisis Information (http://www.zki.dlr.de/). By collaborating with host country experts and government agencies access may be gained to additional geospatial data not otherwise accessible to incoming researchers.

3.1.3 Logistical information

No survey can be conducted if it is impossible to reach the field area. The best source of information on how to access field areas is the Host Country Co-ordination Committee and the Tsunami National Contact.

3.1.4 Discipline-specific information

Different ITSTs and sub-groups within an individual ITST may have a need for specific types of data to take into the field. For example, water-level teams need to have access to tidal data so that measurements are calibrated to a common datum. It is the responsibility of the ITST Leader to make sure that all members of the team have the relevant information to accomplish the tasks required of their survey.

3.2 Data types and special considerations

This section gives an overview of data typically collected by ITSTs and what is currently considered the best practices where appropriate. Much of the detailed information including templates, lists of equipment and standard techniques is included in Annexes. The types of survey data are organized in the following categories:

- Tsunami modelling and hydrodynamic data including inundation, runup, and flow speed, depth, and direction;
- Geophysical and seismological monitoring data;
- Tsunami impacts on the built environment;
- Geology and tectonics including subsidence/uplift, scour, and deposits;
- Ecosystem and biological impacts on both terrestrial and marine environments;
- Eyewitness accounts and surveys; and
- Social, human and economic impacts.

3.2.1 Tsunami modelling and hydrodynamic data

Most tsunami research efforts depend upon the characteristics of the tsunami. A significant part of the ITST effort will include describing the tsunami in time and space including:

- Extent and variability of inundation;
- Water heights at specific locations and along profiles;
- Timing and duration of tsunami surges;
- Flow directions; and
- Current speeds.

Measuring water heights, inundation extent, and flow directions requires recognition of the signs of a tsunami and care must be taken not to confuse a tsunami with other natural processes such as storms and tides, or human causes. Groups taking water height measurements must also be careful to reference heights to benchmarks or another recognizable datum. Water heights may vary significantly over space so it is essential that ITSTs focusing on height measurements consider how to adequately sample an area. Care should be taken to account for co-seismic uplift/subsidence when referencing depths to the datum. For a discussion on this topic and its relevance to supporting further modelling efforts, see the review by Fryer (2011). Annex V provides further information on measuring water levels.

In the absence of coastal tide gauges, determining the timing of tsunami surges requires interviewing of eyewitnesses. Extreme care must be taken in talking to tsunami survivors and in getting an accurate assessment of what they observed. More information on interviews is given in the section on eyewitness accounts below and in Annex X.

The velocity of tsunami currents is an essential factor in determining the forces exerted on structures or the landscape and is one of the more difficult parameters to accurately assess. Amateur, security, and media footage is becoming more widely available and ITST groups should make an attempt to collect as much footage as possible as velocity estimates can be made from them.

3.2.2 Geophysical and seismological monitoring

Groups looking at source characteristics may wish to deploy seismographs and strong motion instruments to investigate aftershock distributions and other seismic aspects of the event. Portable networks of Global Positioning Satellite (GPS) instruments can give important information about land level changes and post event deformation. It is assumed that groups involved in these and other auxiliary activities will understand the requirements necessary to conduct such field investigations, so further details are not provided in this manual.

Annex VI provides additional information on Geophysical and Seismological Monitoring techniques.

3.2.3 Built environment

The built environment refers to all marine and terrestrial human-made structures ranging from residential or commercial buildings to water supply or energy networks and coastal protection structures. Assessing damage to structures and lifelines is important for understanding tsunami forces and to developing design and planning guidelines. Damage is influenced by the flow of water that causes drag and uplift forces, the funnelling of flows between structures, and the cycling of tsunami surges through flood and drawdown. Surveys of tsunami impacts on structures require an understanding of the architectural and structural elements of the structures impacted and recognition of the variety of ways in which a tsunami can cause damage including buoyancy, debris impact, scour, and the internal pressures produced when a tsunami repeatedly floods a structure and then recedes. If the tsunami was caused by an earthquake, seismic effects such as ground shaking and liquefaction may complicate the analysis of damage. ITSTs should strive to separate damage from tsunamis from damage from other processes (e.g., earthquake, landslide, etc.), especially foundation damage from liquefaction, scour, etc. When possible, collecting ‘before’ photos of the impacted area can improve damage assessments.

Further information is provided in Annex VII.

3.2.4 Tsunami geology

Geologic effects relevant to tsunamis include changes to the land surface such as uplift and subsidence and the impacts of the tsunami flow including scour and deposition. Subduction zone earthquakes and landslides are likely to cause changes in the ground-level surface and measuring areas of uplift, subsidence and identifying other geologic features such as fractures or surface faulting may help to constrain the tsunami source characteristics. Land-level changes that occur coincident with or shortly after the source event may also affect the vulnerability of the area to the tsunami surges. ITSTs looking at land-level changes should have geotechnical expertise in order to recognize the difference between earthquake- and tsunami-caused impacts on the landscape. Interviews with eyewitnesses and coastal residents may help to gather anecdotal evidence of changes in land elevation and coastal landscapes. See the section below on interviews for more information and Annex VIII.

There is great value to mapping, investigating and recording geological deposits left by tsunamis – both those associated with the event in question and palaeotsunamis where these might be identifiable. Analysing deposits can provide important information about the flow on land and help in the interpretation of palaeotsunami deposits both locally and in other parts of the world. Care needs to be taken to distinguish tsunami deposits from other sedimentary material such as beach sands and storm deposits. ITSTs measuring and collecting tsunami deposits need to follow careful collection and measuring protocols so that data is not contaminated – see Annex VIII.

As part of the survey of the contemporary deposits it is reasonably simple to add a module for an initial study of possible palaeotsunami deposits. While the time available is unlikely to allow a comprehensive core and trench study, it may be possible to gather suitable core data through gouge coring, D-corer or vibracoring coupled with a study of deeper trench records where a mechanical digger is available.

Further information is provided in Annex VIII.

3.2.5 Ecosystem and biological impacts

Researchers have been aware that tsunamis affect both marine and terrestrial ecosystems for some time, but only in recent years has the systematic approach to studying such changes been included in ITSTs (McAdoo *et al.,* 2011). The study of the ecological impacts is important not only for a more complete understanding of tsunamis, but also for issues related to coastal protection, economic impacts and recovery. Such work may help address the following:

- How natural coastal systems and human modifications may exacerbate or reduce impacts;
- The economic impacts of a tsunami as well as contaminants and other urban releases in to the environment for populations that rely on coastal activities for their livelihood; and
- How rapidly ecosystems recover.

The ecosystems, and the reliance of people on these ecosystems, will vary between tropical and temperate climates and between countries and regions. The environmental and biophysical data that should be obtained in these regions will also differ, however the tools for collection are largely the same. Marine and terrestrial features that can reflect, refract, or diffuse tsunami energy should be mapped, along with vegetation that can stabilize sediment. In the offshore, these might include coral reefs (tropical), oyster reefs (temperate), and seagrass beds, mapped by high-resolution satellite data and marine geophysical surveying, ground-truthed and quantified by swim-transects. On land, intertidal mangroves as well as supratidal dune grasses, and coastal forests and other vegetation must be considered.

A challenge in assessing the damage to the ecosystems is to determine the pre-tsunami condition of the coupled human-environment system. Pre- and post-satellite imagery can often be used to look at the changes in offshore features such as coral reef, seagrass beds, sand bars and should be examined in the context of onshore runup and damage. Intertidal and terrestrial ecosystems such as mangroves, salt marsh, dunes, etc. should be similarly investigated. Identification of past or ongoing ecological research efforts in a region that may pertain to these studies requires that ITSTs reach out to the national and international environmental sciences community that often is not aware of or been included in tsunami research efforts.

It is important to identify existing studies that may be available to provide a base-line to measure tsunami impacts and recovery. These studies may be in disciplines that are not typically involved with tsunamis such as ecology, wildlife, and fisheries and it is important for ITSTs to query diverse academic communities for the availability of such studies.

Further information is provided in Annex IX.

3.2.6 Eyewitness observations

No ITST effort is complete without knowing how the tsunami impacted humans and human activities. Interviews with eyewitnesses and survivors, both formal and informal, are essential to a full understanding of the event and for meaningful tsunami risk-reduction programmes. Talking to people can yield critical information about:

- Tsunami characteristics – water height, timing of surges;
- How people responded to natural warnings;
- How people received official warning messages and how they responded and why;
- Evacuation behaviour including triggers and routes;
- Pre-event awareness and preparedness;
- Effectiveness of response and relief efforts; and
- Where to get additional information such as photographs and videos, local resources, or other important eyewitnesses accounts.

There are many different types of interviews. Some research groups may want to ask a fixed set of questions to a large sample of people. Others may take a more open approach, or will wish to document individual survivor stories. In a typical ITST conducted soon after the tsunami, it is generally not possible to conduct statistically-significant social science surveys; however, informal surveys can identify general themes and issues for more robust studies conducted later.

There are a number of aspects of interviewing people that are common to almost all cultures.

- When talking to groups of people, a group dynamic may develop where everyone agrees with a particular version of events. In some cultures this may be related to gender or status. It is always desirable to get multiple perspectives from different people.
- It is important to genuinely listen to what a person is saying. This can be frustrating to a team who may only be interested in a specific piece of information such as how high the water reached. For a survivor, sharing observations has an emotional cost and it is never appropriate to cut off an interview because the specific goal has been obtained.
- Initial versions of an account are often incomplete and may reflect the interviewee's desire to report what they think the group wishes to hear. Allowing the person to take their time, or even recounting specifically what they did during the event, may result in more complete and accurate data.
- Many eyewitnesses are willing to recount their experiences when approached in a culturally sensitive way; however it is important not to push an unwilling respondent and to make it clear that they are free to stop the interview process whenever they wish.
- Information provided by eyewitnesses tends to converge on a common opinion due to media and community influences in the weeks after an event, making early interviews

critical. Consequently, information should be field verified with the eyewitness if possible. The latter step may sometimes result in realizing that the "eyewitness" was not present at the location or not able to actually observe the ocean.

More information about specific interview techniques and sample interview templates are included in Annex X.

3.2.7 Social, human and economic impacts

The goal of ITST efforts is to reduce losses and enhance resiliency in coastal areas that have been or may be affected by future tsunamis. The United Nations International Strategy for Disaster Reduction (UN/ISDR) has recognized that disasters are ultimately a social construct and that understanding the human system in all its many parts is as important as the understanding of the physical and technological aspects of potential events. This requires that experts from many discipline fields including, but not limited to, human geography, sociology, economics, planning, policy and decision-making, risk and emergency management, anthropology, human health, political sciences, Indigenous studies, history, religious studies. These experts should be encouraged to participate in an ITST where appropriate.

The types of data collected by such experts cover a broad range including (but not limited to):

- Disaster demographics including casualties, injuries, displaced and sheltered, etc.;
- Direct and indirect economic losses;
- Pre-event planning, mitigation efforts, preparedness and capacity;
- Evacuation behaviour;
- Risk perception; and
- Response, relief and recovery planning.

This manual does not seek to be prescriptive nor can it be exhaustive given the range of social, human and economic sciences that could be involved in an ITST. Experts from such disciplines will know the latest, best and most appropriate data collection tools, methods and approaches to be used. Other post-event assessment teams will likely be working in the affected regions and such teams will also comprise human and socio-economic researchers under the guise of host government agencies, professional organizations, and/or international organizations such as the World Bank, Asian Development Bank, the UNDP and so forth. It is strongly recommended that ITSTs should, wherever possible, work collaboratively with such teams to avoid duplication of efforts and to find opportunities to pursue additional avenues of human and socio-economic research that takes into account the expertise of ITST members.

Annex XI provides some basic guidelines on undertaking human system focused work as part of an ITST.

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Annex I – Past International Tsunami Survey Team surveys, dates and locations

Table I.1 provides a list of post-tsunami surveys undertaken since 1992 and these surveys are located in Figure I.1. Figure I.2 shows the spatial distribution of 2004 Indian Ocean surveys. The references listed are published peer-reviewed articles. Surveys were conducted for the 1994 Alaska, 2010 Mentawai, Indonesia tsunamis, but there were no published articles.

Table I.1. International Tsunami Survey Team reconnaissance after tsunami events

Date of tsunami	Location of event	Published references associated with post-tsunami surveys
1992 Sep. 2	Nicaragua	Satake, K., J. Bourgeois, K. Abe, K. Abe, Y. Tsuji, F. Imamura, Y. Iio, H. Katao, E. Noguera and F. Estrada (1993). Tsunami field survey of the 1992 Nicaragua earthquake. *Eos*, **74**, 145–157. doi:10.1029/93EO00271 Piatanesi, A., S. Tinti and I. Gavagni (1996). The slip distribution of the 1992 Nicaragua Earthquake from tsunami runup data. *Geophysical Research Letters*, **23**, 37–40. doi:10.1029/95GL03606
1992 Dec. 12	Flores, Indonesia	Imamura, F., E. Gica, T. Takahashi and N. Shuto (1995). Numerical simulation of the 1992 Flores tsunami: Interpretation of tsunami phenomena in northeastern Flores Island and damage at Babi Island. *Pure and Applied Geophysics*, **144**, 555-568. doi:10.1007/BF00874383 Tsuji, Y., H. Matsutomi, F. Imamura, M. Takeo, Y. Kawata, M. Matsuyama, T. Takahashi, and S.P. Harjadi (1995). Damage to coastal villages due to the 1992 Flores Island earthquake tsunami. *Pure and Applied Geophysics*, **144**, 481-524. doi:10.1007/BF00874380
1993 Jul. 12	Okushiri, Japan	Abe, K. (1995). Modeling of the runup heights of the Hokkaido-Nansei-Oki tsunami of 12 July 1993. *Pure and Applied Geophysics Pure and Applied Geophysics*, **144**, 735-745. doi:10.1007/BF00874392 Oh, I. and A. Rabinovich (1994). Manifestation of Hokkaido Southwest (Okushiri) Tsunami (12 July 1993) at the coast of Korea. *The International Journal of the Tsunami Society*, **12**, 93-116. http://library.lanl.gov/tsunami/00394725.pdf Shimamoto, T., A. Tsutsumi, E. Kawamoto, M. Miyawaki and H. Sato (1995). Field survey report on tsunami disasters caused by the 1993 Southwest Hokkaido earthquake. *Pure and Applied Geophysics*, **144**, 665-691. doi:10.1007/BF00874389 Shuto, N. and H. Matsutomi (1995). Field survey of the 1993 Hokkaido Nansei-Oki earthquake tsunami. *Pure and Applied Geophysics*, **144**, 649-663. doi:10.1007/BF00874388
1994 Jun. 2	Java, Indonesia	Dawson, A.G., S. Shi, S. Dawson, T. Takahashi and N. Shuto (1996). Coastal sedimentation associated with the June 2nd and 3rd, 1994 tsunami in Rajegwesi, Java. *Quaternary Science Reviews*, **15**, 901–912. doi:10.1016/S0277-3791(96)00059-5

Date of tsunami	Location of event	Published references associated with post-tsunami surveys
(1994 Jun. 2)		Maramai, A. and S. Tinti (1997). The 3 June 1994 Java Tsunami: A Post-Event Survey of the Coastal Effects. *Natural Hazards*, **15**, 31-49. doi:10.1023/A:1007957224367 Synolakis, C., F. Imamura, Y. Matsutomi, S. Tinti, B. Cook, Y.P. Chandra and M. Usman (1995). Damage, conditions of East Java Tsunami of 1994 analyzed. *Eos*, **76**, 257. doi:10.1029/95EO00150 Tsuji, Y., F. Imamura, H. Matsutomi, C. Synolakis, P. Nanang, Jumadi, S. Harada, S. Han, K. Arai and B. Cook (1995). Field survey of the East Java earthquake and tsunami of June 3, 1994. *Pure and Applied Geophysics*, **144**, 839-854. doi:10.1007/BF00874397
1994 Oct. 4	Kuril Islands, Russia	Yeh, H., V. Titov, V. Gusiakov, E. Pelinovsky, V. Khramushin and V. Kaistrenko (1995). The 1994 Shikotan earthquake tsunamis. *Pure and Applied Geophysics*, **144**, 855-874. doi:10.1007/BF00874398
1994 Nov. 3	Alaska, USA	Kulikov, E.A., A.B. Rabinovich, R.E. Thomson and B.D. Bornhold (1996), The landslide tsunami of November 3, 1994, Skagway Harbor, Alaska. *Journal of Geophysical Research*, **101**, 6609–6615. doi:10.1029/95JC03562
1994 Nov. 14	Mindoro, Philippines	Imamura, F., C. Synolakis, E. Gica, V. Titov, E. Listanco and H. Lee (1995). Field survey of the 1994 Mindoro Island, Philippines tsunami. *Pure and Applied Geophysics*, **144**, 875-890. doi:10.1007/BF00874399
1995 Oct. 9	Mexico	Borrero, J., M. Ortiz, V. Titov and C. Synolakis (1997). Field survey of Mexican tsunami produces new data, unusual photos. *Eos*, **78**, 85–88. doi:10.1029/97EO00054
1996 Feb. 17	Biak, Indonesia	Matsutomi, H., N. Shuto, F. Imamura and T. Takahashi (2001). Field Survey of the 1996 Irian Jaya Earthquake Tsunami in Biak Island. *Natural Hazards*, **24**, 199-212. doi:10.1023/A:1012042222880 Pelinovsky, E., D. Yuliadi, G. Prasetya and R. Hidayat (1997). The 1996 Sulawesi Tsunami. *Natural Hazards*, **16**, 29-38. doi:10.1023/A:1007904610680
1996 Feb. 21	Southern Peru	Bourgeois, J., C. Petroff, H. Yeh, V. Titov, C. Synolakis, B. Benson, J. Kuroiwa, J. Lander and E. Norabuena (1999). Geologic Setting, Field Survey and Modeling of the Chimbote, Northern Peru, Tsunami of 21 February 1996. *Pure and Applied Geophysics*, **154**, 513-540. doi:10.1007/s000240050242
1998 Jul. 17	Sissano, Papua New Guinea	Kawata, Y., B. Benson, J. Borrero, H. Davies, W. deLange, F. Imamura, H. Letz, J. Nott and C. Synolakis (1999). Tsunami in Papua New Guinea was as intense as first thought, *Eos*, **80**, 101–105. doi: 10.1029/99EO00065

Date of tsunami	Location of event	Published references associated with post-tsunami surveys
(1998 Jul. 17)		Lynett, P., J. Borrero, P. Liu and C. Synolakis (2003). Field Survey and Numerical Simulations: A Review of the 1998 Papua New Guinea Tsunami. *Pure and Applied Geophysics*, **160**, 2119-2146. doi:10.1007/s00024-003-2422-0 Synolakis, C., J-P. Bardet, J. Borrero, H. Davies, E. Okal, E. Silver, S. Sweet and D. Tappin (2002). The slump origin of the 1998 Papua New Guinea Tsunami. *Proceedings of the Royal Society* Series A, **458**, 763-789. doi:10.1098/rspa.2001.0915 Dengler, L. and J. Preuss (2003). Mitigation Lessons from the July 17, 1998 Papua New Guinea Tsunami. *Pure and Applied Geophysics*, **160**, 2001-2031. doi:10.1007/s00024-003-2417-x
1999 Aug. 17	Izmit, Turkey	Altinok, Y., S. Tinti, V. Alpar, A. Yalciner, S. Ersoy, E. Bortolucci and A. Armigliato (2001). The Tsunami of August 17, 1999 in Izmit Bay, Turkey. *Natural Hazards*, **24**, 133-146. doi:10.1023/A:1011863610289 Yalciner, A., Y. Altinok, C. Synolakis, J. Borrero, F. Imamura, S. Ersoy, U. Kuran, S. Tinti, M. Eskijian, J. Freikman, Y. Yuksel, B. Alpar, P. Watts, U. Kanoglu and J-P. Bardet (2000). Tsunami Waves in Izmit Bay. *Earthquake Spectra*, **16**, 55-62. doi:10.1193/1.1586146
1999 Sep. 13	Fatu-Hiva, French Polynesia	Okal, E., G. Fryer, J. Borrero and C. Ruscheral (2002). The landslide and local tsunami of 13 September 1999 on Fatu Hiva (Marquesas Islands; French Polynesia). *Bulletin de la Société Géologique de France*, **173**, 359-367. doi:10.2113/173.4.359
1999 Nov. 26	Vanuatu	Caminade, P., D. Charlie, U. Kanoglu, S. Koshimura, H. Matsutomi, A. Moore, C. Ruscher, C. Synolakis and T. Takahashil (2000). Vanuatu earthquake and tsunami cause much damage, few casualties. *Eos*, **81**, 641–647. doi:10.1029/EO081i052p00641-02
2001 Jun. 23	Southern Peru	Dengler, L., J. Borrero, G. Gelfenbaum, B. Jaffe, E. Okal, M. Ortiz and V. Titov (2003). Tsunami. *Earthquake Spectra*, **19**, 115-144. doi:10.1193/1.1737247 Okal, E., L. Dengler, S. Araya, J. Borrero, B. Gomer, S. Koshimura, G. Laos, D. Olcese, M. Ortiz, M. Swensson, V. Titov and F. Vegas (2002). Field Survey of the Camaná, Perú Tsunami of 23 June 2001. *Seismological Research Letters*, **73**, 907-920. doi:10.1785/gssrl.73.6.907
2002 Sep. 8	Wewak, Papua New Guinea	Borrero, J., J. Saiang, B. Uslu, J. Freckman, B. Gomer, E. Okal and C. Synolakis (2003). Field Survey and Preliminary Modeling of the Wewak, Papua New Guinea Earthquake and Tsunami of 9 September 2002. *Seismological Research Letters*, **74**, 393-405. doi: 10.1785/gssrl.74.4.393

Date of tsunami	Location of event	Published references associated with post-tsunami surveys
2004 Nov. 21	Les Saintes, Guadeloupe	Zahibo, N., E. Pelinovsky, E. Okal, A. Yalciner, C. Kharif, T. Talipova and A. Kozelkov (2005). The earthquake and Tsunami of November 21, 2004 at Les Saintes, Guadeloupe, Lesser Antilles. *Science of Tsunami Hazards*, **23**, 25-39. http://library.lanl.gov/tsunami/ts231.pdf
2004 Dec. 26	Sumatra, Indonesia, Indian Ocean	Borrero, J., C. Synolakis and H. Fritz (2006). Northern Sumatra Field Survey after the December 2004 Great Sumatra Earthquake and Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 93-104. doi:10.1193/1.2206793 Choowong, M., N. Murakoshi, K. Hisada, P. Charusiri, V. Daorerk, T. Charoentitirat, V. Chutakositkanon, K. Jankaew and P. Kanjanapayont (2007). Erosion and Deposition by the 2004 Indian Ocean Tsunami in Phuket and Phang-nga Provinces, Thailand. *Journal of Coastal Research*, **23**, 1270-1276. doi:10.2112/05-0561.1 Dominey-Howes, D. and M. Papathoma (2007). Validating a Tsunami Vulnerability Assessment Model (the PTVA Model) Using Field Data from the 2004 Indian Ocean Tsunami. *Natural Hazards*, **40**, 113-136. doi:10.1007/s11069-006-0007-9 Fritz, H. and J. Borrero (2006). Somalia Field Survey after the December 2004 Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 219-233. doi:10.1193/1.2201972 Fritz, H. and E. Okal (2008). Socotra Island, Yemen: field survey of the 2004 Indian Ocean tsunami. *Natural Hazards*, **46**, 107-117. doi:10.1007/s11069-007-9185-3 Fritz, H., J. Borrero, C. Synolakis and J. Yoo (2006). 2004 Indian Ocean tsunami flow velocity measurements from survivor videos. *Geophysical Research Letters*, **33**, Issue 24, L24605. doi:10.1029/2006GL026784 Fritz, H., C. Synolakis and B. McAdoo (2006). Maldives Field Survey after the December 2004 Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 137-154. doi:10.1193/1.2201973 Goff, J., P. Liu, B. Higman, R. Morton, B. Jaffe, H. Fernando, P. Lynett, H. Fritz, C. Synolakis and S. Fernando (2006). Sri Lanka Field Survey after the December 2004 Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 155-172. doi:10.1193/1.2205897 Ioualalen, M., E. Pelinovsky, J. Asavanant, R. Lipikorn and A. Deschamps (2007). On the weak impact of the 26 December Indian Ocean tsunami on the Bangladesh coast. *Natural Hazards and Earth System Sciences*, **7**, 141-147. doi:10.5194/nhess-7-141-2007 Jaffe, B., J. Borrero, G. Prasetya, R. Peters, B. McAdoo, G. Gelfenbaum, R. Morton, P. Ruggiero, B. Higman, L. Dengler, R.

Date of tsunami	Location of event	Published references associated with post-tsunami surveys
(2004 Dec. 26)		Hidayat, E. Kingsley, W. Kongko, Lukijanto, A. Moore, V. Titov and E. Yulianto (2006). Northwest Sumatra and Offshore Islands Field Survey after the December 2004 Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 105-135. doi:10.1193/1.2207724 Kench, P., R. McLean, R. Brander, S. Nichol, S. Smithers, M. Ford, K. Pamell and M. Aslam (2006). Geological effects of tsunami on mid-ocean atoll islands: The Maldives before and after the Sumatran tsunami. *Geology*, **34**, 177-180. doi:10.1130/G21907.1 Kurian, N., T. Prakash, M. Baba and N. Nirupama (2006). Observations of Tsunami Impact on the Coast of Kerala, India. *Marine Geodesy*, **29**. doi:10.1080/01490410600748301 Liu, P., P. Lynett, H. Fernando, B. Jaffe, H. Fritz, B. Higman, R. Morton, J. Goff and C. Synolakis (2005). Observations by the International Tsunami Survey Team in Sri Lanka. *Science*, **308**, 1595. doi:10.1126/science.1110730 Okal, E., H. Fritz and A. Sladen (2009). 2004 Sumatra-Andaman Tsunami Surveys in the Comoro Islands and Tanzania and Regional Tsunami Hazard from future Sumatra Events. *South African Journal of Geology*, **112**, 343-358. doi:10.2113/gssajg.112.3-4.343 Okal, E., A. Sladen and E.A.-S. Okal (2006). Rodrigues, Mauritius, and Réunion Islands Field Survey after the December 2004 Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 241-261. doi:10.1193/1.2209190 Okal, E., H. Fritz, R. Raveloson, G. Joelson, P. Pancoskova and G. Rambolamanana (2006). Madagascar Field Survey after the December 2004 Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 263-283. doi:10.1193/1.2202646 Okal, E., H. Fritz, P. Raad, C. Synolakis, Y. Al-Shijbi and M. Al-Saifi (2006). Oman Field Survey after the December 2004 Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 203-218. doi:10.1193/1.2202647 Papadopoulos, G., R. Caputo, B. McAdoo, S. Pavlides, V. Karastathis, A. Fokaefs, K. Orfanogiannaki and S. Valkaniotis (2006). The large tsunami of 26 December 2004: Field observations and eyewitnesses accounts from Sri Lanka, Maldives Is. and Thailand. *Earth Planets Space*, **58**, 233-241. http://www.terrapub.co.jp/journals/EPS/pdf/2006/5802/58020233.pdf Paris, R., P. Wassmer, J. Sartohadi, F. Lavigne, B. Barthomeuf, E. Desgages, D. Grancher, P. Baumert, F. Vautier, D. Brunstein and C. Gomez (2009). Tsunamis as geomorphic crises: Lessons from the December 26, 2004 tsunami in Lhok Nga, West Banda Aceh (Sumatra, Indonesia). *Geomorphology*, **104**, 59–72. doi:10.1016/j.geomorph.2008.05.040

Date of tsunami	Location of event	Published references associated with post-tsunami surveys
(2004 Dec. 26)		Satake, K., T. Aung, Y. Sawai, Y. Okamura, K. Win, W. Swe, C. Swe, T. Swe, S. Tun, M. Soe, T. Oo and S. Zaw (2006). Tsunami heights and damage along the Myanmar coast from the December 2004 Sumatra-Andaman earthquake. *Earth Planets Space*, **58**, 243–252. http://www.terrapub.co.jp/journals/EPS/pdf/2006/5802/58020243.pdf Synolakis, C. and L. Kong (2006). Runup Measurements of the December 2004 Indian Ocean Tsunami. *Earthquake Spectra*, **22**, 67-91. doi:10.1193/1.2218371 Tsuji, Y., Y. Namegaya, H. Matsumoto, S. Iwasaki, W. Kanbua, M. Sriwichai and V. Meesuk (2006). The 2004 Indian tsunami in Thailand: Surveyed runup heights and tide gauge Records. *Earth Planets Space*, **58**, 223–232. http://www.terrapub.co.jp/journals/EPS/pd. f/2006/5802/58020223.pdf Umitsu, M., T. Charlchai and B. Patanakanog (2007). Effects of landforms on tsunami flow in the plains of Banda Aceh, Indonesia, and Nam Khem, Thailand. *Marine Geology*, **242**, 141–153. doi:10.1016/j.margeo.2006.10.030/ Worachananant, S., R. Carter and M. Hockings (2007). Impacts of the 2004 Tsunami on Surin Marine National Park, Thailand. *Coastal Management*, **35**, 399-412. doi:10.1080/08920750601169667 Yeh, H., M. Francis, C. Peterson, T. Katada, G. Latha, T. Chadha, R. J. Singh and G. Raghuraman (2007). Effects of the 2004 Great Sumatra Tsunami: Southeast Indian Coast. *Journal of Waterway, Port, Coastal and Ocean Engineering*. **133**, Special issue: Tsunami Engineering, 382–400. doi:10.1061/(ASCE)0733-950X(2007)133:6(382)
2005 Mar. 28	Nias, Indonesia	Borrero, J., B. McAdoo, B. Jaffe, L. Dengler, B. Gelfenbaum, B. Higman, R. Hidayat, A. Moore, W. Kongko, Lukijanto, R. Peters, G. Prasetya, V. Titov and E. Yulianto (2011). Field Survey of the March 28, 2005. Nias-Simeulue Earthquake and Tsunami. *Pure and Applied Geophysics*, **168**, 1075-1088. doi:10.1007/s00024-010-0218-6
2006 Jul. 17	Java, Indonesia	Fritz, H., W. Kongko, A. Moore, B. McAdoo, J. Goff, C. Harbitz, B. Uslu, N. Kalligeris, D. Suteja, K. Kalsum, V. Titov, A. Gusman, H. Latief, E. Santoso, S. Sujoko, D. Djulkarnaen, H. Sunendar and C. Synolakis (2007). Extreme runup from the 17 July 2006 Java tsunami. *Geophysical Research Letters*, **34**, L12602. doi:10.1029/2007GL029404
2006 Nov. 15	Kuril Islands, Russia	Levin, B., V. Kaistrenko, A. Rybin , M. Nosov, T. Pinegina, N. Razzhigaeva, E. Sasorova, K. Ganzei, T. Ivel'skaya, E. Kravchunovskaya, S. Kolesov, Y. Evdokimov, J. Bourgeois, B. MacInnes and B. Titzhugh (2008). Manifestations of the tsunami on November 15, 2006, on the central Kuril Islands and results of

Date of tsunami	Location of event	Published references associated with post-tsunami surveys
(2006 Nov. 15)		the runup heights modelling. *Doklady Earth Sciences*, **419**, 335-338. doi:10.1134/S1028334X08020335 MacInnes, B., T. Pinegina, J. Burgeois, N. Razhigaeva, V. Kaistrenko and E. Kravchunovskaya (2009). Field Survey and Geological Effects of the 15 November 2006 Kuril Tsunami in the Middle Kuril Islands. *Pure and Applied Geophysics*, **166**, 9-36. doi:10.1007/s00024-008-0428-3
2007 Apr. 1	Solomon Islands	Fritz, H. and N. Kalligeris (2008). Ancestral heritage saves tribes during 1 April 2007 Solomon Islands tsunami. *Geophysical Research Letters*, **35**, L01607, doi:10.1029/2007GL031654
2007 Apr. 21	Islin, Chile	Naranjo, A. and M. Clavero (2009). Mass movement-induced tsunamis: main effects during the Patagonian Fjordland seismic crisis in Aisén (45°25'S), Chile. *Andean Geology*, **36**, 137-145. http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-71062009000100011&lng=es&nrm=iso
2007 Aug. 15	Southern Peru	Fritz, H., N. Kalligeris, J. Borrero, P. Broncano and E. Ortega (2008). The 15 August 2007 Peru tsunami runup observations and modelling. *Geophysical Research Letters*, **35**, L10604. doi:10.1029/2008GL033494
2007 Sep. 12	Sumatra, Indonesia	Borrero, J., R. Weiss, E. Okal, R. Hidayat, Suranto, D. Arcas. and V. Titov (2009). The tsunami of 2007 September 12, Bengkulu province, Sumatra, Indonesia: post-tsunami field survey and numerical modelling. *Geophysical Journal International*, **178**, 180-194. doi:10.1111/j.1365-246X.2008.04058.x
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2010 Jan. 3	Solomon Islands	Newman, A., L. Feng, H. Fritz, Z. Lifton, N. Kalligeris and Y. Wei (2011). The energetic 2010 MW 7.1 Solomon Islands tsunami earthquake. *Geophysical Journal International*, **186**, 775-781. doi:10.1111/j.1365-246X.2011.05057.x
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Date of tsunami	Location of event	Published references associated with post-tsunami surveys
(2010 Jan. 12)		earthquake, *Pure and Applied Geophysics*, April 2012. doi:10.1007/s00024-012-0479-3
2010 Feb. 27	Chile	Fritz, H., C. Petroff, P. Catalan, R. Cienfuegos, P. Winckler, N. Kalligeris, R. Weiss, S. Barrientos, G. Meneses, C. Valderas-Bermejo, C. Ebeling, A. Papadopoulos, M. Contreras, R. Almar, J. Dominguez and C. Synolakis (2011). Field Survey of the 27 February 2010 Chile Tsunami. *Pure and Applied Geophysics*, **168**, 1989–2010. doi:10.1007/s00024-011-0283-5
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2011 Mar. 11	Tohoku, Japan	Chagué-Goff, C., K. Goto, J. Goff and B. Jaffe (editors) (2012). The 2011 Tohoku-oki tsunami. *Sedimentary Geology*, **282**, 1-374. doi:10.1016/S0037-0738(12)00317-X .[Special issue with a number of studies of the Tohoku Tsunami]. Fritz, H., D. Phillips, A. Okayasu, T. Shimozono, H. Liu, F. Mohammed, V. Skanavis, C. Synolakis and T. Takahashi (2012). The 2011 Japan tsunami current velocity measurements from survivor videos at Kesennuma Bay using LiDAR. *Geophysical Research Letters*, **39**, L00G23. doi:10.1029/2011GL050686 Gokon, H. and S. Koshimura (2012). Mapping of building damage of the 2011 Tohoku earthquake tsunami in Miyagi Prefecture. *Coastal Engineering Journal*, **54**, 125006-1-12. doi:10.1142/S0578563412500064 Goto, K., C. Chague-Goff, S. Fujino, J. Goff; B. Jaffe, Y. Nishimura, B. Richmond, D. Sugawara, W. Szczucinski, D.R. Tappin, R.C. Witter and E. Yulianto (2011). New insights of tsunami hazard from the 2011 Tohoku-oki event. *Marine Geology*, **290**, 46-50. doi:10.1016/j.margeo.2011.10.004 Mori, N., T. Takahashi, T. Yasuda and H. Yanagisawa (2011). Survey of 2011 Tohoku earthquake tsunami inundation and runup, *Geophysical Research Letters*, **38**, L00G14. doi:10.1029/2011GL049210 Satake, K. A.B. Rabinovich, D. Dominey-Howes, and J.C. Borrero (2012). Introduction to ''Historical and Recent Catastrophic Tsunamis in *the World*: Volume I. The 2011 Tohoku Tsunami'. Pure and Applied Geophysics. doi: 10.1007/s00024-012-0615-0 [Special issue with a number of studies of the Tohoku Tsunami]. Sato, S. (editor) (2012). Special Anniversary Issue on the 2011 Tohoku Earthquake Tsunami. *Coastal Engineering Journal*, **54**, doi:10.1142/S0578563412020019 [Special issue with a number of studies of the Tohoku Tsunami].

Date of tsunami	**Location of event**	**Published references associated with post-tsunami surveys**
(2011 Mar. 11)		Shimozono, T., S. Sato, A. Okayasu, Y. Tajima, H.M. Fritz, H. Liu and T. Takagawa (2012). Propagation and Inundation Characteristics of the 2011 Tohoku Tsunami on the Central Sanriku Coast. *Coastal Engineering Journal,* **54**, 1250004, March 2012. doi:10.1142/S0578563412500040 Suppasri, A., S. Koshimura, K. Imai, E. Mas, H. Gokon, A. Muhari and F. Imamura (2012). Damage characteristic and field survey of the 2011 great east japan tsunami in Miyagi prefecture. *Coastal Engineering Journal*, **54**, 125005-1-30, 2012, doi:10.1142/S0578563412500052 Suppasri, A., N. Shuto, F. Imamura, S. Koshimura, E. Mas and A.C. Yalciner (2012). Lessons Learned from the 2011 Great East Japan Tsunami: Performance of Tsunami Countermeasures. Coastal Buildings, and Tsunami Evacuation in Japan, *Pure and Applied Geophysics*. doi 10.1007/s00024-012-0511-7

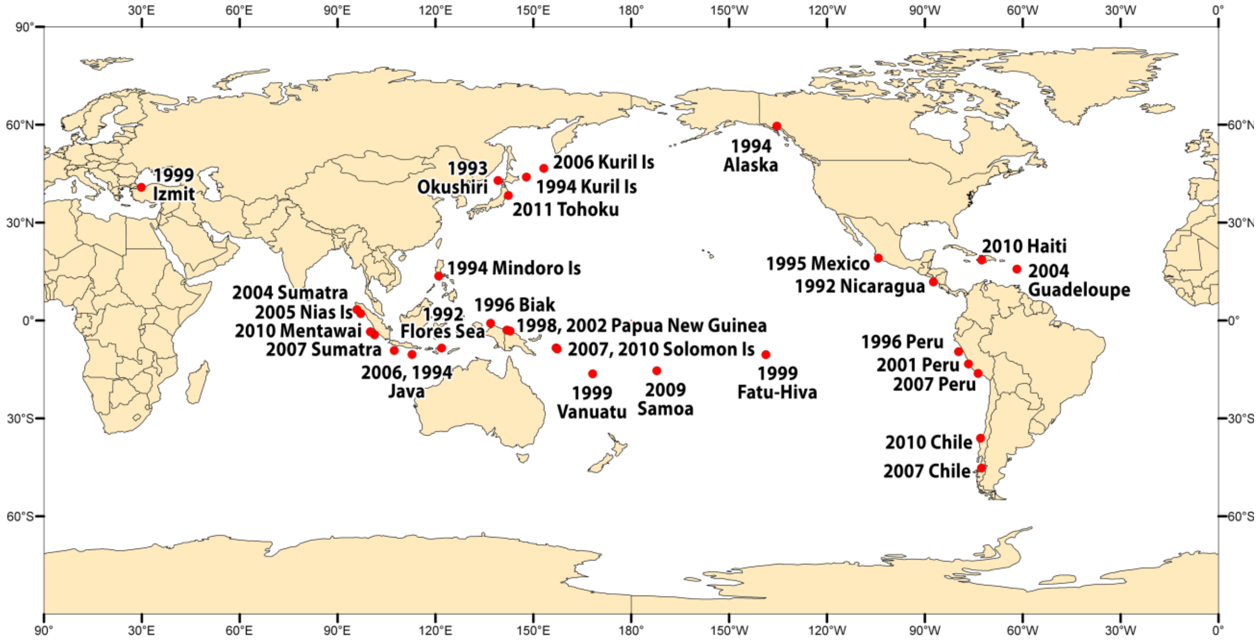

Figure I.1. Spatial distribution (and dates) of ITSTs globally.

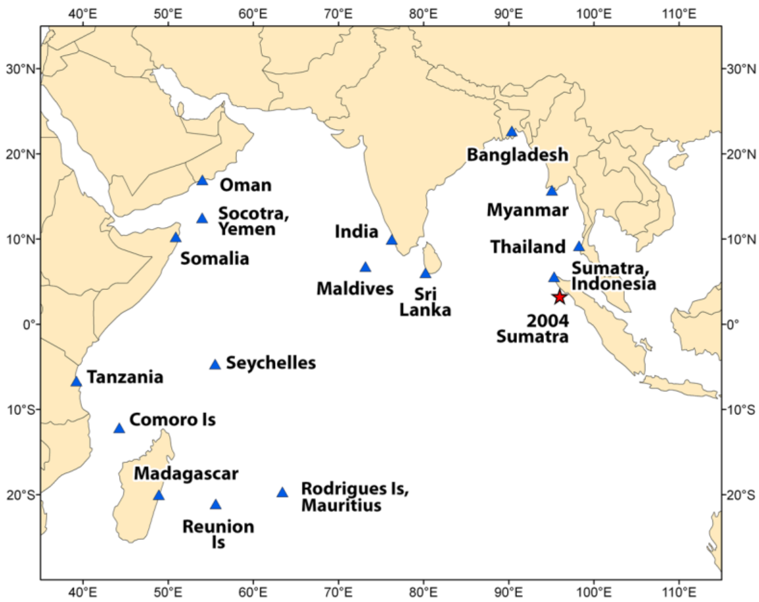

Figure I.2. Spatial distribution of 2004 Indian Ocean surveys.

Annex II – Issues to consider in regard to undertaking an ITST

Scheduling

ITSTs and their Leader should consider the following:

- Survivors of disasters are in a highly stressed condition and authorities and governments and humanitarian agencies are working under difficult circumstances with incomplete information. Their priority is the affected communities – not ITSTs;
- Is there political resistance to allowing an ITST to enter an affected area for a period of time?
- Are there safety issues after a tsunami requiring teams to wait before entering affected areas?
- Resources on the ground to support an ITST will most likely be extremely limited and emergency response has priority;
- What does government of the affected country consider the optimum time for the ITST to enter the affected areas?
- If there is a scientific urgency for ‘rapid’ ITST deployment to an area, only the ITST Leader, together with IOC-UNESCO, should negotiate with the host government to avoid multiple people trying to get ‘authorisation’ and assistance to enter an area.
- Duplication of ITSTs can be avoided through communication with IOC-UNESCO and following the protocols outlined in this manual, with the additional benefit of maximising data acquisition.
- ITSTs should be kept as short as reasonable, while allowing time necessary to gather meaningful data;
- It is important to be flexible about survey timing and understanding of the need for host governments to sometimes shift the ‘ideal’ survey date and reschedule. It can help to communicate effectively with the host government to decide the best date for the survey and what might be the ‘maximum’ size of survey team a region can support.

Access, translation and guide service

Each ITST Leader should inform the ITIC or Host Country Co-ordination Committee, providing the name, position, institution, and photograph of all arriving ITST participants.

The nature and form of any identity badge will be culturally variable and thought should be given to their meaning and likely effects. For example, in some places, the wearing of an ‘official identity badge’ might draw the attention of survivors to survey team members in the expectation that the person wearing the badge can provide immediate disaster response or emergency aid help or official government support. Possible scenarios and solutions should be discussed on a country-by-country basis.

Additionally, each ITST could be provided with an official letter of support signed by the Tsunami National Contact and/or the responsible government organization overseeing post-tsunami impact and damage assessments (in the local language and in English). The letter should identify each participant, the team’s research tasks and will request that person’s assistance in helping the team. The letters may be helpful in situations where official endorsement is required to obtain information.

Communication
Here, the most important to the overall performance of the ITST is highlighted. These should be considered carefully, *prior* to departure in to the field and incorporated into an ITST plan:

- Communication between all ITST members and the host government and its representatives needs to be carefully considered. This communication will most likely be via email. It is suggested to minimise overall communication traffic and adopt protocols regarding communication between specific people/sub-teams. For example, the ITST Leader may take the responsibility to liaise directly with the host government and then passes the information to incoming ITST members;
- Communication between team members once in the field – especially if team members are not returning to a 'base camp' at the end of each day;
- Transportation of team members on a daily basis – how many vehicles are required, where will they be sourced, how long are suitable vehicles available for, who pays for transportation costs;
- Coordination between teams: will there be a 'base camp' at which information is centrally stored and co-ordination decisions can be easily made? Can sub-team leaders have decision-making and co-ordination activities delegated to them?
- Responsibility for organizing logistics for large ITSTs – especially those based at a single 'base camp'. Logistics will need to be carefully planned and modified throughout the survey period to take account of daily needs and team size. This task can be *very* significant and may need a single person allocated to that core task. Who does this and what recognition do they get for their efforts (e.g., co-authorship of publications arising even when they have not collected data)?
- Consider infield safety issues and procedures such as the potential for aftershocks and evacuation in the case of potential further tsunamis.

At the start of the work of an ITST, when there may be multiple teams entering the field simultaneously, it is useful to have an ITST briefing organized by the Host Country Co-ordination Committee and if possible hosted by the Tsunami National Contact. The meeting could be held at the ITST base camp or another location. At this briefing, final team composition can be confirmed, presentations made by host government officials, and the final research tasks decided. If there are coincident research tasks, then it is advised that where possible, efforts are made to minimize duplication of work.

At this briefing, all relevant protocols (including daily activities and briefings and survey, post-survey and end survey reporting) should be detailed.

When there is a base camp that hosts team lodging, daily briefings should be held. These should be:

- At the start of each day, short (circa 15 min), perhaps informal (such as at breakfast) and discuss where the work programme for the day is set;

- At the end of each day, there should be:
    - An evening information briefing by each team to share pertinent observations or field logistics conditions status;
    - Data transfer by a nominated person from each team to the ITST Tsunami Technical Clearinghouse (TTC, shared data repository). The TTC can be local, e.g., external hard drive at the base camp, or remote, e.g., cyber-based through internet connection. All team members must have access to the TTC to ensure

all members have access to all data at the end of the survey. These data will also be made available to ITIC/UNESCO according to their usual data acquisition protocols. It is understood that each volunteer ITST member will have specific research questions that they wish to answer and as volunteers, their right to publish data they have collected must be respected and honoured.

Working in post-disaster situations is stressful and can be upsetting. Team members should be aware of the need to take care of each other, take time to ask if others are ok, take time to sit and listen to each other at the end of each day – formally if needed but definitely informally. Effort should be made to respect each other professionally and to understand everyone's roles and responsibilities as researchers.

Training

Training means at least the following key things:

1 – Disciplinary expertise and relevant training (BEFORE) going in to the field. Volunteering team members should ensure they are trained to do what they want to do or are asked to do by the ITST Leader. Such training might be formal training – e.g., academic research qualifications and/or professional practice (e.g., as a surveyor, geologist, social scientist, engineer, etc.), or it might be very specific training by your own organization in a relevant form.

2 – In the field training. The overall ITST Leader should take responsibility to ensure their field team members are all properly trained to undertake relevant field tasks PRIOR to departure in to the field. The ITST Leader should take responsibility for finding time (perhaps half a day) to make sure everyone understands what they are to do, their role and that all team members are properly prepared. This could include developing a standard template for data collection, practicing levelling, agreeing on the meaning of 'key terms' (e.g., maximum runup, etc.). This is easier to achieve for smaller survey teams. Where a large survey team has been assembled and is broken in to separate research sub-teams (e.g., geologists or engineers, etc.), the 'Sub-team Leader' could be given responsibility for ensuring all members of the sub-team are properly trained and prepared before survey work commences. Again, it may be necessary to spend a few hours practicing tasks prior to survey work beginning.

ITSTs are reminded that they are working in disaster zones. As such, training should include how to respond to ongoing events – e.g., earthquake aftershocks and further tsunami warnings; how to communicate between team members and the base camp if regular communication channels have failed, as well as basic disaster survival techniques.

Consideration should be given to the idea that survey team participants might need some form of 'cultural and/or social' training (orientation) for the specific country in which survey work is being undertaken (see Section 2.1.6). By this, it is meant that a local expert from the host country who is a member of the team should brief all team members (especially international members not from that country) on the basic do's and don'ts of working and behaviour in that region to avoid difficult situations, accidental offence and misunderstandings.

There may be a need for some training and guidance for survey team members on what they should say and do when confronted by local people in the field seeking 'official' government information. Despite best intentions, most survey team members are not trained to provide local survivors with humanitarian guidance, psychological care and alike but might feel under pressure to do so or to help. These issues should be discussed and prepared for prior to the team going in to the field.

Annex III – Suggestions regarding data sharing

Introduction and background

Several, password-protected survey data repositories have been utilized to support the collection and sharing of tsunami data acquired during post-tsunami surveys. These include the US-funded NEES Tsunami Reconnaissance Data Repository implemented after the 2004 Indian Ocean event, and the ITIC-supported ITST-Chile 2010 and Mentawai 2010 clearinghouse sites. The Earthquake Engineering Research Institute (EERI), which sponsors post-earthquake investigations that have also included tsunami impacts, provides an information clearinghouse for reports submitted by survey teams, and supports during-survey contributions through its blog service (Comerio *et al.,* 2003).

The NEES data repository objectives were to preserve key data that would otherwise be scattered or lost, and make data widely accessible via web interfaces and tools in compatible standards so tsunami data could be linked and cross-analysed with related information from other sources. Planned tools included searching, exploring, analysing, and extracting data by survey scientists and the public. The repository was developed by a team of experts in computer technology and tsunami science after the conclusion of the 2004 Indian Ocean Tsunami surveys and with feedback from the survey scientists.

The ITST-Chile and ITST-Mentawai clearinghouse objectives were to serve as a simple but secure information-sharing mechanism for survey scientists and government officials of the affected countries during and immediately after the survey. Survey plans, during-survey progress and data sharing, preliminary field results, and survey final reports could be posted as files and email communication with trusted users was enabled.

In 2002, ITIC worked with the Hawaii State Civil Defense-sponsored Tsunami Technical Review Committee (TTRC), the Hawaii State Earthquake Advisory Committee (HSEAC) and the Pacific Disaster Center to develop a model for a secure post-disaster technical clearinghouse for tsunamis in Hawaii (Kong *et al.,* 2002).

ITST Survey Data Repository/Technical Clearinghouse

During and following field surveys, ITSTs are strongly encouraged to share their findings through a data repository or post-tsunami survey technical clearinghouse (TTC) coordinated by IOC-UNESCO/NOAA International Tsunami Information Center (ITIC). These data will provide guidance for investigators to better plan their field surveys, including areas where more detailed measurements would be valuable. Data should include the following metadata: survey team members; type of data; when, where, and how the data were collected. The preliminary data should also include the processing metadata such as GPS locations, astronomical tide, flow height, type of measurement (water mark or debris in a tree, on a building, wall, etc.). Through the TTC, data are available to other ITSTs but should not be considered public information. The original survey team retains the intellectual property rights to the data. Once the data are finalized, investigators should contribute data to the public, long-term archive.

Clearinghouse minimum requirements

The following are minimum attributes for an ITST Tsunami Technical Clearinghouse:

- Real-time sharing to support disaster response and subsequent surveys
- Secure
- Easy-to-use with flexibility to facilitate in-field reporting/data sharing

Data should as far as possible also include:

- Survey Plan (metadata)
- During Survey status (logistics, findings, survey maps, photos, etc.)
- After Survey Preliminary report (check-out briefing)
- Final report

Data sharing in the field

ITST Leaders, when possible, should provide regular reports to the TTC during their surveys. However, due to the disaster, normal communications infrastructure may be poor or inoperable. In this case, ITSTs are encouraged to develop and utilize satellite-based communications for data collection and sharing. For example, several recent surveys have employed portable hand-held devices to collect data (photos, location, voice notes and measurements) and these data have then been uploaded daily to a remote server. This data collection method provides data backup from the field ensuring that data will not be lost in the case of later mishaps or malfunction of in-field instruments.

Data management and policies

Central to the ITST is the belief that data collected are owned by the investigators themselves and will be proprietary for a length of time to allow them to conduct further research and analyses and publish their results.

After the end of each ITST and its information-sharing through the TTC, it is recommended that each ITST Leader submit all collected tsunami survey data to the ICSU (International Council of Scientific Unions) World Data Service – Marine Geology and Geophysics who are responsible for maintaining the world's long-term tsunami data archive (see below). These data should be submitted as soon as possible, but no later than two (2) years after the data are collected. Inventories (metadata) of all data collected should be submitted to the designated WDS-MGG within sixty (60) days after the survey.

An example Data Management Policy – the USA National Science Foundation

Investigators receiving funds from the US National Science Foundation (NSF) are required to have a data management plan (http://www.nsf.gov/bfa/dias/policy/dmp.jsp). The NSF Grant Proposal Guide requires that proposal project descriptions outline plans for preservation, documentation, and sharing of data, samples, physical collections, curriculum materials and other related research and education products. The general ocean sciences data policy states that principal investigators are required to submit all environmental data collected to the designated National Data Centers as soon as possible, but no later than two (2) years after the data are collected (NSF, 2011). Inventories (metadata) of all marine environmental data collected should be submitted to the designated National Data Centers within sixty (60) days after the observational period/cruise (http://www.nsf.gov/pubs/2011/nsf11060/nsf11060.pdf).

An example data management plan from the NSF Division of Atmospheric and Geospace Sciences is available at: http://www.nsf.gov/geo/geo-data-policies/ags/index.jsp. The 2-page data management form includes questions on the type of data collected, volume of data, if metadata will be included, how the data will be made available to the public, file formats, how long the data will be kept private, and policies for distribution and archiving.

Long-term Tsunami Data Archive

The National Geophysical Data Center (NGDC) and co-located ICSU World Data Service for Geophysics and Marine Geology (WDS) maintain a national and international tsunami data archive (Dunbar *et al.,* 2008). The NGDC-WDS and ITIC work closely together starting immediately after an earthquake or volcanic eruption to collect tsunami event data through eyewitness reports, news, ITST surveys, government reports, published scientific articles, and final reports. The data are considered public information and may be distributed or copied. The archive now consists of:

- A global historical tsunami (event and runup) database
- A global tsunami deposits database
- A Hazards Photos and Videos database
- A Hazards References database
- A Coastal water-level data (i.e., digital tide gauge data and marigrams on microfiche) database; and
- Bottom pressure recorder (BPR) data as collected by Deep-ocean Assessment and Reporting of Tsunamis (DART ®) and tsunameter buoys.

The final field survey data will be assimilated into the global historical tsunami, deposits and damage photos databases.

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Annex IV – Real-time and archived sites for water level information for both coastal tide gauge locations and deep-water sites

Introduction and background to the discipline field and data to be collected

The history of *in situ* tsunami measurements and the present state-of-the-art of international tsunami observing networks as of 2007 were described in detail by Mofjeld (2009). He outlines coastal tide gauges, autonomous pressure gauges deployed in the open ocean, and submarine cable-based pressure systems deployed on or near the continental shelf and slope. This Annex focuses on water-level data that are publicly available in near-real-time. Systems and instruments that are currently used in research or are not available in real-time such as global positioning systems (GPS) on surface buoys (Kato *et al.,* 2011) are not described.

Coastal tide gauge data

Coastal tide gauge data are available from the Global Sea Level Observing System (GLOSS). GLOSS is an international programme conducted under the auspices of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) of the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. The main component of GLOSS is the Global Core Network (GCN) of 289 sea-level stations located around the world that is used for oceanographic sea level monitoring and determining long-term climate change. Near-real-time (up to 30 days) GLOSS data can be displayed and downloaded from the IOC-UNESCO Sea Level Station Monitoring Facility (http://www.ioc-sealevelmonitoring.org/). The sampling rate, transmit intervals and delay times vary. These data have not been quality-controlled or de-tided, but spikes and outliers can be removed in the display. Research quality sea level data are available from the GLOSS designated data centres at the Permanent Service for Mean Sea Level (PSMSL, http://www.psmsl.org/), the British Oceanographic Data Centre (BODC, http://www.bodc.ac.uk/), the University of Hawaii Sea Level Center (UHSLC, http://ilikai.soest.hawaii.edu/uhslc/datai.html) or the data originators. A list of links for several real-time tide gauge data originators is maintained on the National Geophysical Data Center/World Data Service for Geophysics (NGDC/WDS) tide data web page (http://www.ngdc.noaa.gov/hazard/tide.shtml).

Deep-Ocean Assessment and Reporting of Tsunami (DART®) data

The information in this section about the DART® data was taken from the paper by Mungov *et al.,* (2012). Please access this paper for more detailed information on the history, processing, distribution and archive of the DART® data.

In the 1980s, NOAA's Pacific Marine Environmental Laboratory (PMEL, http://www.pmel.noaa.gov/) developed deep-ocean tsunameters for operational early detection, measurement, and real-time reporting of tsunamis in the open ocean based on developments by numerous researchers described by Mofjeld (2009). In 2003, operational responsibility of the DART® network was transitioned from PMEL to the US National Data Buoy Center (NDBC). Each DART® and tsunameter system consists of an anchored seafloor bottom pressure recorder (BPR) and a companion moored surface buoy for real-time communication through an acoustic link. Today, a network consisting of 55 U.S. DART® and internationally owned tsunameter systems is deployed throughout the world oceans (Mungov *et al.,* 2012). NDBC acquires and manages real-time DART® data from all ocean basins and monitors hourly messages containing real-time 15-minute data. An internal tsunami detection algorithm (Mofjeld, 1997) monitors the estimated water level to detect changes in successive 15-second values exceeding a threshold. When the internal detection software identifies an event, the system begins event mode transmission. In event mode, 15-second values are transmitted during the initial few minutes, followed by 1-minute averages. Also, all currently operating tsunameters can be set in event mode by an operator's request. The standard 15-minute and real-time event data are displayed and made available for download in near real-time on the NDBC website (http://www.ndbc.noaa.gov/dart.shtml). Historical data for all ocean basins are accessible from the same NDBC website.

Two types of DART® systems are currently used: Tsunameters of DART® second generation technology (DART® II) store 15-second pressure and temperature measurements on an internal memory card downloaded after unit recovery. The compact DART® Easy-to-Deploy (ETD) system incorporates the same technological features of the DART® II, but is deployed as a disposable unit having an operational life in excess of four years. The DART® ETD bottom unit is not retrieved. Both systems transmit real-time data, but internally recorded 15-second pressure and temperature data from the DART® II systems are available after the BPR unit is retrieved. The 15-second observational data that are downloaded from the internal memory cards of the DART® II tsunameters are sent to NGDC/WDS for processing (NOAA Data Management Committee, 2008). NGDC/WDS archives and distributes the raw, edited and processed data along with the available metadata (http://www.ngdc.noaa.gov/hazard/DARTData.shtml). The archive currently includes raw data from 1983–2001 deployments and processed (calibrated, edited and de-tided) data from 2002–2010 deployments. NGDC/WDS is also now archiving and processing recent significant event-specific DART® data. The event-specific web pages include a tsunami travel time map (Wessel, 2009) that shows which buoys were triggered and links to the highest resolution data that are available for download.

After a tsunami, researchers should first check the NGDC/WDS website to determine if the related DART® data have been processed and archived. If the data are not yet available from NGDC/WDS, they will be available from the NDBC website.

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Annex V – Tsunami modelling and hydrodynamic data

Introduction and background

The objective of a post tsunami field survey from a hydrodynamics point of view is to collect and interpret physical evidence observed in the field and reconstruct the tsunami flow characteristics including water height, inundation extent, current velocity, and timing of wave arrivals in as much detail and over as wide an area as possible. These data can be used for a variety of purposes, including the development and calibration of hydrodynamic models for hazard assessment and real-time forecasting, as well as using established models for tsunami behaviour that will enhance understanding of the tsunami source mechanism. Using numerical models before the survey can help survey teams identify the likely areas of maximum impact and make better decisions of where to go, the survey plan and area needed to be covered, what equipment is needed and other logistical issues.

Survey considerations for collecting hydrodynamic data in an ITST will vary depending upon the scope of the event. In the case of a localized near-field tsunami (i.e. Nicaragua, 1992, Mexico 1995, Peru 2001, Solomon Islands 2010, Haiti 2010 and Mentawai Island 2010, etc.), one small survey team may be able to cover the entire coastal extents of an event in a relatively short amount of time. In larger events, such as the 2004 Indian Ocean Tsunami, 2010 Chile or 2011 Japan, it may take dozens of teams and hundreds of researchers working over a time span of months to completely document the event.

Tsunami modelling

Tsunami modelling is one of the essential components of tsunami studies. Tsunami models solve the governing and boundary equations using the valid numerical methods. Post-tsunami surveys provide invaluable data that can calibrate and validate tsunami models. Tsunami modelling includes the mathematical description of the problem with initial and boundary conditions, appropriate approximations and assumptions, solving the governing equations with reliable numerical techniques, simulating tsunami propagation and coastal amplifications, and computing all necessary tsunami parameters in the impact region.

The main parameters computed by tsunami modelling in relation to post tsunami surveys are:

- Arrival time of first wave (when water level exceeds ± 15 cm at 10 m water depth) and maximum wave (the maximum amplitude near at 10 m water depth). (If no accurate bathymetry is available the coastline can be used as an alternative. If models don’t use inundation schemes appropriate extrapolation to the coastline can be made);
- The wave shape;
- Initial sense of motion of wave (towards land or towards ocean);
- The distributions of maximum positive and negative wave amplitudes near the coastal zone;
- Maximum water level in the inundation zone;
- Inundation distance;
- Maximum water level at the inundation limit;
- Flow depth in the inundation zone;
- The characteristics flow velocities.

To model the tsunami, first it is necessary to define its source mechanism. While most tsunamis are tectonic in origin, landslides, volcanoes and other mechanisms can also cause tsunamis. The complexity and the uncertainty in fault rupture or other tsunami generation processes can cause difficulties in developing tsunami source model and in validation of tsunami propagation models using observed tsunami waveforms recorded at coastal tide stations. This guide primarily addresses tectonic tsunamis. However, modelling has been developed for other types of tsunami sources (Weiss *et al.,* 2009), and the field procedures outlined here are applicable to all types of tsunamis.

For earthquake sources, initial numerical modelling done immediately after the event usually assumes that the fault rupture is terminated almost instantaneously, producing a likewise instantaneous sea surface displacement that is identical to the vertical sea floor displacement. The analytical solution for vertical surface deformation caused by slip on a rectangular fault in an elastic half-space is used to obtain a simple evaluation of co-seismic sea-floor displacement, (e.g., Mansinha and Smylie, 1971 and Okada, 1985). The fault parameters and the mechanisms of fault rupture should be interpreted using tectonic settings and CMT (Centroid Moment Tensor) solutions that are released shortly after the earthquake occurs (e.g. USGS and Global CMT project).

The accuracy of modelling results directly depends on the reliability of the source parameters and the accuracy of the bathymetric and topographic data especially in the shallow and near shore regions. In order to obtain reliable results in tsunami modelling, the shoreline of the model data must fit well with actual shoreline and the bathymetric data used in the model must be based on the accurate measurements and database. Since the early tsunami numerical modelling should have global coverage, bathymetry or the merged bathymetry/topography grids are needed. As of 2013, several bathymetry and topography grids of global coverage are available. Table 1 gives merged bathymetry/topography and digital elevation models (DEM) that can be used for early tsunami numerical modelling.

Table V.1. Specification of digital elevation models and merged bathymetry and topography grids.

	WorldDEM	ASTER GDEM	SRTM3	GTOPO30	GEBCO	ETOPO1
Data	DEM	DEM	DEM	DEM	Merged	Merged
Distribution	EADS	METI/NASA	NASA/USGS	USGS	GEBCO	NGDC
Release year	2014	2009	2003	1996	2008 (recent version)	2008
Spatial resolution	12 m	30 m	90 m	1000 m	30 sec. and 1 min.	1 min.
Accuracy	2 m (relative) 10 m (absolute)	7 - 14 m	10 m	30 m	N/A	N/A
Coverage	Global	83°N to 83°S	60°N to 56°S	Global	Global	Global

The history of tsunami modelling is given in Synolakis and Bernard (2006). There are a number of numerical models in common use. The methods of validation and verification of tsunami numerical models are given in Synolakis *et al.,* (2007). Several research organizations have their own resident numerical models such as the TUNAMI-code (Tohoku University's Numerical Analysis Model for Investigation of Tsunami), MOST (Method of Splitting Tsunami) model from PMEL, NOAA, and FUNWAVE (Shi *et al.*, (2012)). Following most significant tsunami events, researchers will post preliminary results on line typically within hours or a day of the event. These preliminary models can then be used to quantify the magnitude of the tsunami, to estimate the extent of affected area and to guide the post-tsunami survey.

Evaluation of tsunami-affected area for decisions by ITST

The primary objective of the early tsunami numerical modelling is to identify the location and scale of likely impacts by combining the initial numerical modelling results with vulnerability information. Geo-informatics, remote sensing and Geographical Information System (GIS) provide the capability to estimate the exposure of coastal populations and infrastructure to the tsunami. Figure V.1 shows how potential survey sites were identified by integrating LandScan^{TM} population data and modelled tsunami wave heights the 2010 Chilean tsunami. Search criteria identified impacted areas by the co-incidence of 4 m or more of modelled tsunami heights and a coastal population of greater than 1000. The 4 m water height was chosen because the probability of fatalities is significantly increased (Koshimura *et al.,* 2009).

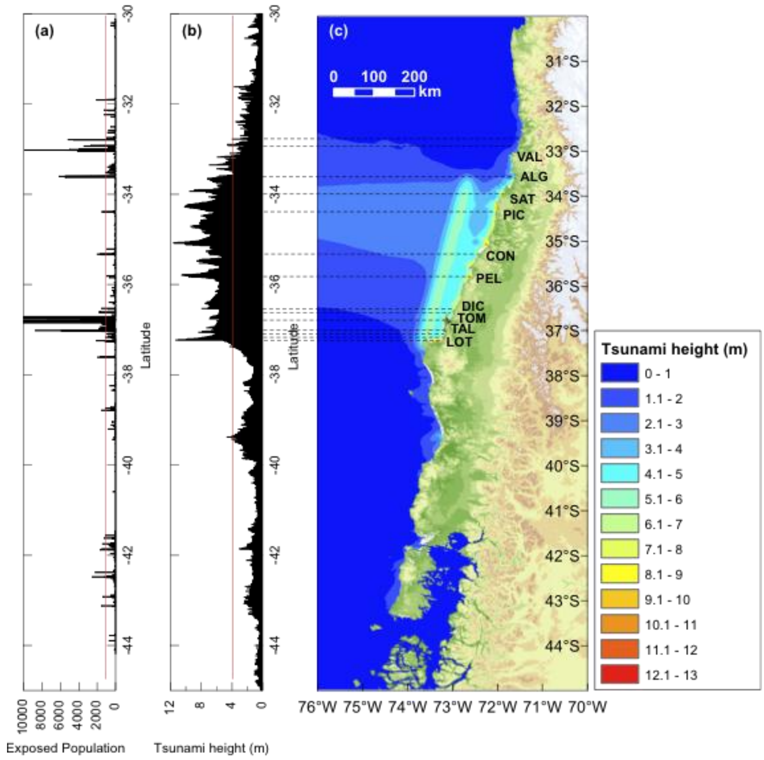

Figure V.1. Population exposure (a), modelled tsunami height (b, c) for the February 27, 2010 tsunami in Chile. The red lines delineate regions where the population exceeds 1000 and the 4 m tsunami water height threshold. Abbreviations as follows; VAL: Valparaiso, ALG: Algarrobo, SAT: San Antonio, PIC: Pichilemu, CON: Constitucion, PEL: Pelluhue, DIC: Dichato, TOM: Tome, TAL: Talcahuano, LOT: Lota).

Other resources such as Google Earth can be used to identify tsunami-affected areas. Numerical model output can be converted to .kmz/.kml files and displayed in the Google Earth's application (Figure V.2). Recently, the Google Crisis Response team took the initiative to assess the severity of disaster by providing updated satellite imagery and maps of affected areas to illustrate infrastructure damage and help relief organizations navigate the affected area.

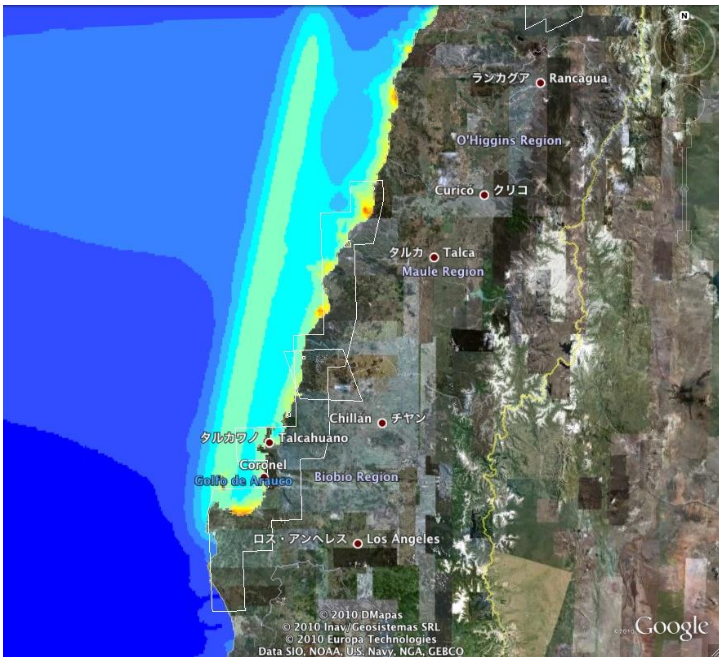

Figure V.2. Superimposing the early tsunami numerical model output on Google Earth's user interface. White rectangles are the post-tsunami satellite footprints reported by Google Crisis Response team.

Using the results of numerical modelling, exposure, and government/media reports, and working with the Host Country Coordination Committee, survey teams can make better decisions on where to go and deploy limited resources.

Glossary / description of discipline specific terms

A number of terms are used to describe the overland flow of the tsunami (Figure V.3). It is essential to use the appropriate term for the types of measurements used. Important quantities include the tsunami flow depth, tsunami height, the runup height and the inundation distance. Runup is the maximum ground elevation wetted by the tsunami on a sloping shoreline. In the simplest case, the runup value is recorded at the maximum inundation distance – the horizontal distance flooded by the wave. Flow depth is the depth of the tsunami flood over the local terrain height while the tsunami height is the total elevation of the water free surface above a reference datum. In some cases where the ground topography is flat, large tsunamis can penetrate for hundreds of metres, and several kilometres inland. In such cases it may not be practical to quantitatively measure inundation distances to the furthest inland extent. In such cases, it is most useful to estimate the tsunami height and flow depths close to the shoreline and as far inland as the conditions and circumstances allow.

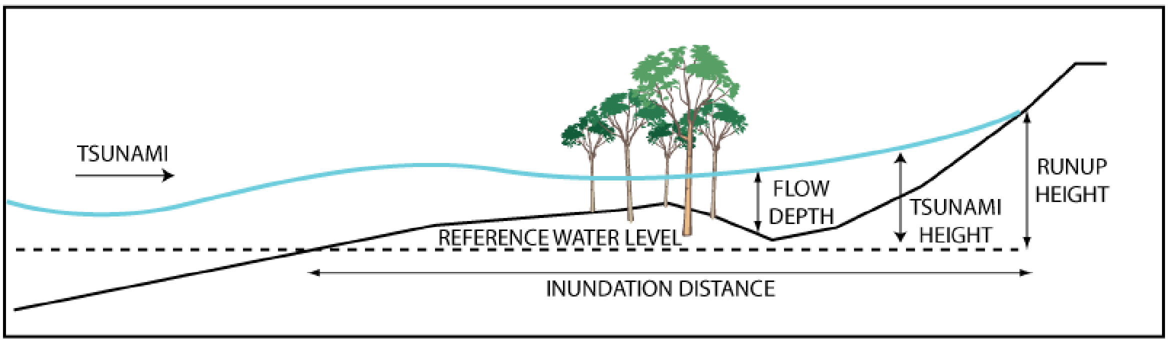

Figure V.3. Tsunami hydrodynamic data terminology.

Current velocity and flow speed data are also important to a complete description of the tsunami characteristics. These data cannot usually be measured directly in the field. However, estimates can often be made from displaced objects and video footage.

List of equipment

Not all workers may have access to the same equipment types. This list is not exhaustive and equally does not require that all items be carried. It offers an element of redundancy and choice. It is recognised that several different types of equipment can achieve the same goal.

Collection of water-level data

To collect water-level and inundation data (i.e. tsunami heights, flow depths runup and inundation distance), the surveyor should be comfortable with the use of levelling equipment. This can include hand-held eye levels, tripod mounted auto-levels, laser-guided total stations or hand-held laser range finders. Each of these pieces of equipment in one way or another allows for a precise quantification of the elevation difference and distance between two points.

Hand-Held Level – Hand-held levels are good for short horizontal distances and moderate elevation differences. A hand level is good to have as a backup, however, its relatively low accuracy and limited capabilities mean it should not be used as a primary tool for data collection.

Optical Auto Level – Optical auto levels are good for measuring elevation changes over longer distances. Optical auto levels can also be used to measure distances when used in conjunction with the stadia marks and a proper surveying rod. Depending on the magnification of the level, distances on the order of 100 m per shot.

Total Station/Laser level – Total stations are relatively complex to use, but with an experienced operator, they can be used effectively to collect large amounts of data over large areas. Total stations are particularly well suited for surveying over flat areas where there may be several water marks visible form one central location. A draw back of the total station is its appetite for power, usually requiring heavy batteries, which can make transport to the site cumbersome and possibly impossible due to airline baggage restrictions on hazardous material. This type of equipment is better sourced through local scientific contacts.

Laser Range Finder – One very quick and effective way to collect accurate water-level data is through the use of laser rangefinders. Ideally, choose a model that has a built in inclinometer and compass. These compact and simple devices can be used without a reflecting prism over shorter distances, as the sensor can pick up reflections off of walls, trees or even people. One must only know the height of the instrument and target to obtain a relative elevation difference. The scale of the runup heights and inundation distances will dictate whether compact hand-held devices are sufficient or higher accuracy monopole mounted instruments are required. Laser Range finders can be used as offset sensors and integrated into fully digital data collection systems with differential GPS sensors (Fritz *et al.,* 2012).

Tripod – Heavy duty aluminium tripods are used to support the auto levels and total stations. They are large and bulky and can be cumbersome to travel with, however they are absolutely vital if working with those types of equipment.

Stadia Rod or **Surveying Rod –** Are generally made from fibreglass and come in 5 m lengths. They a collapsible, but cannot usually be carried as hand luggage.

Other Gear

Dry Bags – for moving equipment between boats and shore.

Strong Adhesive Tape – Silver or clear packing tape. Useful for packing equipment in cardboard or attaching the stadia rod to another piece of luggage for air travel.

Power – Plug adaptors, automobile power inverters, batteries, chargers, extension cords, etc.

Preserve your notes! Use waterproof paper and notebooks. The weather may be bad, you could drop your notebook overboard, be splashed by a wave, or it may simply be hot and you will sweat all over your notes. **Bring good pens!** it is almost impossible to have enough of these. Bring several colours and thicknesses.

Collection of Distance Data

- **Measuring tapes** – can be used, but can be a hassle. They are better for short distances.
- **Auto level and Stadia Rod** – are traditionally used, but are a bit time consuming and require detailed note taking a post processing of field notes.
- **Laser Range Finder** – these can give quick, accurate distances up to ~100 m per shot for handheld devises while up to 600 m per shot are possible with more accurate pole or tripod mounted instruments. See above for examples.
- **Handheld GPS** – with accuracies on the order of 4-10 m, using a hand-held GPS to calculate distance is an acceptable solution for extensive inundation distances of several hundred metres or more. See below for more information on GPS.
- **Car odometer** – If there is road access from the coast to the inundation line, the car odometer can give a quick approximation of the inundation distance.

Collection of Position Data

- **GPS** – Hand held units are ubiquitous these days; most 'smart' phones have them built in as well. It may be desirable to have a dedicated surveying GPS that is capable of displaying local maps, hydrographic or topographic charts. To avoid confusion and misplacing of site locations, ensure that an appropriate standard co-ordinate frame is set-up. This is normally World Geodetic System 84 (WGS 84), but it is worth checking. It is also important to note the time zone the GPS is recording to sync with cameras, notes, etc. Most hand-held GPS units do not have the accuracy to be used to measure vertical distances. However, there are dedicated surveying grade GPS that can attain 10 cm accuracy with data post-processing if GPS base station recording files are available within 100 km of the survey GPS rover.

Collecting Photographic Imagery

Camera: take the best one you can get your hands on with the highest resolution possible and with a good wide lens for overview shots. Be sure to have plenty of memory cards and battery back-up. Set the camera time to the preferred reference (UTC or local) and document this by photographing a GPS time screen. A local time reference has the advantage of jogging the memory when viewing photographs.

Video camera: Useful for recording interviews and audio notes. Note that processing of the video data following the survey can be very time consuming.

Tips on Tsunami Photography

It is advisable to keep a running log of photographs, noting the file number and time each one was taken and if possible an associated GPS location. Newer camera models often have this information contained in the image file metadata, however it is often quite cumbersome to retrieve the information and copy/paste it in to a spreadsheet or other database. If not using a GPS enabled camera, note the GPS location as well as the heading for which the shot was taken. Some cameras will record GPS, but the direction in which the photo was taken is also very important. Many digital cameras allow the user to assign a prefix to their photographs. Particularly for larger teams, it can be useful for each person to assign a unique prefix (e.g. their initials) to their photos. This helps with tracing the photographer when many photos are compiled post-survey. Often it can be just as easy and time efficient to simply note things like 'Photos 38 – 42 taken at location waypoint 33, 3:50 p.m.' It may make life simpler when you get back to the office. Try to sort the photos by location at least daily if not more often. Re-label with relevant information as soon as possible (Figure V.4).

Figure V.4. Field survey of Iwate Prefecture Japan. Georeferenced Photo label is: DSCF0248_5-13-11_Taro Fishing Port_Bridge Deck System Turned Upside Down off Piers Adjacent to Canal Control Structure_RMN.JPG.

Panoramic shots – Often the damage in a particular area cannot be covered in a single frame. Panoramic shots produced by overlaying multiple frames are useful and effective in showing the degree of the tsunami severity (Figure V.5).

Figure V.5. A panoramic view of the western side of Sibigau in the Mentawai Islands, Indonesia, October 2010. Photo is taken from the point of maximum runup.

Aerial Photography – Getting up in the air can provide scientifically valuable and breathtaking views of the tsunami effects (Figure V.6). Getting airborne however can be difficult and is usually quite expensive. However, the access to remote areas and the insight gained from the aerial perspective can be very valuable. Sometimes, serendipitous aerial images can be taken from inbound transport flights; always ask for a window seat. Another option is for the team leader and possibly a member of the Host Country Coordinating committee to take an aerial survey flight prior to starting the survey in order to select locations and pan logistics.

Figure V.6. (left) Helicopter perspective of the west side of Sibigau. (right) Inundation extent in Aliepata on the eastern side of Upolu. This image was taken from the window of an inter-island shuttle flight from Apia to Pago Pago.

Field Methods

Collection of Water Level Data

To collect water level and inundation data (i.e. tsunami heights, flow depths runup and inundation distance), the surveyor should be comfortable with the use of the levelling equipment described above. If possible, water level data should be collected along a shore perpendicular transect to the point of maximum inundation. Topographical elevation and the tsunami flow depth should be recorded at several points along the transect. Topographical measurements should be made at obvious breaks in the coastal topography, where the ground slope has a significant change or where there is a feature of particular interest. Figure V.7 below shows a series of water level transects recorded during a survey of the 2009 Samoa tsunami. Along each transect, topographic relief was recorded as well as indicators of the tsunami water level at various locations.

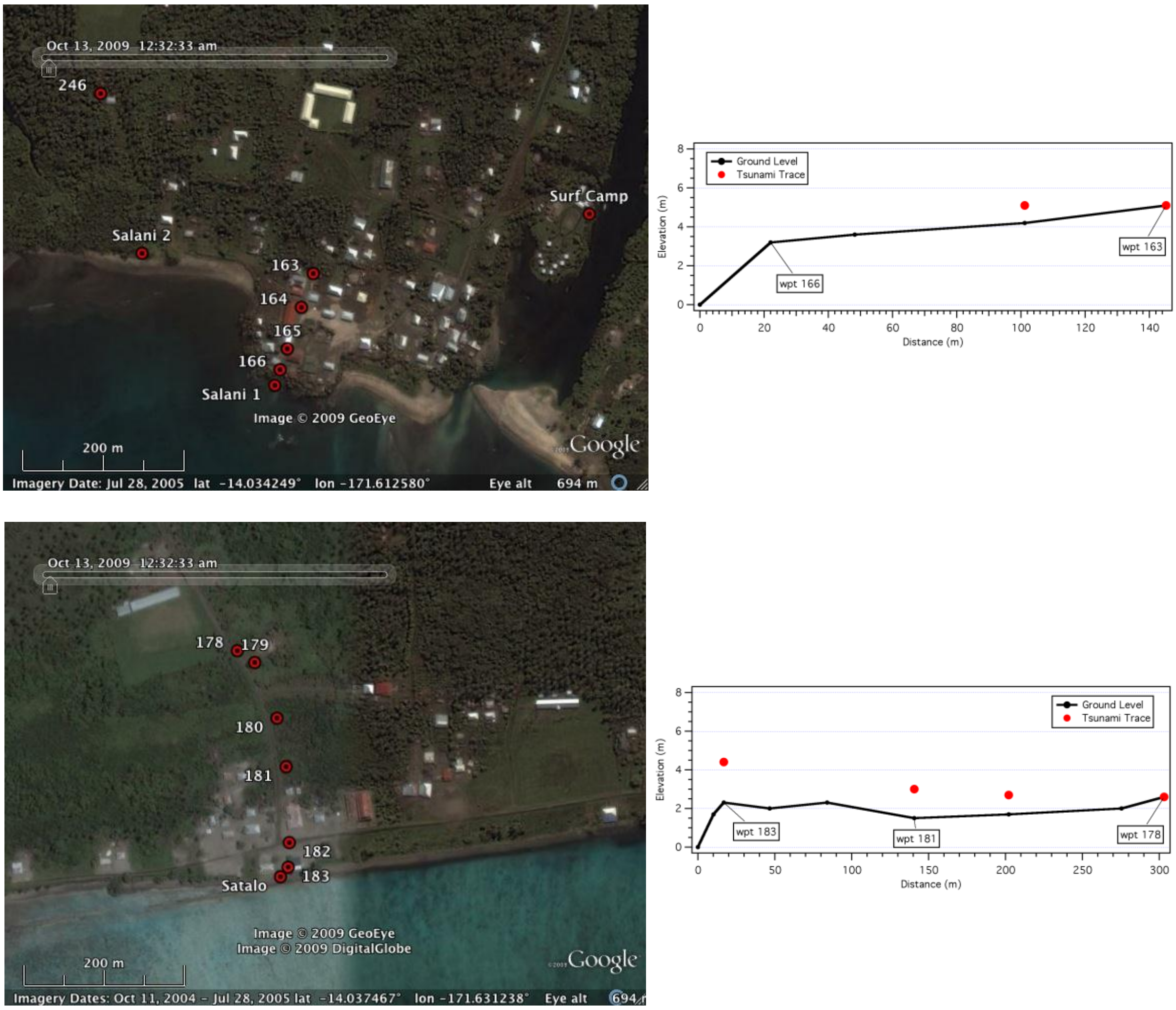

Figure V.7. Water level transects from 2009 Samoa ITST. Sampling locations on left, profiles and water level indicators on right.

Correction for Tide

All collected water-level data must be corrected for tide. It is important to be aware of the tidal conditions at the time of the tsunami and also at the time of the survey. Tidal data can be obtained through the use of tidal prediction software or through standard water levels at nearby reference stations. In some locations, the tidal variation may be small relative to the tsunami height and the correction may be small. Other locations have large tidal ranges and the tidal height can be very important. At higher latitude areas, the tidal stage may make the difference between on-land inundation for modest tsunami events. The duration of the tsunami inundation can also interact with the tidal variation, amplifying or diminishing the destructive capacity of later arrivals in the tsunami wave train. It will be left to the survey team to understand these considerations and accurately account for them in the reporting of the tsunami data.

Identification of Tsunami Traces and Watermarks

Paramount to the collection of tsunami water-level data is the proper identification of tsunami watermarks and traces. In some cases it can be obvious, but in other situations, it can be quite difficult. Care must be taken to ensure that what is being measured is indeed a tsunami flow mark. Tsunami traces can include strand lines of debris, denuded hillsides, debris left on stairs, or broken branches. In the case of broken branches or debris caught in trees, the surveyors should assure themselves that the candidate tsunami mark was caused by the tsunami and not by some other event such as strong winds or storm waves. In tropical areas surveyors should be particularly wary of palm fronts in the tops of other types of trees. Coconut palms can grow to be quite tall and shed their fronds regularly. As such they are often blown around or fall on to the tops of other trees and can be mistaken for a tsunami deposit.

It is important to understand that a visible watermark does not always represent the highest elevation reached by the tsunami. Some of the strongest watermarks are left by trapped water after the largest surges have subsided. Tsunami trace may vary from one side of a structure to the other, and differ between the interior and the exterior. Careful interior examination may be necessary as people may scrub walls to remove marks, but miss hidden surfaces.

Figure V.8. (left) A clearly identifiable tsunami trace in American Samoa, 2009; (mid) Indicators of tsunami flow depth in this example from Niuatoputapu Island, Tonga (2009) – note the scour at the roots broken branches and bark damage and (right) flow depth indicated on a photograph by an eyewitness in Mentawi 2010.

Data Quality and Special Considerations

Field work should be carried out in teams. Team size and composition are best arranged according to the planned mode of transport and availability of measuring equipment. Regular morning and evening group/sub-group discussions are recommended to not only plan the work that needs to be done but also to discuss what has been collected and how. Data sharing and cross-correlation between the work of individuals and teams should help to ensure that quality control is maintained and that data are reliable. There is never enough time to complete all of the work, and there will always be something that is forgotten or poorly recorded; this cannot be avoided, but it can be reduced by repeated data checking. If time permits it is recommended that at least one site be resurveyed/resampled to provide a check on the data collected.

One of the most significant issues in recent immediate post-tsunami research efforts has been the recognition that there tends to be a bias towards recording only the maximum runup and inundation at any one site, or the thickest and most extensive deposits – these are valuable data but only cover a part of the story. If time permits, teams should make efforts to undertake more comprehensive surveys at each site visited. When possible, the surveyors should try to recover a range of tsunami heights.

Teams should not focus only on areas where there was damage or the tsunami was high. It is just as important to document areas where the inundation is modest and to clearly identify the limits of the inundation by validating the absence of a tsunami.

Most hydrodynamic data collected in the field will have some uncertainties associated with them. These uncertainties include instrumental precision, location precision, and variability in the flow. It is suggested that ITSTs discuss the issue of uncertainty and develop field protocols to address it. Some water-level indicators may be very sharp and easy to measure such as a debris line indicating the landward extent of inundation. Other indicators may be more uncertain such as trying to estimate water heights in scattered trees from broken branches or debris.

Conducting Interviews

Fieldwork should include interviews of local residents, fishermen and public officials to gather anecdotal accounts of changes in sea level, coastal landscapes (geomorphology), and damage to reefs. Where possible, interviews should be in video form in order to allow for post-visit analysis. See Annex X for more information.

Collecting Current Velocity Data

It is becoming increasingly likely that eyewitnesses will video tape the tsunami on smart phones and tablets and this video data can be used to estimate current velocities if the location of the camera is precisely known (Fritz *et al.,* 2012). Other sources of direct measurements of currents are from security cameras that are often located in harbour areas. Security camera footage is often erased on a daily or weekly basis so it is important for the Host Country Coordinating Committee to encourage preservation of such footage as soon as possible. Indirect estimates of current velocities can be made from displaced objects, but only when the initial location of the object is precisely known and if it is certain that debris did not contribute to the displacement of object.

Flow Direction Indicators

It is likely the field team will see many indicators of flow direction in the inundation zone. Features may be subtle, such as oriented grass, or pronounced such as tilted and broken trees. In some cases, indicators may show two different directions of flow (Figure V.8) in response to the varying flow regime. Directions should be carefully noted and linked to photographs.

Figure V.8. Two directions of flow indicators, Natori City, Miyagi after the March 11, 2011 tsunami. Note trees in the background displaced to the left and dead grass in the middle displaced to the right.

Remote Sensing Data Collection

High-resolution satellite images can be useful for both pre-trip planning and post event analysis of tsunami affected areas. Since 1999, commercial satellites with high-resolution optical sensors (i.e. IKONOS) have been launched. Many satellites have captured the images of tsunami-affected areas and the imagery used for disaster management activities including emergency response, relief and recovery. Table V.2 shows the specifications of high-resolution optical satellite sensors that can be used for inspecting the affected areas. The highest spatial resolution of optical sensor is about 50 cm (pan-sharpened composite image) and the acquired image has sufficient resolution to identify structural damage. Inspecting the pre- and post-event images can clearly indicate the spatial extent of tsunami affected areas and damage on structures. Figure V.9 is an example of the result of visual inspection of structural damage in Pago Pago, American Samoa using pre- and post-tsunami satellite images from QuickBird which took the images of pre-tsunami (21:43, 24 September 2009 (GMT)) and post-tsunami (four hours after the earthquake occurred, 21:48, 29 September 2009 (GMT)).

Table V.2. Specifications of high-resolution optical satellite sensors.

	QuickBird	WorldView-2	IKONOS	GeoEye-1	SPOT-5	FORMOSAT-2
Organization	DigitalGlobe	DigitalGlobe	GeoEye	GeoEye	CNES	NSPO
Launch Date	Oct. 18 2001	Oct. 8 2009	Sep. 24 1999	Sep. 6 2008	May 4 2002	May 21 2004
Altitude	450 km	770 km	681 km	681 km	832 km	891 km
Revisit frequency	2-3 days	1.1 or 3,7 days	3 days	3 days	2 - 3 days	Daily
Period	93.4 min.	100 min,	98.3 min.	98 min.	101.4 min.	103 min.
Swath Width	16.5 km	16.4 km	11.3 km	15.2 km	60 km	24 km
Sensor bands	PAN MS(4bands)	PAN MS(8bands)	PAN MS(4bands)	PAN MS(4bands)	PAN MS(4bands) SWI	PAN MS(4bands)
Sensor resolution (Pan)	61 cm	46 cm	82 cm	41 cm	2.5 m	2 m
Sensor resolution (MS)	2.4 m	1.8 m	4 m	1.65 m	10.0 m	8 m

Shortly after a major natural disaster occurs, space agencies and space system operators activate emergency satellite observations to contribute to the management of crises arising from natural or technological disasters. The International Charter aims to provide a unified system of space data acquisition and delivery to those affected by natural or man-made disasters. In 2003, UNOSAT (UNITAR operational satellite applications programme) began rapid mapping activity to produce geospatial information in relief and coordination operations in the aftermath of disasters. Mapping efforts of satellite image interpretation and geospatial information significantly contribute on planning survey itinerary and access to the site, in addition to understanding the situation of the affected area.

Figure V.9. An example of the result of visual inspection of pre- and post-tsunami satellite images acquired in Pago Pago, American Samoa (QuickBird). The event occurred at 17:48, 29 September 2009 (UTC). QuickBird satellite successfully took the images of pre-tsunami (21:43, 24 September 2009 (GMT)) and post-tsunami (four hours after the earthquake occurred, 21:48, 29 September 2009 (GMT)).

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Annex VI – Geophysical and Seismological Monitoring Data

Introduction and background

The detailed methods involved with geophysical reconnaissance studies are beyond the scope of this manual. However, some ITSTs may be involved with geophysical investigations as well, and it is important to have a general understanding of the purpose or such studies. Geophysical monitoring and measurements provide information and valuable data to construct an earthquake source model that can be used for the initial conditions of tsunami modelling. These include installing seismometers, GPS receivers or measuring land (or sea) levels or gravity. Note that if such measurements are started after the earthquake, only post-seismic or post-tsunami information can be obtained. It is important to identify areas where geophysical data (such as seismological or geodetic) were taken before the earthquake that caused the tsunami, even if only intermittently or during a short campaign. This can help in the location of instruments for the post-event study and allow a better comparison between pre- and post-event conditions.

Glossary / description of discipline specific terms

Co-seismic change refers to a change in values (e.g., land levels) before and after the earthquake, whereas post-seismic changes refer to those after the earthquake occurrence.

Smaller earthquakes following the main shock are called aftershocks, and can be monitored by installing a set of seismometers. The aftershock distribution usually coincides with the fault area of the main shock or the tsunami source area. The number of aftershocks usually decays with time since the main shock, but it is not unusual for a large aftershock to re-excite the sequence and be followed by a secondary aftershock sequence.

Post-seismic ground deformation is usually smaller and often shows different spatial distribution from that of the co-seismic deformation.

List of equipment

- Seismometer, data logger, battery and/or solar panel, GPS clock
- GPS receivers for geodetic measurements
- Other instruments for measurements (e.g., gravimeter for measuring gravity change, levelling equipment or total station for land (sea) level measurements)

Field Methods

For large or great earthquakes that occur in an area with sparse or no seismic networks, seismological observations to monitor and locate aftershocks will help to understand the main shock. Precise aftershock distributions can be used to estimate the static parameters of the causative fault, such as location, size, depth and dip angle, hence contributes to reliable initial condition of tsunami numerical simulation. In order to accurately locate earthquakes, at least four but ideally more seismic stations must be set up to record aftershocks for weeks to months. Factors to consider for such measurements include site selection (high sensitivity instruments must be set up at hard rock sites), station distribution (to cover the aftershock area), data storage and power supply, protection of instruments from vandalism, and custom clearance of imported instruments. Coordination and collaboration with local and international seismologists are essential for such geophysical measurements.

Data quality and special considerations

Coordination and collaboration with local and international geophysicists and/or seismologists are essential.

Location of instruments and timing of records must be controlled by GPS receiver and clocks, respectively.

Annex VII – Built Environment

Introduction

The built environment includes all the structures and systems resulting from human activity that modify a natural landscape. In coastal areas exposed to tsunamis this may include residential and commercial structures, port and harbour facilities, coastal protection structures, infrastructure for power, communication and transportation systems, navigation, fisheries and agriculture as other landscape-altering activities such as parks and public spaces.

Damage summaries and analyses of impacts on the built environment have many important uses. They can assist in the evaluation of economic losses and in reconstruction planning. Carefully documented observations can be used to improve model-based estimates of structural and non-structural damage. Trained observers can also differentiate the relative impacts of the tsunami and other earthquake-related factors such as ground shaking, liquefaction and surface disruption. One of the most important goals of post-event damage surveys is to recommend building practices and codes that will reduce casualties and damage from future tsunamis.

Typically, ITSTs of the built environment split into sub-groups based on different engineering disciplines: e.g. structural engineers survey buildings, coastal engineers look at ports and shore protection, and geotechnical engineers review foundations and earthworks. It is important that each group coordinate with colleagues from the affected area, not only to enhance the exchange of knowledge, but also to understand the local building practices and historical and cultural contexts. Local colleagues can provide valuable information such as design drawings and plans as well as contacts with community officials in charge of buildings and infrastructure. Within the ITST, all members should discuss the different approaches and practices of their discipline on an equal footing.

The timing of the ITST survey is very important. As in the case of a hydrodynamics survey (Annex V) the team must weigh the need to gather ephemeral data against the disturbance this will cause to the vital rescue and recovery efforts that take place right after a tsunami. One of the first tasks of recovery is to re-establish transportation pathways as well as power and water supply. Often this means that evidence of damage to these systems must be destroyed before repairs can begin. An ITST that looks at bridges must understand that a damaged bridge on a critical roadway may be removed almost immediately to conduct recovery operations. A survey that focuses on coastal protection will have to consider that local erosion near detached breakwaters and groins will change rapidly in the days following a tsunami as sand transport resumes a normal pattern. Other timing considerations are logistics of travel in the affected area and the health and safety of the team. The ITST Leader should work with the Host Country Coordinating Committee to determine an appropriate time for the survey and any efforts that can either assess or document types of damage that cannot be preserved for survey.

List of equipment

The type and amount of equipment that the ITST needs to carry depends to some extent on whether a thorough hydrodynamic survey has already been carried out in the area. A survey of the built environment requires accurate information about flow depth around structures, extent of inundation and, in some instances, runup heights. If these specific details are not known ahead of time, the ITST should be prepared to make these measurements along with their damage assessments. Annex V contains a detailed commentary on the equipment needed to record water-level data for a tsunami and should be consulted for further information on these items.

Equipment for measuring water level includes:

- Handheld level,
- Optical autolevel,
- Laser range finder,
- Total station laser level,
- Stadia or surveying rods.

Additionally the following equipment is recommended to survey the built environment:

- **Camera:** A camera should have the largest megapixel size possible and with a good macro facility for close-up shots. Ideally the camera should automatically record the GPS location for a geo-referenced record of shot locations. Bring plenty of memory cards and battery back-up and consider a download cable for daily backups and downloads (some cameras can download wirelessly or via Bluetooth). Set the camera time to the preferred reference time (UTC or local) and document this by photographing a reference time screen. A local time reference has the advantage of jogging the memory (e.g. I took that sample right after lunch) when viewing photographs.

  Camera Tips: Make note of the heading (compass angle) of the photo for future reference. For view shots, include a person as a reference for visual scale. For close-up shots use an object of known size for scale: e.g. a ruler or a coin. Record the date, location, photographer and reason for taking the photograph, either in field notes, or by changing photo titles as soon as possible after taking them: e.g. "_5-16-11_Sendai Port Facility_Damage_to_Gantry_Container_Crane_RMN.jpg".

- **Global Positioning System (GPS):** To avoid confusion and misplacing of site locations ensure that an appropriate standard co-ordinate frame is set-up. This is normally World Geodetic System 84 (WGS 84), but it is worth checking. It is also important to note the time zone the GPS is recording to sync with cameras, notes, etc.

  GPS Tips: Pre-load topographic maps of the survey area to the GPS unit. This can be helpful for confirming site locations as well as for navigation if road access is interrupted. Consider taking a GPS waypoint that coincides with each photograph even if the camera is GPS enabled.

- **Measuring tapes**: Preferably long (100 m), medium (20-30 m) and short (5 m) tapes. These are useful in measuring and recording the size and characteristics of various structural features. In the absence of GPS or surveying equipment, a simple rod-and-level topographic survey can be achieved using measuring tapes and a long pole.

- **Video camera**: Can be used for interview footage and area overview. Also useful for recording the context for trench/coring work and the nature and extent of erosion, deposition or subsidence. Like a camera – the highest resolution available is preferred.

  Video Tip: Remember that video cameras record audio – simultaneous narration of the video can be very helpful when reviewing the footage while inappropriate commentary will also be recorded.

- **Callipers or a fine scale metal ruler**: These are useful for measuring things like crack widths, reinforcing steel, or dimensions of small parts. Also consider bringing a protractor for estimating angles of structural connections or member failure.

- **Compass and maps**: Consider bringing an analogue compass for backup in the event of a power failure or lack of batteries. Use an appropriate northern or southern hemisphere compass. Topographic and other maps can supplement electronic data and can be marked up easily in the field. Tourist maps can be useful in surveys of the built environment since they usually indicate the functions of many buildings, a feature unavailable on topographic maps.

- **Binoculars** of high quality: These are useful for examining potential sites from a distance or for planning a survey sequence.

- **Plans and specifications** for structures and facilities to be visited, where available.

- **Aerial photographs** of survey areas: If possible obtain views before, and immediately after the tsunami.

- Miscellaneous items:
  - **Sample bags** for small structural parts or sediments,
  - **Power adapters** for charging electronics in a moving vehicle,
  - **Waterproof notebook** and writing implements.

The following safety equipment is also helpful for survey inside damaged structures or in severely impacted areas. It is also sometimes required by the host organization:

  - **Hard hat** – for hanging or loose falling debris,
  - **Steel-toed boots** – for heavy, loose or sharp debris,
  - **Survey vest** in a highly visible colour– for increased visibility to vehicles and construction equipment,
  - **Respiratory protection** – for airborne contaminants from clean-up,
  - **Eye protection** – for hanging debris and dust.

Since each ITST is a specialized team composed of experts, the team members should decide the specific areas that will be addressed by the survey beforehand. As such this summary of field methods is not intended to be prescriptive but presents some of the issues that the ITST should consider during the planning phase.

<u>General considerations</u>

- The ITST members should agree on the specific focus of the survey and the uses of the survey data. For example: is the object to gather thorough and exhaustive data sets at a few selected sites, to survey many sites for a general list of lessons learned, to gather data for model calibration or to scout out areas for further case study?
- As much as possible, documentation of failure and damage should consider the causes of failure (buoyancy, drag or impact forces, soil saturation, combined forces, etc.), the failure mechanisms (buckling, shear, overturning, etc.) as well as the timing of the failure (on-rush, down-rush, multiple wave cycles, etc.).
- Data collection should take into account how the data may be used later to refine numerical models for wave propagation, inundation and flow – structure interactions. For example: any indicators of the flow velocity or water surface variation around structures are important for model refinement.
- It is important to note which structures did not fail as well as those that did fail.
- If the ITST has many members working independently gathering similar data, the team should consider establishing a data template to facilitate the later synthesis and reduction of data. Alternately, if appropriate, there are a number of published protocols for assessing the structural integrity of various facilities (e.g. for a breakwater survey:

ERDC/CERL TR-REMR-OM-26 - Condition and Performance Rating Procedures for Non-rubble Breakwaters and Jetties).

Specific considerations

Structures – Structural damage includes tsunami effects on residential, commercial and public buildings as well as industrial facilities. The building materials for these structures can range from wood and brick to reinforced concrete and structural steel. Tsunami effects can vary widely as well: from damage to windows, interior and exterior walls, structural walls and frame, foundation damage and scouring, right through to total collapse. The level of damage is related to many things including the characteristics, type and location of the structure, erosion and scour levels, deposition and debris accumulation as well as the level of previous damage (from earthquake shaking for example).

Tips:

- Damage in the survey area should be assessed for a sufficient number of similar buildings or structures in the same area – both damaged and undamaged – so that both an average level of damage, the variety of the damage and spatial distribution of damage can be determined properly.
- During the damage survey, pictures should be collected to document findings and should include views of the structure from different angles and sides.
- Record as much as possible about the purpose of use, type, height, size, age, and construction materials used for the structure. Since failed structures are usually rapidly demolished, it is good to recognize and record the kind of data that will not be available to a later survey group e.g. slab thickness, size of reinforcing steel, concrete quality, dimensions and angles of cracks or buckling, evidence of debris impacts, etc.
- The description of a surveyed structure should include the location, address or GPS coordinates, as well as ground elevation, distance to the shoreline, orientation to the incoming waves and existence of and distance to nearby buildings.
- Data on the composition of the ground surrounding the structure as well nearby erosion, deposition or scour should be collected.

Geotechnical Issues – The geotechnical aspects of an ITST survey span a wide range: from inspection of building foundations like footings and piling, review of earthworks such as levees and dams to assessment of slope stability. Some of the methods presented in Annex VIII (Geology) apply well to evaluating large-scale effects of an earthquake and tsunami event like co-seismic uplift and subsidence as well as large area erosion and deposition. Local effects on the built environment like liquefaction, local scour and slumping as well as wave induced flow and pore pressure effects require more specialized engineering knowledge of how the affected structures are designed. An ITST that is conducting a survey of structural foundations and soils should consider the following:

- The survey should coordinate with ITSTs doing geological surveys in the same area to share valuable data and insights.
- On a plan view for each area, the ITST should note both large scale and small scale terrain and earthwork changes and, if possible, determine how and when they occurred. These include uplifted or subsided zones, erosion (scarps, exposed surfaces, slides) and deposition (extent of sand and mud transport), areas of seismically or hydraulically induced liquefaction and local scour or slumping.
- Where scour or slope failure has occurred as a result of flow interaction with a structure, careful measurements should be made to determine the cause and sequence of the failure. For example, was soil removed because it was liquefied by earthquake shaking,

as a consequence of inundation and saturation or by high velocity flows around or over a structure?

Ports and Navigation – Port facilities include large and small boat harbours, marinas, as well as vessel loading, offloading and container storage areas. Both maintained (dredged) and unmaintained navigation channels in the vicinity of the port are considered part of port operations. Additional areas, such as fuel storage facilities, are sometimes also considered. ITSTs investigating ports should consider the issues outlined above under **Structures** and **Geotechnical Issues** sections. The following principal port damages should be documented for any kind of small craft, fishery or large ship harbours in the survey area:

- Damage to port structures,
- Inundation in the port storage area,
- Damages resulting from the parting of vessel moorings,
- Damages resulting from out-of control movements of manoeuvring or unmoored vessels transported by tsunami-induced currents,
- Damages when vessels are lifted out of the water onto piers, quays or port uplands,
- Damages from tsunami-induced transport of containers, vehicles and equipment within the port boundaries,
- Damages due to tsunami-induced sediment scour, deposition, slope failure or liquefaction, and
- Damage or changes to navigation channels bathymetry.

Coastal and River Works – Often an ITST is formed with the specific intent of assessing the performance of shoreline structures during a tsunami. These structures are typically associated with storm and flood protection as well as sediment management on coastlines and river banks. Structures include seawalls, dikes, groins, levees, jetties, breakwaters, weirs and water gates. In addition, a survey of coastlines and rivers should include an assessment of the tsunami effects on beach, estuary and river morphology as well as vegetated barriers and parklands near the waterline. ITSTs investigating coastal and river works should consider the issues outlined above under **Structures** and **Geotechnical Issues** sections. Other suggestions are as follows:

- The survey should coordinate with ITSTs doing geological surveys in the same area to share valuable data and insights.
- Confirm the specific purpose and design conditions for the coastal or river structure – i.e. Was the design wave height for a tsunami or storm wave? Is the structure intended to stabilize the bank or shoreline or to prevent flooding?
- As much as possible, the survey should document the sequence and mechanisms of failure or response during the tsunami (What failed first? How did the damage evolve?). Since coastal structures are often the first point of tsunami impact, it is very important to get a good idea of the complex interaction of the tsunami with the structure, its foundation and debris.
- Carefully record the transport (or stability) of revetments and individual armour units. If possible, the dimensions of shore and river bank protection should also be measured, since transport of simply shaped objects can be used to refine numerical models.
- During the planning phase, the ITST or team Leader should evaluate carefully the need for a boat and or underwater survey, both from a logistical and a safety standpoint.

- Beach and channel characteristics (width, slopes, grain-size, etc.) should be documented at the time of survey so they can be compared with other available data, both pre- and post-tsunami, to document morphological changes.

Infrastructure Systems – As part of a built environment ITST, the team may be asked to assess the performance of integrated systems that have structural, mechanical and personnel components. Aside from documenting damages to structures and facilities related to these systems, the ITST should insure that if tasked with infrastructure assessment, team members have adequate expertise in the relevant areas. These include but are not limited to:

- Transportation: roads, railways, bridges, airports, ferries;
- Utilities: water, power, communication, liquid and solid waste disposal;
- Emergency Response: fire and police, hospitals and medical, evacuation and temporary shelters; and
- Agriculture, Aquaculture and Fisheries.

Data quality and special considerations

Each damage survey team should have a Leader who has extensive experience in immediate post-tsunami surveys and an up-to-date understanding of the latest methods and techniques available for field work. The Leader will act to ensure consistency of data collection and provide quality control over the team's (or sub-team's) work, as well as coordinating with local authorities to obtain pre tsunami conditions of the survey site.

One of the particular competencies of a built environment ITST is the ability to document the behaviour of engineered objects with known dimensions and material properties. The response of railings, posts, and armour units to hydrodynamic loading can be used to refine predictions of tsunami forces and inundations which in turn can improve planning and design in tsunami prone areas. The ITST should try to gather as much quantitative evidence as possible about deformation, transport distances and impacts of:

- Cylindrical objects : Posts, poles, railings and trees;
- Block units: Precast shore and river armour, revetments and boulders;
- Buoyant objects: Vehicles, vessels and containers including storage tanks and mechanical equipment

The ITST should consider and incorporate the possible effects of multiple hazards on the findings of the survey. What conditions occurred prior to the tsunami (e.g. liquefaction due to earthquake) and between the time of tsunami and the survey (reworking of the beach face from a storm event)?

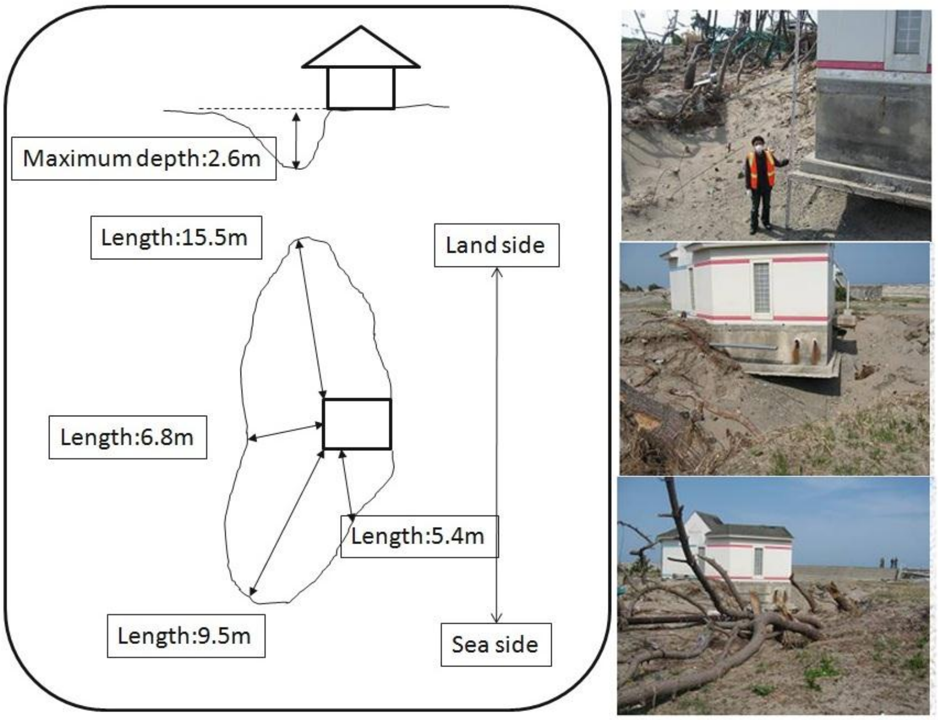

Figure VII.1. Scour pattern and multiple views of reinforced concrete structure: Arahama Beach, Sendai, Japan, May 16, 2011, two months after tsunami.

Figure VII.2. Pile-supported dock with local subsidence failure of dockside infill: Kesennuma Port, Japan, March 10, 2012, one year after tsunami.

Data quality and special considerations

The properties (coordinate, time and direction of shooting, etc.) of the picture, and all specifications (brand, model, etc.) of the camera should be given in the survey report of the built environment.

It is recommended that each damage survey team has a leader with extensive experience in immediate post-tsunami surveys and an up-to-date understanding of the latest methods and techniques available for field work. They should act to ensure consistency of data collection and provide quality control over the team's (sub-team's) work.

Further Reading

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Annex VIII – Geologic, Tectonic, and Geotechnical Information

Introduction and background to the discipline field and data to be collected

The collection of geologic, tectonic, and geotechnical Information is in essence work undertaken to capture changes to the physical environment. It involves the reporting and recording of coastal uplift or subsidence (itemising the indicators used), the study of deposits laid down by the tsunami both in onshore and offshore settings, and determining the extent of erosional features and geomorphological change associated with the event. Where time allows there is also scope for preliminary work on palaeotsunami deposits in order to place the most recent event in the context of past tsunami activity in the region.

List of equipment

Not all workers may have access to the same equipment types. This list is not exhaustive and equally does not require that all items be carried. It offers an element of redundancy and choice. It is recognised that several different types of equipment can achieve the same goal.

- Compass: Use an appropriate northern or southern hemisphere compass.
- GPS: Not everyone will have one but they are reasonably common. To avoid confusion and misplacing of site locations ensure that an appropriate standard co-ordinate frame is set-up. This is normally World Geodetic System 84 (WGS 84), but it is worth checking. It is also important to note the time zone the GPS is recording to sync with cameras, notes, etc.
- Electronic distance and elevation meters. These are becoming increasingly available as prices fall.
- Measuring tapes: Preferably long (100 m), medium (20-30 m) and short (5 m) tapes. In the absence of GPS or surveying equipment a simple rod-and-level topographic survey can be achieved using measuring tapes and long pole (e.g. Morton *et al.,* 2008).
- D-handled shovel/spade about 1 m long (handle plus blade) and/or round pointed (cupped blade) shovel. Square point (flat blade) spade. All digging equipment should have a sharp edge to the cutting blade – it is recommended that a file or stone be used to keep the blade sharp. The shaft can be painted/marked (e.g. red/white paint) at 10 cm intervals to provide photo scale.
- Folding shovel: Space saving, convenient. Shaft can be painted/marked (red/white paint) at 10 cm intervals to provide photo scale.
- Scraper hoe: Some researchers prefer to use these to clean the face of a section/trench. It has a sharp edge on one side.
- Trowel: Blade has two sharp edges and a point (maintain sharp edges/point using file/stone). Useful to have large (15 cm blade) and small (2 cm blade) for cleaning the face of a section/trench and for the fine detail work.
- Brushes: For cleaning up face of section/trench – this helps highlight bedding. Preferable to have large (~8 cm wide) and small (~1 cm wide) for variable detail of work.
- Water spray bottle: Any type of laundry spray bottle filled with water. Useful with dry sands or unconsolidated sediments – it helps to retain integrity of section.
- Augers/corers: There are many varieties with extension rods – a core/auger has value for examining sediments in wetlands, estuaries, all types of water bodies. In the absence of trenchable areas or with only shallow trenches available these also has value for penetrating deeper below the surface to look for evidence of past events. Most common/convenient are Gouge Augers – these have variable barrel widths and lengths

and work well for consolidated sediments but do not retain dry sands or unconsolidated material well; D-corer or Russian-type corer – they have variable barrel widths and lengths, the rotating blade retains a length of core that can be extracted and examined later back in the laboratory. It is always good to have one or both of these to augment trench work. Hand held piston cores are also a possibility.

- Camera: take one with the largest megapixel size possible and with a good macro facility for close-up shots, plus plenty of memory cards and battery back-up. Set the camera time to the preferred reference (UTC or local) and document this by photographing a GPS time screen. A local time reference has the advantage of jogging the memory (e.g. sample taken right after lunch) when viewing photographs.
- Video camera: Useful for recording the context for trench/coring work and the nature and extent of the deposit at any one point. Like a camera – the highest resolution available is preferred.
- Binoculars: High quality – useful for examining potential sites from a distance. They can also be a time-saving device (e.g. is it worth crossing river to examine deposit?).
- Sample bags, sample tags, marker pens. It is almost impossible to have enough of these. Whatever type of coring-related equipment is taken in the field it is essential to have the relevant sample collection material. This may be plastic core tubes for storing samples, or it may be by sample bags, but equally duct tape and plastic wrap (e.g. Saran wrap, glad wrap) are extremely useful for securing samples collected.
- Supplies for sediment peels: Taking a peel from a trench face is becoming an increasingly common practice BUT needs appropriate training because the hydrophilic grout used contains highly toxic chemicals. For this reason researchers from many countries are unable to access the material because it cannot be imported. The technique is moderately simple, but breathing apparatus and strong gloves are essential. The key supplies are the grout, a roll of plastic mesh, several litres of water, gloves, breathing apparatus, a plastic spatula or two, and some disposable plastic containers to mix the grout with water. Consult with colleagues to determine the best grout source in a region.

Field Methods

Coastal uplift or subsidence (indicators used), surface faults, tilt

Fieldwork should include interviews of local residents, fishermen and public officials to gather anecdotal accounts of changes in sea level, coastal landscapes (geomorphology), and damage to reefs. Where possible, interviews should be in video form in order to allow for post-visit analysis. See further discussion in Section 2.2.2, Annex II and Annex X.

Field teams should complement interview data with on-site observations and measurements including the identification, location and estimates of the extent of possible coastal uplift or subsidence. Where possible and subject to equipment availability, GPS vertical positioning of existing benchmarks would be useful. The field team should note and estimate vertical movements based upon the presence of:

- Submerged or salt-burnt vegetation or green leafy plants in the inter tidal zone;
- Uplifted barnacles, mussels, seaweed, or any other subtidal/intertidal flora;
- Changes in tidal limits – new high tide marks;
- Cracks, liquefaction, tilting or warping in the ground, evidence of fault creep and direction of the motion, landslides.

Measurements of estimated uplift based on these features have uncertainties of ± 0.5 m, but nevertheless they serve to define broad spatial variations in the magnitude of vertical deformation along a coastline.

Aerial reconnaissance – extensive coastal surveys – can identify the presence of uplifted wave-cut platforms cut into bedrock. These platforms will be covered in dead intertidal marine organisms, and will be clearly visible from the air. Similarly, well documented/mapped coastal structures such as lighthouses may be uplifted and will provide more precise indications of uplift/subsidence.

Tsunami deposits – onshore and offshore and erosion and geomorphological change

ITST members are advised to observe and note the presence of boulders, sand, silt, gravel and/or mud sheets deposited by the tsunami in tidal wetlands, coastal lakes/lagoons, coastal plains, over and behind barrier beaches, in dune systems, and on man-made surfaces (e.g. roads, building foundations).

- Take photographs of the setting before disrupting it by trenching or coring.
- Dig trenches with the long axis parallel to flow direction. Trenches should extend below the tsunami deposit to allow characterization and sampling of the pre-tsunami sediment.
- Clean trench walls before photographing, describing, and sampling.
- Take trench samples with a spatula or a similar tool.
- Take photographs of trench walls after sampling to document where samples were taken.
- Take core samples either with a d-corer, piston corer, or other augering device.
- Take photographs of cores.

If possible, a sampling regime should include numerous trenches and cores from landward to seaward sites along the pathway of inundation – this may be perpendicular to the shoreline, but equally may be sub-parallel to the coast. Prior to undertaking any sampling regime it is vital to determine the flow direction, assess the maximum extent of inundation, identify sediment sources and deposit thickness. Where possible both core and trench data should be collected in order to have a better understanding of vertical and horizontal continuity of the deposit. Samples of sediment sources for the deposit (underlying eroded sediment, beach sediment, shallow near-shore if possible, etc.) should be collected as well.

Teams should measure the thickness and horizontal extent of fine sediment deposits, and also the a, b, c axes and orientation of large clasts. Coarse sediment deposits such as boulders should have their distance from the shore and source area, and elevation above sea level measured. Equally, the transport mode for large clasts should be determined by identifying striations, chatter marks and the association between fine and coarse sediment deposits. All deposits should be surveyed and tied to mean sea level at the time of the survey or a suitable survey point that can be referenced to a sea-level datum. Samples should be collected at as high a resolution sampling regime that is possible given the time available. Sediment cores, peels from trenches, high resolution photographs for subsequent grain-size analyses, monoliths sampled from trench walls, or closely spaced vertical sampling at sub-cm intervals are some of the techniques recommended.

It is vital to determine the nature of the tsunami as it came inland – eroding, creating a bypass zone, depositing, and then the relationship between the maximum inundation distance of the water compared with sediment and detritus. Detailed studies of the entire deposit are extremely valuable – not solely the sediments but also the nature of the lower contact – crushed vegetation, erosional, etc. Elements of the deposit, such as incorporated shells, wood, organic matter, or anthropogenic material, all help to understand the nature of the erosion-entrainment-deposition process.

The study of submarine deposits is in its infancy and there are considerable logistical difficulties associated with gathering data. Conditions may not permit safe sample collection so the team must make a decision about the most appropriate methods of data collection. Collection by SCUBA and/or snorkel survey is the most appropriate since it involves low cost and relatively simple shore based work. At the very least, it is recommended that personnel have a high proficiency certificate in either SCUBA or snorkelling and also have relevant first aid facilities on-hand. The most likely scenario is that teams carrying out submarine work will be part of a later group of researchers to access the area once the initial emergency response has passed.

Factors such as water clarity, tidal conditions, currents, and debris in the water all need to be considered. If possible a sonar/side scan survey should be carried out to determine the extent of submarine deposits prior to selective push core sampling. Maintaining the integrity of the sediment samples is vital and as such, the work should not be carried out without relevant underwater research expertise. If time permits, a fully gridded section of the deposit should be studied with a complete photographic survey of the area tied in to an appropriate benchmark on land.

Where there has been deposition there may also have been associated erosion. It is vital to undertake a comprehensive study of both zones since these in essence comprise the full geological evidence for the tsunami. A study of eroded areas is both a study of the source area for much of the material deposited on land and a measure of the fluctuating energy regime within the tsunami itself since backwash erosion is often noted and will clearly contribute sediments to the submarine component of the deposit. This work should be carried out in conjunction with a study of the deposit and efforts should be made to associate zones of erosion with zones of deposition since these indicate the size of material that moved and over what distance inland and what elevation. Where possible a detailed topographic survey should be carried out of key areas where both zones of deposition and erosion are clearly defined, preferably with an onshore and offshore component. This will also serve to provide a detailed geomorphology of the area that can be compared and contrasted with earlier topographic information if available.

The importance of a holistic study of features associated with the “deposit” cannot be overstated. Erosion and deposition are intimately connected and equally they in turn form a unique suite of geomorphological features that remain in the landscape to complement the geological evidence. All forms of data gathering should be undertaken, but it is vital to place the sedimentological and stratigraphic evidence in the context of the process environment. This requires detailed surveying by any available tools such as total stations, GPS, rod and level. These on-the-ground data can be compared with satellite or other remotely gathered data later to ground-truth a broader interpretation of the inundation area.

Palaeotsunami deposits survey

As part of the survey of the contemporary deposit it is reasonably simple to add on an initial study of possible palaeotsunami deposits. While the time available is unlikely to allow a comprehensive core and trench study, it is a simple process to gather suitable core data through a PVC tube (transparent), a D-corer or vibracoring coupled with a study of deeper trench records where a mechanical digger is available.

The most reasonable locations for augering and coring work would be coastal wetland areas that allow for easy penetration of the ground surface. Trenches are unlikely to penetrate as deep as an augering/coring regime but they provide key data on the lateral continuity of suspected palaeotsunami deposits.

In the field there are two different types of work that can be carried out depending upon whether data have been collected through auger/coring or trenching. For the former, other than ensuring that the appropriate site location and contextual data have been collected it is relatively simple to sample and store the extracted core material and return to the laboratory for later analysis. For trench work, any potential palaeotsunami deposit can be treated in a similar manner to the contemporary event but with a particular focus on attempting to establish a chronology for the event(s) in question.

Treating the potential palaeotsunami deposit in a similar fashion to the contemporary event however, means that a substantial amount of time needs to be spent at a single site to process all of the information. Since this work would normally represent an addition to the study of the contemporary deposit there may be little time to do more than take a few preliminary samples. If time allows, then a more complete study can be carried out. If not, this preliminary work provides crucial location data for a return visit once funding permits.

As an interim measure it is recommended that a simple “core” be taken from the side of the exposed trench. The current practice is to cut 50 cm lengths of plastic core pipe lengthwise and push it up against the trench wall. By cutting around the sides of the pipe with a trowel a vertical section of the trench wall is retained in the plastic pipe. This process can be continued from the top downwards to the base of the trench. In this manner one can retain an intact core sequence with contacts preserved and with a good understanding of the lateral continuity of the deposit(s) in relation to each other.

Data quality and special considerations

Fieldwork is carried out in teams and as such it is recommended that there are regular morning and evening group/sub-group discussions to not only plan the work that needs to be done but also to discuss what has been collected and how. Data sharing and cross-correlation between the work of individuals and teams should help to ensure that quality control is maintained and that data are reliable. There is never enough time to complete all of the work, and there will always be something that is forgotten or poorly recorded; this cannot be avoided, but it can be reduced by repeated data checking. If time permits it is recommended that at least one site be resurveyed/re-sampled to provide a check on the data collected. One of the most significant issues in recent immediate post-tsunami research efforts has been the recognition that there tends to be a biasing towards recording only the maximum runup and inundation at any one site, or the thickest and most extensive deposits – these are valuable data but only cover a part of the story. If time permits, teams should make efforts to undertake more comprehensive surveys at each site visited.

It is recommended that each geology team has a leader who has extensive experience in immediate post-tsunami surveys and an up-to-date understanding of the latest methods and techniques available for fieldwork. They should act to ensure consistency of data collection and provide quality control over the team’s (sub-team’s) work.

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Annex IX – Ecosystems

Survey Equipment

Standard data collection instruments can be adapted for the marine environment; however some specialized equipment is necessary. During the initial reconnaissance surveys, researchers interested in the effects on nearshore ecosystems (coral reef in the tropics, seagrass and algal communities as well as oyster reefs and the like in temperate regions) should focus on manta tows (Kenyon *et al.,* 2006) snorkelling transects, which are faster so more area can be covered (ICRI/ISRS, 2005). Recommended equipment includes:

- Snorkel, fins, and mask;
- Wetsuit (for sun and warmth);
- Gloves;
- Waterproof camera;
- Pencils, slate for notes;
- Sealable, plastic bags for sediment samples; and
- Floatable board to attach GPS unit (with waterproof covering).

Follow-up surveys should consider bringing quadrants, manta-tow board, and weighted transect tapes. Certified divers might bring a buoyancy compensator and regulator if quality tanks and air are available in the field area, while keeping in mind space limitations.

Detailed nearshore water depth data is critical for inundation models, yet it is a challenge to collect multi-beam swath bathymetry in shallow water environments (less than 30 m). A simple, portable echo sounding unit with side scan sonar capability is ideal as they measure water depths and the side-scan provides a qualitative view of seafloor roughness, which can be used to assess both habitat and constrain tsunami propagation models. Simple and affordable, off the shelf technology can be useful (e.g., Humminbird 998C SI Combo- http://store.humminbird.com/products/341046/998c_SI_Combo; Tronde-Inge *et al.,* 2002), and more advanced systems would be beneficial for the best data quality (e.g., http://www.starfishsonar.com/products/starfish450h.htm).

Documenting seafloor displacements including surface rupture and potentially tsunamigenic landslides as well as submarine palaeoseismology requires a survey of the trench and continental slope of the subduction zone (usually greater than 200 m). The first possible limitation for undertaking deepwater surveys is the availability of a suitable research vessel in the affected region. As a minimum, a specialized research vessel would have the following:

- Multi-beam sonar (with side-scan sonar, if available);
- Seismic profiler (chirp); and
- Coring facilities (gravity, piston, and/or box corers).

The best case scenario would involve a ship that also has the ability to collect visuals on the seafloor – either a camera-sled, remotely-operated vehicle, or a manned submersible.

The multi-beam and side-scan sonar can map scarps generated either by surface faulting or landslides; however it is not possible to determine when they occurred purely from survey data. Seismic reflection data can show transparent or chaotic layers indicative of mass-transport deposits, potentially generated by earthquakes. Sediment cores are required to date these deposits, and in some cases, stacked mass-transport deposits can give a recurrence interval of past earthquakes. As this research is very costly, financial resources must be secured as well as the human resources necessary to process the data.

Environmental and Biophysical Information

While some of the most damaging and deadly tsunamis over the last 100 years have occurred in tropical, Least Developed Countries (LDCs), the potential also exists for an event to occur in higher latitude, temperate developed regions (e.g., Japan, North and South America, New Zealand, etc.). It is important to keep in mind that people living in LDCs rely on ecosystem services for their livelihoods and safety more than those living in developed countries (Sudmeier-Rieux *et al.,* 2006). For example, coral reefs provide not only a potential physical buffer against tsunami, but may also provide for fisheries that generate food and income and the tourism industry (see McAdoo *et al.,* 2011). Similarly, mangroves can buffer some tsunami energy, but fragmentation of the ecosystem by people seeking wood for fuel or building material can decrease its effectiveness (Cochard *et al.,* 2008). It is therefore critical to ascertain the tsunami damage done to these systems.

The ecosystems, and the reliance of people on these ecosystems, will vary between tropical and temperate climates. The environmental and biophysical data that should be obtained in these regions will also differ, however the tools for collection are largely the same. Marine and terrestrial features that can reflect, refract, or diffuse tsunami energy should be mapped, along with vegetation that can stabilize sediment. In the offshore, these might include coral reefs (tropical), oyster reefs (temperate), and seagrass beds, mapped by high-resolution satellite data and marine geophysical surveying, ground-truthed and quantified by swim-transects. On land, intertidal mangroves as well as supratidal dune grasses, and coastal forests and other vegetation must be considered. Again, pre- and post-tsunami satellite data provides a large overview of the region, and observations on the flora (and fauna) as well as the interactions of the local population with the ecosystems should be collected by ecologists familiar with the region.

Ecosystems require periodic disturbances to maintain proper functioning, however the degree of the disturbance will affect how long it takes for it to recover. A low-frequency, high magnitude tsunami stresses the environment by damaging coral and benthic flora, eroding sediment from the coastal zone and redepositing vast amounts both on land and in the offshore, salinizing soils, etc. Material mobilized by the tsunami, including hydrocarbons, human waste, and solid debris will damage the ecosystems that people rely on, and must be carefully documented. The health of these ecosystems will help determine their resilience – those less affected by pollution, fragmentation and other stressors will return to providing crucial services faster.

A challenge in assessing the damage to the ecosystems is determining the pre-tsunami condition of the coupled human-environment system. Maps and satellite imagery are often available from Google Earth (http://earth.google.com), Relief Web (http:// www.reliefweb.int), or the Centre for Satellite Based Crisis Information (http://www.zki.dlr.de/). From these high-resolution data, offshore features such as coral reef, seagrass beds, sand bars, and the like can be observed, and should be examined in the context of onshore runup and damage. Intertidal and terrestrial ecosystems such as mangroves, salt marsh, dunes, etc. should be similarly investigated. Each of these entities affect wave propagation, and the tsunami will have an effect on them. *The degree of impact will determine the length of time until these ecosystems will return to providing services*.

Once in the field, researchers must determine how the affected populations interacted with the ecosystems prior to the tsunami. In some cases it is clear; others more nuanced. For example, in developing countries, subsistence and commercial fishermen often live in the coastal zone to have better access to their livelihoods. If their primary catch is from an inshore reef fishery then it is important to know what their catch was prior to the event, if their equipment was compromised during the tsunami, and if the catch had changed subsequently (McAdoo *et al.,* 2011). Based on the observations, it might be necessary for government and/or aid agencies to support this community helping to replace equipment, supplement food supplies, or provide long-term aid if the reef ecosystem was severely damaged.

The more nuanced effects require local knowledge. It is critical to involve government officials as well as the local people that live and work in the coastal zone. Ideally, this would be done using structured interviews by trained researchers. However, rudimentary information can be easily attained by an initial response team while measurements are being made, especially if there are in-country members of the team that are familiar with the physical, economic and cultural landscapes.

Conducting post-tsunami ecological surveys

The initial, rapid response survey teams should include at least one member that is familiar with a variety of coastal ecosystems. The ecologist can make quick, first-cut observations while an area is being surveyed for water-level data. They must determine what critical flora and fauna live offshore and in the terrestrial coastal zone, how they were affected by the tsunami, how they affected the tsunami, and how the people interface with their surrounding ecosystems. These observations must be made quickly so that the entire inundated coastline (offshore and onshore) can be covered in a short period of time.

Recommendations can be made for areas of interest for follow up investigations

During the initial survey, it is important to document interactions between people and ecosystems, especially in tropical developing countries, where people often rely on ecosystems for their sustenance and livelihoods (Sudmeier-Rieux *et al.,* 2006). The services that the coastal ecosystems provide are crucial to their survival. For example, coral reefs are the first line of defence against large tropical storms and cyclones (and possibly tsunami), providing buffers that reduce the wave energy and minimize coastal erosion. Shallow lagoons between the barrier reef and land provide for the local fishing industries by providing a nursery services as well as habitat for a variety of commercially viable species. Healthy fisheries provide both nutrition and income for coastal residents, making them less vulnerable to a variety of hazards. Furthermore, many tropical developing countries rely on tourism as a significant contributor to their economies (see McAdoo *et al.,* 2008), and reef damage could compromise this expected income.

Nearshore ecosystems

Because of these multiple and intersecting vulnerability factors, post-tsunami surveys must assess the health of offshore ecosystems as well as collect offshore physiography data that can be used for inundation models. Nearshore surveys should collect bathymetry data using sonar linked to a GPS for water depths up to 30 m, documenting bottom character including sediment type, rocks, flora and fauna, as well as fish in the water column. In coral reef coasts, survey areas will be constrained by accessibility. Access to the seaward portions of the reef will be limited by channels and shallow water in the lagoon may preclude boat access. Therefore efforts must be made to acquire shore-parallel data, both from satellite and in the water (on wading or swimming) where it is too shallow to drive a boat. Special attention should be paid to features that might buffer the tsunami, including offshore sand bars, seagrass beds, and fore reefs, so bathymetric transects should be taken seaward of these barriers for the tsunami propagation models. Sidescan sonar is also helpful as it provides a qualitative view of seafloor roughness and potential habitats.

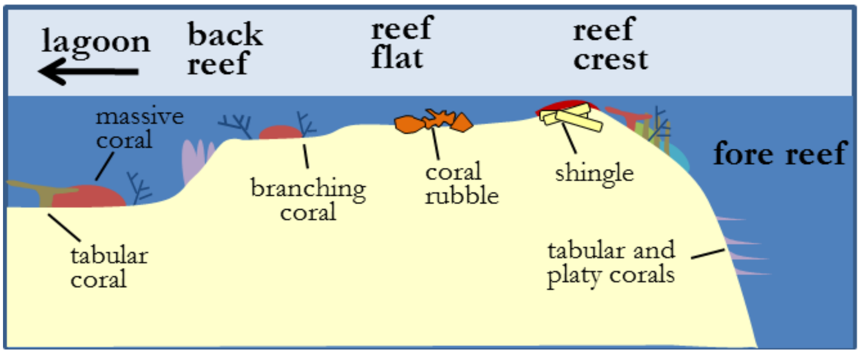

Figure IX.1. Coral reef zonation.

In shallow coral lagoons, surveys should aim to document seafloor substrate, percent of live coral, coral species, incidents of disease, algae, benthic fauna and fishes. Initial efforts should be made to tie in an offshore bathymetry survey with the on-land topography and inundation surveys. Depending on the local offshore physiography, shore-parallel (alongshore) surveys should be conducted along bathymetric contours at fixed distances from the shoreline, outside of the zone of wave breaking where any evidence of the tsunami would have been erased.

The International Coral Reef Initiative/International Society for Reef Studies (ICRI/ISRS) provides detailed post-tsunami survey and sampling guidelines (ICRI/ISRS 2005; available at http://www.reefbase.org). The guidelines offer procedures for rapid response surveys to long-term, post-tsunami monitoring. For the rapid surveys, large swaths of coastline must be covered, and the sample unit should be on the order of 10 m^2, so that large features such as boulders can be captured. It is very important to use the same survey methodology so that data can be easily compared.

Based on the time and resources available, there are several options to consider for how to conduct the nearshore transects:

- Timed swim or fixed distance snorkelling, shore parallel ‘virtual’ transects of a few hundred metres are useful to document alongshore changes as damage is often irregular. Transect lines are preferred, but are time consuming so should probably be saved for follow-up work. It is important to consider that observations are subject to observer bias, and there can be variations between different observers;
- Manta tows (only conducted by experienced swimmers and boat drivers) cover large areas and sidescan sonar can simultaneously document seafloor roughness, water depth and GPS location. Again, observer subjectivity can be an issue; and
- SCUBA and transect-based surveys can be used in particular areas of interest such as the deeper channels that could act to focus tsunami flow, but are more cumbersome, gear intensive, and time consuming, and cannot cover as much area as snorkelling.

During the surveys, special attention should be paid to the following:

- In coral environments, is there evidence of disease and/or bleaching?
- Is there an active fishery industry? If so, is it industrial or artisan? How have fish takes changed historically, and post-tsunami?
- Are there aquarium fish collecting in the region? What are the target species? What effect does their harvest have on the ecosystem? How are they collected (e.g. cyanide, bombing)?
- What are the recreational activities in the region? What effect do they have on the environment? Economy?

- Are there invasive species?
- When was the last extreme weather event? How did it affect the region?

Table IX.1. Tsunami Damage in Nearshore Environments (modified from ICRS/ICRI, 2005).

		Indicator	Code	Explanation
Tropical	**Benthic**	live hard coral	LCC	Live coral that survived the tsunami. Estimate area as proportion of bottom.
		recently killed coral	RKC	Hard coral that has clearly died recently. The skeleton will appear a dirty white, with sediment and/or algal filaments. Estimate as proportion of LIVE CORAL identified in previous indicator.
		coral life forms, alive	CLF	Write the main coral lifeform types from the standard list below (table 3). A - Acropora; TS - Table/staghorn Acropora; B - Branching; E - Encrusting; M - Massive/submassive; F - Foliose/plate/laminar; S - Soft coral; WF - Sea whip/sea fan
		filamentous algae	FAG	Filamentous algae (e.g. *Enteromorpha*) - very fine filaments, grow within 3-4 weeks due to high nutrients. This may not be observable any more from tsunami, but may occur due to latent nutrients in silt.
		thick turf/fleshy algae	TAG	Thick algal turf and fleshy algae, maybe developing from filamentous algal bloom after tsunami. May be prevalent where nutrients are increased and/or fish populations are depleted.
		rock/bare surface	RC	Rock framework of the reef, including with a thin algal turf.
		Rubble	RB	Old coral rock and pebbles in natural position with covering of algal turf and coralline algae
		Sandy	SD	Soft substrate, often in base of channels or between coral heads.
	Damage-Corals	overall damage to corals	CDAM	Estimate the proportion of the coral community affected/damaged by the tsunami. Include dead coral in this estimate.
		up-turned coral	UPC	Live corals, but broken and overturned or lying on the bottom.
		broken coral	BCC	Live corals in growth position, but physically fragmented, cracked or broken.

		Indicator	Code	Explanation
		recently killed coral - standing	RKC-S	Recently dead coral tissue, in growth position.
		recently killed coral - upturned	RKC-U	Recently killed corals, upturned and toppled.
		coral life forms, damaged	CLF-D	List coral life forms most damaged, in all of the damage categories listed below (table 3). A - Acropora; TS - Table/staghorn Acropora; B - Branching; E - Encrusting; M - Massive/submassive; F - Foliose/plate/laminar; S - Soft coral; WF - Sea whip/sea fan
	Damage-Waves	overall damage to substrate	SDAM	Estimate the proportion of the substrate affected/damaged by the tsunami.
		Erosion	CRE	Erosion of reef slopes caused by slumping of rubble from reef zones above.
		rubble piling/movement	RBP/M	Movement of old and new rubble by waves, distinguished by piles and drifts of rubble.
		loose rocks < 50 cm	R<50	Loose rocks (framework, or dead corals) of a small size (approximately 50 cm diameter and less).
		loose rocks > 50 cm	R>50	Loose rocks (framework, or dead corals) of a medium size (between approximately 50 cm and 1 m diameter).
		boulders > 1 m	BLD	Large boulders (framework, or dead corals) moved over the reef surface, of approximately 1 m diameter and larger).
		scars/exfoliation	SCR	Scars in the reef framework and exfoliation of surface organisms caused by movement of rocks and debris.
		cracks	CRCK	Cracks in the reef framework caused by wave forces/battering with rocks.
	Damage-Backwash	silt smothering live coral surface	SILC	Silt smothering live coral surfaces. May become chronic due to silt stored in reef sediments.
		silt on reef surface/sand pockets	SIT	Silt smothering reef surfaces and/or collected in sand pockets and drifts.
		debris-stone/solid	DBS	Loose debris from land - stone, metal and solid items, e.g. from buildings, appliances, vehicles, etc.
		debris-vegetation/ seagrass	DBV	Loose debris - vegetation; from trees, mangroves, seagrass, etc.
		debris-litter (plastics/text.)	DBL	Loose debris from land - litter and rubbish, plastics, textiles, etc.

		Indicator	Code	Explanation
		coral disease	CD	Coral diseases, potentially enhanced by microbial fauna in terrestrial silt.
		coral reef fish	CRF	Coral reef fish. Brief notes - space is included on Reef Check datasheets for notes on key species. For detailed monitoring, Underwater fish surveys should be conducted.
		seagrass reduction	SGD	Uprooting or defoliation of *in situ* seagrasses in sample units.
		mangrove debris	BMG	mangrove debris transported to sample areas.
Temperate	**Benthic**	sandy	SD	loose, fine grained sediment
		rocky (loose)	RK-L	loose gravel > 2 mm up to boulders (> 250 mm)
		rocky (outcrop)	RK-O	bedrock, free of loose sediment cover
		bedforms	BED	Ripples, channels. Estimate ripple height, spacing, symmetry.
		non-coral reef builders	NCR	clam/oyster beds
		vegetation	VEG	including seagrass, kelp and other macroalgae
		offshore bar	BAR	presence or absence of offshore bar and water depth
	Damage	debris-stone/solid	DBS	Loose debris from land - stone, metal and solid items, e.g. from buildings, appliances, vehicles, etc.
		debris-vegetation/ seagrass	DBV	Loose debris - vegetation; from trees, wetlands, seagrass, etc.
		debris- litter (plastics/text.)	DBL	Loose debris from land - litter and rubbish, plastics, textiles, etc.
		scars/exfoliation	SCR	Scars in the reef framework and exfoliation of surface organisms caused by movement of rocks and debris.
		cracks	CRCK	Cracks in the reef framework caused by wave forces/battering with rocks.
		vegetation reduction	VGD	Uprooting or defoliation of *in situ* seagrasses/macroalgae in sample units.

Terrestrial coastal zone ecology

On land, vegetation in the coastal zone will also interact with the tsunami, in some cases providing a buffer, but in other cases, providing a source of debris that might cause damage inland depending on the size of the waves and health of the particular ecosystem.

Sometimes, the vegetation might not be a direct buffer – for example – dune grasses (as seagrasses offshore) while not buffers themselves, stabilize sediment drifts that are effective at retarding the inland progression of waves (e.g. Cochard *et al.,* 2008). Similar to the offshore reef ecosystems, plants in the coastal zone provide a variety of services to communities on land past physical buffers against waves and sediment stabilization, including wood for building and fuel, food, shade and aesthetics. These plants are key elements to the coastal zone economy, especially in developing nations.

Onshore ecologic surveys should tie in with the offshore transects. Beginning in the backshore, ecological transects should follow the inundation survey lines as well as documenting changes in the ecosystems parallel to the coastline. In the initial, rapid response surveys, it is important to document the species, distribution, and overall health of the dominant coastal zone ecosystems. Local and regional partners will be critical not only in helping to identify native and non-native species, but also in determining the state of the ecosystems prior to the tsunami, and how the local population interacts with the ecosystem. While this pre-tsunami information can be bolstered by satellite data, qualitative assessments from local officials as well as the communities that interact with these systems on a daily basis are important. The following factors should be considered:

- Are there any industrial activities (factories, power plants, agriculture, sewage facilities) that could affect the offshore health?
- What are the terrestrial ecosystems that could affect the health of offshore flora and fauna?
- Where are the wetlands? Are they healthy? Are they likely to become places where earthquake debris is dumped?
- Are there commercially important resources that were affected? If so, who owns them?
- Is there a coastal zone management plan in place?
- Prior to the tsunami, what were the stresses on the ecosystem?
- Do land-use patterns have any effect on fragmentation?

Follow-up surveys can focus on more detailed ecological transects; however in the early stages, it is important for decision makers to have these data so that resources can be allocated appropriately.

While the force of the tsunami wave has direct impacts on coastal ecosystems, there are a variety of secondary impacts that can affect the long-term recovery of the region. Debris from damaged buildings is often pushed landward, sometimes into sensitive wetlands, and can also be dragged offshore with the backwash. Accompanying this debris can be a suite of toxic chemicals that should be documented, from septic tanks and fertilizer storage to a variety of hazardous wastes, from fuel storage tanks and acids from batteries. A catalogue of these potential pollutants will be particularly helpful as the region plans for debris removal and disposal.

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Annex X – Eyewitnesses and Interviews

Introduction and background

All ITSTs will find the need to talk to people impacted by the tsunami. The nature of interview questions and techniques will depend upon the focus of the ITST and the purpose of the interview. There are three general types of interviews discussed here:

1) Interviews about the characteristics of the tsunami

The most common type of interview is with eyewitnesses to confirm water height or inundation extent, number and timing of significant surges, ambient conditions (e.g., tidal stage, storm conditions, etc.), and localized impacts. These interviews are usually conducted by scientists and engineers participating in ITSTs studying water levels, tsunami deposits, damage, or geotechnical impacts and sights, sounds and changes of water conditions. These interviewers do not usually have training or experience in conducting surveys. All members of ITSTs should be aware of the general comments about communicating with people in the impacted area (Section 2.2). Availability of interview subjects will depend on who happens to be in the field area where the team is working. It is not possible to statistically sample survivors. See discussion under Data Quality and Special Considerations below as to how to reduce bias.

2) Broader impacts

Some ITSTs are interested in acquiring information on the broader impacts of the tsunami and vulnerability/resilience factors that may have exacerbated or reduced impacts. Examples include factors influencing evacuation, pre-event planning and preparedness, emergency response and/or recovery issues. The limited amount of time of an ITST does not usually lend itself to an exhaustive treatment of these issues, but may be able to identify important areas for more detailed investigations at a later date. ITSTs interested in these aspects of the tsunami should include an interdisciplinary group of researchers and talk to as broad as spectrum of people as possible including planners and emergency managers, teachers, business people, politicians, first responders, and members of the media in addition to the general public.

3) Personal recollections of the tsunami event for outreach and education

Walter Dudley (Pacific Tsunami Museum, Hawaii) pioneered recording tsunami survivor accounts of the 1946 and 1960 tsunamis in Hawaii. The initial purpose of his project was to record accounts of aging survivors before they were lost and to give a human face to the tsunami experience and the interviews were conducted many years after the event. The project has been expanded to participation in ITSTs and to record these accounts in weeks to months after the tsunami event. More information on the field techniques and processing is included in the additional background section of this Annex and the references. Shorter accounts have been collected by other researchers (Atwater *et al.,* 1999; Yulianto *et al.,* 2010) to package into lessons for outreach.

This Annex does not address detailed social science surveys of behaviour as it is assumed they will be conducted by researchers with expertise in the conduct and analysis of such surveys.

Field Methods

During an ITST, it is usually not possible to sample respondents in a statistically significant way. For ITSTs gathering eyewitness accounts, the availability of interview subjects will depend upon who is in the field area where the ITST happens to be working. The section below addresses ways to avoid bias and to get the most accurate information from these interviews. The Host Country Co-ordination Committee may be able to assist groups in identifying other potential interview subjects. Pre-ITST communication with the Host Country Co-ordination Committee will facilitate this process as long as the intent of ITST has been communicated in advance. Reports from and communication with earlier ITSTs can also aid in targeting people to talk to and avoid unnecessary duplication.

It is important to re-iterate the points in Section 2.2:

- Be aware of cultural issues;
- Always request permission before recording/videotaping an interview or taking photographs;
- The process of recounting the event may be traumatic. It is essential to be patient and to respect the interviewee.

Be very sensitive to how you approach people. In many cases, survivors are quite willing to share their stories and will often come up to ITST groups working in the field on their own accord. The Host Country Co-ordination Committee can also give you advice on how best to communicate with survivors in the field.

There are two interview templates at the end of this Annex. They may be adapted to the needs of the particular ITST. Translated versions of the selected questions should be made before the team arrives in the country. The translations should be reviewed by the Host Country Co-ordination Committee before use. It is very important to thoroughly discuss interview protocol with translators, particularly if they are not part of the ITST research group.

Anyone considering interviewing tsunami survivors who has little or no prior interviewing experience should review basic texts on human geography and social science research methods about ‘interviewing participants’. These will provide many useful guides and tips on what to do, how to approach and work with interviewees. A very good basic text to start with is Minichiello *et al.,* (2008) and Hay (2010).

Data quality and special considerations

Eyewitness perceptions of a tsunami event are rarely objective. Following the recommendations below will help to reduce bias and improve survey data quality.

1) If possible, talk to single individuals as opposed to groups. Groups tend to create a common story and may be influenced by dominant individuals and their stories could be affected by the dynamics among members of the group.
2) Template questions can be a useful guideline to begin an interview but sometimes the most interesting information will come out in discussions outside of a specific question. Don’t be impatient to quickly get through a set of questions, but allow respondents to contribute additional information.
3) Eyewitness estimates of time are often inaccurate. Sometimes there are time markers such as an aftershock that can be used to constraint times.
4) Having a respondent walk through what they did during the tsunami event (where they were, what they did) can also constrain the timing and may help to bring back details of the event.
5) Interview multiple eyewitnesses in an area if possible. The accounts of a single individual may not represent the event very accurately. But if multiple eyewitnesses, interviewed independently, have converging stories, they are more likely to be true.
6) Sometimes people will want to tell you what they think you want to hear. Avoid asking leading questions. Accounts may change as the interview progresses.

7) Ask respondents what the area looked like before the tsunami. This can often lead to identifying key structures or markers to help describe impacts. When appropriate, ask for photographs or other pre-event documentation of the setting.

Additional relevant background information

Tsunami Survivor Interview Protocol – High-quality Video Interviews – by Walter Dudley. Interviews with tsunami survivors have now become a regular part of social science studies of tsunami events. More recently, the use of interviews as a way to collect data of value to physical scientists has also been recognized. Tsunami survivor stories also have great value for tsunami education. There is no messenger more credible for tsunami education than someone who has actually gone through the experience. Questionnaires and written accounts can be valuable for tsunami education and as an aid for social science studies and for integrating physical data acquired through field surveys, but they lack the emotive power of video recording the first-hand experiences told by tsunami survivors in their own words. Video interviewing of tsunami survivors is one of the most effective and efficient ways to gather physical and social science data and creates compelling educational tools because they contain visual emotive elements not found in other media.

This section describes interview techniques that can be followed by any ITST. It does not require the use of professional film crews.

Video Interview Techniques
For over a decade the Pacific Tsunami Museum (Hilo, Hawaii) has sponsored the collection of video oral histories of tsunami survivors. The museum's archives contain over 400 survivor interviews for 12 different tsunamis in the Pacific and Indian Oceans from 1923 to 2009.

The current protocol is based upon a combination of scientific and pragmatic lessons. It is critical that the interview protocol be customized to recognize the local culture and customs and avoid offending local sensibilities, especially during a time of community stress and grieving. The progression from set questionnaires, to written accounts, to a combination of audio tapes and their transcription, and finally to video recordings and their transcription, is indicative of this learning process. The final videos are of excellent quality, having been recorded with sophisticated digital video equipment. The current model in use is a Sony HDR FX1 high-definition (1080i) digital video camera with a BeachTek DXA-FX audio adaptor to allow for XLR stereo microphone inputs.

Protocol:
Ideally a team of four people is used, though by combining roles, three people can successfully carry out the interviews. The team consists of a Project Director (PD), typically a scientist with interest and/or colleagues in the region, who serves as producer, camera operator, and sound/light technician. A Field Coordinator (FC) serves as production assistant and is chosen on the basis of previous experience in the region. The On-Site Facilitator (OSF) is typically a local resident, with expertise and/or sincere interest in tsunami preparedness, knowledge of the tsunami event(s) in question, fluency in local languages and the ability to translate interviews into English (if required). A Logistical Coordinator (LC) liaises between interviewees and team members. Normally the OSF serves as interviewer (after on-site coaching), although the role can also be carried out by either the FC or LC. For organizational purposes, the process of collecting video interviews is divided into three phases: pre-interview, interview, post-interview.

Pre-interview Phase:
The OSF contacts potential interviewees, explains the reason why the data are being collected and the interview process. This may involve intermediate steps, for example, in some countries, immediately upon entering a village, it may be appropriate for the OSF to seek the local chief or a respected elder to explain the mission and seek advice on selection of appropriate survivors

to be interviewed. Among the factors the OSF considers in the selection of potential interviewees are:

- The individual's personal experience during the tsunami event;
- The ability to effectively communicate this experience; and
- The lesson(s) that can be learned from the experience.

Care must also be taken in the selection of interviewees because of the emotional impact on survivors of reliving a painful experience through their interview, especially if it is soon after the event (Bird *et al.,* 2011). Though often emotional, interviews usually prove to be cathartic for most interviewees.

When possible, interviewees should also reflect a range of ages, sexes, and community positions. An appointment for the video interview is set up and a location chosen. Typically the location is one that makes the interviewee feel comfortable, but also needs to meet certain criteria to ensure the overall quality of the video product. The site should not be a high noise area and, where possible, should be away from all motor traffic noise. The OSF uses their judgment and local knowledge to select the initial interview site. It is often desirable to schedule time to meet with, and potentially arrange to interview, local leaders or other community members.

A test interview is carried out by the entire crew and reviewed for all aspects of the process to include interview technique, camera work, lighting and sound. At this time the OSF is provided with a list of recommended interview questions that include queries designed to gather important physical and social science data, as well as deliver a powerful description of tsunami experience. If necessary, culturally appropriate behaviour is discussed with the OSF once the mix of interviewees is known.

The LC ensures that all appropriate documentation is in order to record key personal information for each interviewee. Each individual (or guardian for minors) signs a release form that allows use of the recording for educational purposes. Where possible, the forms should be translated into the local language so that the interviewee understands fully what they are signing. The nature and extent of the questions to be asked are also discussed at this time either by the LC or OSF (Sample video questionnaire template). Prior to the interview, all forms (biographical, release) and the tape (and case) for each interviewee are assigned a unique Interview Code number consisting of a location abbreviation, the date of interview, and the interview number in the series for the particular assignment. Photos of the site and interviewee (full face) are taken either prior to, during, or after the interview, whichever is felt to be least intrusive. These actions help to minimize the likelihood of incorrect archiving in the future.

Interview Phase:
Tsunami survivor interviews must be recorded in a single video with no second takes. It has been suggested that interviewees might embellish their stories to make them more interesting or exciting. However, other experiences have also shown that, for many survivors interviewed, it was not the simple telling of a story but the reliving of the most traumatic experience of their lives, thereby putting them in a state in which invention or embellishment was highly unlikely.

Interviewees are usually asked to begin their story with when they woke up on the day of the event and to describe the day and their activities prior to tsunami. The following are recommendations during the interview:

- Subjects must be allowed to recall and describe events without coaching;
- Avoid interrupting their train of thought;
- Avoid closed-questions, such as those that could be answered with a "yes" or "no"; and

- Never lead the discussion. This can give the interviewee a sense of what the interviewer might be "looking for" leading them to give the responses that they perceive are desired.

When the initial narrative is complete however, the interviewee may be gently prodded for additional information, overlooked details, and other useful information. Follow-up questions may be asked about the appearance, number, height, direction, and timing of waves. The final questions used to terminate each interview are: "What advice would you give to others about tsunami safety" or words to that effect, followed by "Is there anything you would like to add?"

Ideally, interviews should be scheduled for a minimum of two hours. In practice however, interviews vary in length from as little as 15 minutes to over an hour, thereby often permitting the collection of three or four interviews in as little as two hours at the same site. Depending upon travel times between sites, location and availability of interviewees, a maximum of about six interviews can be accomplished in a full day.

If an interviewee is willing and able, additional footage may be shot at sites meaningful to the story, otherwise background footage (B-roll) is shot separately. Upon arrival at the interview site it is important for the PD and FC to determine if it meets the criteria for sound, light and movement. Once a suitable site has been found with reasonable sound quality, it must be checked for appropriate lighting. The optimum time of day for recording is when the sun is low. For mid-day shooting, a partially shaded area should be selected. In these circumstances, the subject is placed in the shade with their face illuminated by reflected light without making them squint. It is important though to choose an area where nothing can move behind the subject. People or animals wandering around in the background are distracting to the viewer. The subject should always be comfortably seated so that they do not fidget, and on a seat that does not squeak.

It is important to let the subject attach the microphone themselves, only providing assistance when asked, so as to do nothing offensive in the host culture. Nothing should actually touch the microphone however, such as a scarf or jewellery and this often requires assistance to ensure the interviewee understands. A lavaliere microphone attached at shirt collar level works best. Under windy conditions the interviewee is shielded from direct wind blowing over the microphone. A microphone windscreen is also used to further dampen wind noise. It also pays to check on regularly scheduled events in the area such as a soccer game or evening prayers, which may require adjusting the scheduled interview time to avoid intrusion of potential loud background noise.

Immediate Post-interview Phase:
Following each interview one practice can be to have the OSF immediately provide a short written summary of the story in English. It is important to allow time for this process immediately after the interview. The immediate post-interview phase also offers the opportunity to arrange for the copying of any documentation of the tsunami provided by the interviewee (e.g. photos), and to accept and process any donated memorabilia. At the end of the day, the team meets to review the day's interviews. Any necessary revisions or additions to the descriptive data that accompany the interview tapes are made immediately while the details are still fresh. An electronic summary interview document is set-up for each assignment. This is updated daily with each reference number assigned to the appropriate interviewee photograph, and brief biographical details.

It is optimum to simultaneously record video and also directly to a hard drive. This will produce a digital videotape and a hard drive backup copy of interviews, thereby eliminating the chore of making backup videotape copies during an expedition. Never place videotapes in checked airline baggage. Immediately following an ITST, all interview tapes are backed up and the back-up copies stored in separate, secure, climate-controlled locations. These DVDs are complete, unedited copies of the interview and contain the time code recorded on the original videotape.

Transcription and Translation of Interviews

Where translation is necessary the DVDs are sent to the OSF who carries out or supervises the transcription and translation of the interviews. The video time code must be entered at frequent intervals (two to five minute intervals) alongside the translated transcription of the interview in order to permit editing of the video. These transcriptions can then be easily converted into a video storyboard. A typical interview lasts between 20 and 40 minutes, although some extend up to two hours. All achieved interview transcripts are recorded in a searchable archive database keyed to specific tsunami events.

Selected interviews may be edited to a three- to four-minute final product, which includes the most important lessons learned. A good practice is to offer DVD copies of the interviews to the interviewee whenever feasible, typically in full-length form. Due to the different video standards used internationally (NTSC, PAL, SECAM), providing copies of interviews for commercial video players can be both an unexpectedly problematic and expensive component of any project, however the provision of videotape copies is often a necessary expense.

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Template 1

Template 1 – sample interview questions adapted from IOC-UNESCO 2010 Chile tsunami ITST

1. Was a tsunami, tidal wave or other unusual water wave activity along nearby coastal areas noted by you or anyone in your community near the date and time indicated on the opposite page? ☐ Yes ☐ No

   If No, please complete item 2 and return this form.

Date ___________ Time ______________ ☐ AM ☐ PM

☐ Standard Time ☐ Daylight

2. To be completed by person filling out this form

Name ____

Address ____

City ____________________ Country____________________

State ____________________ Zip Code___________________

Tel ____________________ Fax ____________________

E-mail ____________________ ____________________

Profession, gender, age ____________________________

Where were you during the earthquake and the tsunami? (a hill, a house, a boat, etc.)

____

Place name (town, village, colony, topographic) ____________________ (locate on maps or air photos)

TSUNAMI ALERT INFORMATION

3. Did you have knowledge/expectation that a tsunami would come? ☐ Yes ☐ No

4. If yes, but what do you know and how did you know it? ______________________

   Did you have experience of or knowledge of previous events? _________________

5. Did you receive a tsunami alert, information bulletin, watch, or warning?
   ☐ Yes ☐ No

6. If yes, indicate type and at what time(s):
   ☐ Alert _____ _____________
   ☐ Bulletin __ ☐ Watch ____ ☐ Warning ____

7. If yes, how did you learn of the alert, warning, bulletin, or watch?
   If more than one, please indicate order:
   ☐ Siren ☐ Radio ☐ TV ☐ Civil Defence ☐ Fire Department
   ☐ Police ☐ Telephone ☐ Internet ☐ Other (explain) ________________

8. What was your response to the alert, warning, bulletin or watch?
   If more than one, please indicate order:
   ☐ Did nothing ☐ Evacuated ☐ Waited for further instructions
   ☐ Other (explain) ____

9. What was the response of different segments of the population
   (elderly, disable, minors and children, etc.)?
   ____
   ____

10. How effective were response planning, operation, and evacuations?
    ____

11. Were there obstacles during the evacuation?
    ____

12. What preparedness actions had you taken well before the tsunami?
    ____

TSUNAMI WAVE OBSERVATIONS

We are interested in documenting the sea-water appearance before, during, and after the tsunami (boiling, foaming, etc.).

Specifically, did the water receded or not before the first tsunami wave arrived?

Were there any sounds (noise) before or during the arrival of the tsunami and of what type?

Were there tsunami-excited seiches in semi-enclosed bays, tsunami generated bore waves traveling up-rivers, trapping, refraction or diffraction of tsunami waves around islands and edge waves along the continental shelf, coastal water piling due to intense hurricane or typhoon winds simultaneous to the arrival of the tsunami?

Were there any evidences and effects of tsunami-induced flows and currents? (estimate magnitude and direction if possible)

What was the situation before the tsunami? (meteorological conditions, sea-level, light conditions, sounds or noise, etc.)

____

13. Did you see unusual waves? ☐ Yes ☐ No

14. If yes, indicate the location and type of water body where you observed the wave:
☐ Open coast ☐ Bay ☐ Harbour ☐ Estuary

Location ____________________________________

15. Indicate the direction the wave came from:
☐ North ☐ South ☐ East ☐ West

16. Indicate the direction the wave went to:
☐ North ☐ South ☐ East ☐ West

17. Indicated the slope of the shore where you observed the wave:
☐ Level ☐ Gently sloping ☐ Steep ☐ Vertical

18. Were there any other natural phenomena at or near the time of the tsunami?
☐ None ☐ Earthquake ☐ Landslide ☐ Volcanic activity
☐ Other (describe) ______________________________

19. What was the water condition before the tsunami waves arrived?
☐ Calm ☐ Ripples ☐ Swells ☐ Choppy ☐ Heavy surf ☐ Stormy

20. Describe any sounds at the time of arrival?
☐ Drum ☐ Thunder ☐ Airplane ☐ Rain ☐ Car
☐ River ☐ Train ☐ No Sound ☐ Other ____________

21. Did the water recede before the first tsunami wave arrived? ☐ Yes ☐ No

22. Indicate the nature of the tsunami wave(s):
☐ Fast rising and falling tides ☐ Breaking waves (swell with white caps)
☐ Calm, slow flooding ☐ Like a river ☐ Wall (bore)
☐ Other ____

23. Describe any sounds or noise, or other unusual happening before or during the tsunami wave arrival:

____

24. How many times did the water rise (How many waves were there)?

____

Local time - from clocks, TV programmes, etc. ______________________________
How much time was there between the main earthquake shock and the tsunami wave arrival ____
(Note that an aftershock may come between the main shock and the tsunami arrival time)
Did the water completely withdraw and came back again?

____
Were there bores, eddies in rivers or bays, or changes in water colour?
____
What was the relative size of the waves? (which one was largest, etc.)?
____

Please give times and heights of the waves at your location:

	Time	Heights (meters or feet)	Location and Observation
First wave:			
Second wave:			
Third wave:			
Fourth wave:			
Fifth wave:			
Other waves:			

25. How far inland did the water travel from high-tide shoreline at your location?
☐ Up to few m (A few feet) ☐ Up to 50 m (165 feet) ☐ Up to 100 m (330 feet)
☐ Up to 25 m (80 feet) ☐ Up to 75 m (245 feet) ☐ More than 100 m (330 feet)

Please provide additional descriptions.
Location and Description ____

____

TSUNAMI IMPACT AND DAMAGE

26. Describe the types of tree damage observed (if any):

☐ Small limbs broken ☐ Tree less than 5 cm diameter broken (2”)

☐ Trees from 5-20 cm diameter broken (2” to 8”) ☐ Trees greater than 20 cm diameter broken (8”)

☐ Trees uprooted ☐ Total destruction of vegetation

27. Describe effects on other types of vegetation:

____

28. Did the water move debris inland (seaward) form the shoreline?
Inland: ☐ Yes ☐ No; Seaward: ☐ Yes ☐ No

29. If yes, identify large rocks, significant debris, houses, ships, etc. moved by the tsunami (and where they were before):

____

30. Make a drawing if necessary.

31. Indicate the predominant type of debris, how far inland (or seaward) beyond the high (low) tide shoreline the debris was moved, and the slope of the shore (i.e. level, gentle, steep):

	Slope	Distance
☐ Sand	______	______
☐ Driftwood	______	______
☐ Rocks to cobble size	______	______
☐ Boulders	______	______
☐ Other (describe)	______	______

32. Were there any permanent changes in sea level after the tsunami? ☐Yes ☐ No
What were the changes in the land surface caused by the tsunami?
Places where there was erosion? Places where it left sediment (deposits)?
What did it look like before the tsunami?
Location ____
Description ____

33. Was there damage to boats of different sizes?

____

34. What percentage of boats were damaged in the harbour?
☐ None ☐ Few (about 5%) ☐ Many (about 50%) ☐ Most (about 75%)

35. List types of damage (moorings, types of boats) and describe how they were damaged, such as by waves, strong currents, debris (boats, pirogues).
Location ____
Description ____

STRUCTURAL DAMAGE

36. What percentage of buildings or structures were damaged by the wave in your locality?

☐ None ☐ Few (about 5%) ☐ Many (about 50%) ☐ Most (about 75%)

37. Check the approximate age of the majority of damaged buildings or structures:

☐ Built before 1945 ☐ Built between 1945-1965 ☐ Built between 1965-1980
☐ Built between 1980-1990 ☐ Built between 1990-2000 ☐ Built after 2000

38. Check the types of buildings or structures, the type of construction (wood, stone, brick, cinderblock, metal, reinforced concrete, etc.), the type of foundation (pilings, cinder block, poured concrete, etc.), and the overall extent of damage

(1-*Slight,* 2-*Moderate,* 3-*Severe,* 4-*Total*):

Type:	Type of construction:	Foundation:	Damage:			
☐ High-rise building	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Low-rise building	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Split-level houses	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Single-level houses	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Breakwaters	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Piers	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Docks	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Wharfs	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Light houses	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Bridges	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Overpasses	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Dams	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Railroad tracks	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Roads	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4
☐ Other	___________	______________	☐ 1	☐ 2	☐ 3	☐ 4

Describe ____

39. Describe the predominant type of ground under the majority of damaged buildings or structures:

☐ Sandy soil ☐ Marshy ☐ Fill ☐ Hard rock
☐ Clay soil ☐ Shale ☐ Don't know

40. Was the slope of the ground under these buildings or structures:

☐ Level ☐ Gently sloping ☐ Steep

41. How far away from the shoreline were the buildings or structures that were damaged?

☐ At the shoreline ☐ Less than 50 m (165 feet) ☐ Between 50-100 m (165-330 feet)
☐ Between 100-200 m (330-660 feet) ☐ More than 200 m (660 feet)

42. Do you know of any injuries or fatalities associated with the wave? ☐ Yes ☐ No

If yes, how many injuries? __________ Fatalities? _______________ ___________

Circumstances? ____

FOR THOSE WHO WERE IN BOATS OR AT THE BEACH

43. Where were you before, during and after the event?
Please describe____

44. What did the sea surface look like? (e.g., boiling, shaking, foaming ripples or waves)
Please describe

____

45. Was there damage to the ship/boat? ☐ Yes ☐ No
Please describe ____

46. Did you notice any other phenomena? (e.g., fish behaviour, light, etc.)

____

____

FOR OLDER PERSONS

47. Have you experienced any other tsunamis like this one in your lifetime, at this same or another place?
When? Where? Please describe such events.__________________________________

____

____

48. Did your parents/grandparents experience any such events?
When? Where? Please give a brief description.

____

____

49. Do you know of stories or legends of such events that have been handed down? Please describe.

____

____

Thank you for taking the time to fill out this information questionnaire.

Template 2

Adapted from the 2009 Samoa ITST

Tsunami survivor/disaster awareness research survey
Research Survey Instrument – Adapted from the 2009 Samoa ITST

Name of Community:____
Name of Household:____
Name of person interviewed:____________________ Age__________________
Gender:____

The following questions should help us to better understand tsunamis. Please help us in that by given your experience with the recent tsunami as best as you can remember.

1. Where were you when you felt the earthquake?

☐ Inside own house
☐ Inside other people's house
☐ Inside school
Inside other:____
☐ Outside own house
☐ Outside other people's house
☐ On the street
Outside other:____

2. What did you do after you felt the earthquake?

☐ I continued with what I was doing
☐ I rushed out of the house to see what was happening
☐ I rushed out of the house to get myself to safety
Other:____

3. When were you first aware of the tsunami?

☐ When I saw the water receding
☐ When I heard the water coming
☐ When someone warned me
☐ When I saw the water coming
Other:____

4. How soon after the earthquake did you notice the tsunami?

☐ Immediately, i.e. I felt the earthquake and then the tsunami came straight away
☐ Less than 5 minutes after the earthquake
☐ Between 5 – 10 minutes after the earthquake
☐ More than 10 minutes after the earthquake
☐ I really don't know

5. How many waves did you experience?

☐ Only one wave More than three waves
☐ Two waves I really don't know
☐ Three waves
☐ More than three waves – estimate how many ______________________

6. Which wave was the largest?______________________________________

7. How much time was there between the waves? ___________________________

8. From what direction did the water come and where did it go to?_____________

9. When and how did you start to evacuate from the tsunami?
☐ Evacuated _______ minutes before the tsunami arrival
☐ Evacuated just after seeing the tsunami coming
☐ Did not evacuate, but stayed in the house
☐ Did not evacuate, but stayed outside

10. How did you evacuate?
☐ Went on foot
☐ Drove a car
Other ____

11. Were you caught in the tsunami water?
☐ Yes outside
☐ Yes in the house
☐ No, I was in a safe place

12. How could you escape from the tsunami?
☐ I was able to swim
☐ I held to floating materials
☐ I could climb onto house / tree
Other reasons: ____

13. What did you know about tsunamis before the tsunami?
☐ Nothing, I had never before heard anything about tsunamis
☐ I had heard about tsunamis before, but was not sure what it is exactly
☐ I knew something about tsunamis, but I was not sure what to do
☐ I knew enough about tsunamis to know what to do

14. How much is your home affected by the tsunami
☐ Home not affected by tsunami
☐ Home partly damaged, still living there
☐ Home partly damaged, moved out to
☐ Home fully damaged, moved out to

15. How were people of your household affected by the tsunami?
☐ People from household died in the tsunami
☐ People from household got injured
☐ People from household are still missing

Additional questions you may wish to consider including either before or after asking the above questions:

1. How are you after the tsunami? What are your worries and concerns?

____

2. What are your needs now?

____

3. How do you see these needs being met?

---

4. What help have you received?

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5. What were your sources of income before the tsunami?

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6. How has this been affected?

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7. Are you planning on rebuilding your homes and where?

Annex XI – Socio-economic Data Collection

Introduction

Researchers interested in people and their associated socio-economic systems will be keen to identify, describe and explain the nuanced socio-economic and political processes affecting impacted communities and the things those communities value. Further, they will want to quantify and explain the socio-economic impacts of the tsunami. An understanding of such processes and impacts can help to identify why the human system impacts are as bad (or not) in a particular place, what factors were at work to influence resilience and adaptive capacity and what the underlying root causes of vulnerability were. Such knowledge is a fundamental requisite for quantifying the impacts so appropriate levels of compensation (i.e., a 'needs assessment') can be organized and delivered to affected communities and for assisting in the design of new disaster risk reduction policies and plans for the future.

In reality, experts from many discipline fields including, but not limited to, human geography, sociology, economics, planning, policy and decision-making, risk and emergency management, anthropology, human health, political sciences, indigenous studies, history, religious studies, etc., may have interest in contributing to socio-economic aspects of an ITST. Their insights will all help to shed light on the effects of tsunamis on people and their communities and why, and how, the event was experienced by survivors. It is also important for them to identify pre-existing cultural, economic, or geographic that influenced resiliency and vulnerability.

List of equipment

This Guide does not provide any specific advice about equipment that would be relevant for socio-economic and human sciences researchers.

As a minimum however, notebooks, pens, laptops and voice recorders will all be useful. Of note, it is worth remembering that field teams will be working in post-disaster contexts where for example, power cannot be guaranteed. As such, any specific equipment taken that requires power (mains electricity or battery) should be entirely self-sufficient. Carry additional batteries yourself and assume mains power will not be available.

Field Methods

This Guide recognizes that in addition to ITSTs, other major post-tsunami disaster assessment teams will very likely be working in the affected regions. Such teams will also comprise human and socio-economic researchers under the guise of host government agencies and/or international organizations, etc.

This Guide strongly encourages that ITSTs should wherever possible, work collaboratively with such teams to avoid duplication of efforts and to find opportunities to pursue additional avenues of human and socio-economic research that takes account of the expertise of ITST members.

Given the variety of expertise that might be included under the banner of 'socio-economic' systems analysis, this Guide cannot be sufficiently prescriptive in terms of providing guidance on field methods. Appropriately qualified experts will know the best tools and methods to use in the field.

The Guide does recommend however, where a team of socio-economic experts (of any discipline fields) come together in the field, pre-arrival discussions about which research questions and consequently, which methods, frameworks and approaches and tools are most appropriate to use, should occur. This will help to facilitate a dialogue and mutual understanding of the task ahead and the range of possible approaches to field based study and analysis. It is likely that researchers focusing on the socio-economic aspects of the tsunami will spend much of their field time talking with survivors, officials, and other persons in the affected area. Annex X provides additional information on considerations and techniques for field interviews.

Exiting research methods and tools

Having indicated that this Guide cannot be prescriptive in relation to the tools and methods to be used, it does recognize, established and widely used 'Damage, Loss and Needs Assessment' tools. For example, the Global Facility for Disaster Reduction and Recovery (GFDRR) has the Damage and Loss Assessment Methodology and Post Disaster Needs Assessment tools (see http://gfdrr.org/gfdrr/node/69). Such tools (though not exclusively) are highly useful for undertaking socio-economic impact assessments.

However, such tools and methods will not meet the needs of health experts or indigenous researchers or other subfields of human, social and economic studies. As such, experts will need to adopt and utilize relevant methods and tools developed and used within their areas of expertise.

Data quality and special considerations

This Guide recognises that for meaningful data analyses within the socio-economic disciplines to occur, establishing a pre-tsunami baseline about conditions and context will be important. Once collected, such baseline data will be useful for enabling an analysis and mapping of the effects of the event.

Additional relevant background information

The 1990s were significant because they were designated by the United Nations as the International Decade for Natural Disaster Reduction. Of particular importance, by the end of 1999, the United Nations via the UN/ISDR had shifted its emphasis in research and language from a scientific paradigm of physical and engineering sciences as providing all relevant answers to hazards and disasters, to a more multi-faceted recognition that disasters are a social construct. Furthermore, the explicit recognition that disasters are social constructions and shortfalls of detection, monitoring and early warning systems coupled with increasing human, infrastructure and economic losses, meant that a shift towards understanding the human system (in all its many parts) context of disasters was as important as understanding the physical earth system processes of the hazard event itself.

It is in the recognition of this shift that this Guide encourages researchers with expertise in socio-economic systems to consider contributing to ITSTs in a more concerted way than has traditionally been the case.

The IOC-UNESCO ITST Samoa working in September–October 2009 was the first ITST to have a significant socio-economic team. That team published a useful paper describing their experience and approach to undertaking socio-economic work as part of a larger multidisciplinary ITST and outlined many of the challenges of working within the tight timeframe of an ITST. Potential ITST participants are encouraged to read van Zijll de Jong *et al.,* (2011) prior to going in to the field.

Templates

This Guide provides no specific templates for collecting socio-economic and human systems data. Researchers intending to undertake such work should negotiate with others in advance and provide copies (ideally circulated electronically beforehand) to team members for modification, approval and adoption.

Here the Guide lists those types of data that can be collected in relation to the socio-economic system. It is not exhaustive but indicative of the types of data governments, communities and Disaster Management Offices are interested in gathering to understand the impacts of a tsunami. They include:

- Number of human deaths and the causes of those deaths and survivor numbers
- Casualty and injury figures and types of injury
- Number of homeless and displaced people
- Emergency shelter requirements
- Food, water, sanitation and medicine requirements
- Damage to and loss of households, household goods and types
- Damage to and loss of agriculture equipment, seeds and stock and animals
- Impacts on life line services, communication and transport systems and critical infrastructure
- Loss of jobs and businesses and business interruption
- Micro and macroeconomic effects
- Experience of survivors of the emergency management procedures and their successes and failings
- Human behaviour, knowledge and experience including decision making processes during the event
- Time line of official events (transcript) from the regional/local/national disaster management office
- Media analysis of what went on from the local, regional, national perspective
- Local/regional/national socio-economic and demographic data to compare disaster effects against (e.g., male/female/children casualty statistics against averages), etc.
- GIS and other national/regional/local database statistics
- Impacts on Indigenous peoples
- Impacts on minorities, women and children

References

van Zijll de Jong, S., D. Dominey-Howes, C. Roman, E. Calgaro, A. Gero, S. Veland, D. Bird, T. Muliaina, D. Tuiloma-Sua and T. Afioga (2011). Process, practice and priorities – reflections on, and suggestions for, undertaking sensitive social reconnaissance research as part of an (IOC-UNESCO) International Tsunami Survey Team. *Earth Science Reviews*, **107**, 174–192.

Annex XII – List of Acronyms

BODC	British Oceanographic Data Centre
BPR	Bottom Pressure Recorder
DART	Deep Ocean Assessment & Reporting of Tsunamis
DEM	Digital Elevation Model
EADS	European Aeronautic Defence and Space Company
EERI	Earthquake Engineering Research Institute
FC	Field Coordinator
GCN	Global Core Network (of GLOSS)
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographical Information System
GLOSS	Global Sea Level Observing System
GPS	Global Positioning System
HSEAC	Hawaii State Earthquake Advisory Committee
ICSU	International Council of Scientific Unions
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IOC-UNESCO	Intergovernmental Oceanographic Commission of UNESCO
ISDR	International Strategy for Disaster Reduction
ITIC	International Tsunami Information Center (IOC/UNESCO)
ITST	International Tsunami Survey Team
JCOMM	WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology
LC	Logistical Coordinator
LDC	Least Developed Country
MOST	Method of Splitting Tsunami (NOAA/PMEL)
NDBC	National Data Buoy Center (NOAA)
NEES	Network for Earthquake Engineering Simulation
NGDC	National Geophysical Data Center (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service (USA)
NSF	National Science Foundation (USA)
NWLON	National Water Level Observation Network (USA)
OSF	On-Site Facilitator
PD	Project Director
PMEL	Pacific Marine Environmental Laboratory (NOAA)
PSMSL	Permanent Service for Mean Sea Level
PTWC	Pacific Tsunami Warning System
TTC	Tsunami Technical Clearinghouse
TTRC	Tsunami Technical Review Committee
TUNAMI	Tohoku University Numerical Analysis Model for Investigation of Tsunami
UHSLC	University of Hawaii Sea Level Center
UN	United Nations
UNDP	United Nations Development Programme

UNESCO	United Nations Educational, Scientific & Cultural Organization
UN/ISDR	United Nations/ International Strategy for Disaster Reduction
USA	United States of America
USGS	United States Geological Survey
UTC	Coordinated Universal Time
WDS-MGG	World Data Service – Marine Geology and Geophysics
WGS-84	World Geodetic System 84
WMO	World Meteorological Organization

IOC Manuals and Guides

No.	Title
1 rev. 2	Guide to IGOSS Data Archives and Exchange (BATHY and TESAC). 1993. 27 pp. (English, French, Spanish, Russian)
2	International Catalogue of Ocean Data Station. 1976. *(Out of stock)*
3 rev. 3	Guide to Operational Procedures for the Collection and Exchange of JCOMM Oceanographic Data. Third Revised Edition, 1999. 38 pp. (English, French, Spanish, Russian)
4	Guide to Oceanographic and Marine Meteorological Instruments and Observing Practices. 1975. 54 pp. (English)
5 rev. 2	Guide for Establishing a National Oceanographic Data Centre. Second Revised Edition, 2008. 27 pp. (English) *(Electronic only)*
6 rev.	Wave Reporting Procedures for Tide Observers in the Tsunami Warning System. 1968. 30 pp. (English)
7	Guide to Operational Procedures for the IGOSS Pilot Project on Marine Pollution (Petroleum) Monitoring. 1976. 50 pp. (French, Spanish)
8	*(Superseded by IOC Manuals and Guides No. 16)*
9 rev.	Manual on International Oceanographic Data Exchange. (Fifth Edition). 1991. 82 pp. (French, Spanish, Russian)
9 Annex I	*(Superseded by IOC Manuals and Guides No. 17)*
9 Annex II	Guide for Responsible National Oceanographic Data Centres. 1982. 29 pp. (English, French, Spanish, Russian)
10	*(Superseded by IOC Manuals and Guides No. 16)*
11	The Determination of Petroleum Hydrocarbons in Sediments. 1982. 38 pp. (French, Spanish, Russian)
12	Chemical Methods for Use in Marine Environment Monitoring. 1983. 53 pp. (English)
13	Manual for Monitoring Oil and Dissolved/Dispersed Petroleum Hydrocarbons in Marine Waters and on Beaches. 1984. 35 pp. (English, French, Spanish, Russian)
14	Manual on Sea-Level Measurements and Interpretation. (English, French, Spanish, Russian)
	Vol. I: Basic Procedure. 1985. 83 pp. (English)
	Vol. II: Emerging Technologies. 1994. 72 pp. (English)
	Vol. III: Reappraisals and Recommendations as of the year 2000. 2002. 55 pp. (English)
	Vol. IV: An Update to 2006. 2006. 78 pp. (English)
15	Operational Procedures for Sampling the Sea-Surface Microlayer. 1985. 15 pp. (English)
16	Marine Environmental Data Information Referral Catalogue. Third Edition. 1993. 157 pp. (Composite English/French/Spanish/Russian)
17	GF3: A General Formatting System for Geo-referenced Data
	Vol. 1: Introductory Guide to the GF3 Formatting System. 1993. 35 pp. (English, French, Spanish, Russian)
	Vol. 2: Technical Description of the GF3 Format and Code Tables. 1987. 111 pp. (English, French, Spanish, Russian)
	Vol. 3: Standard Subsets of GF3. 1996. 67 pp. (English)
	Vol. 4: User Guide to the GF3-Proc Software. 1989. 23 pp. (English, French, Spanish, Russian)
	Vol. 5: Reference Manual for the GF3-Proc Software. 1992. 67 pp. (English, French, Spanish, Russian)
	Vol. 6: Quick Reference Sheets for GF3 and GF3-Proc. 1989. 22 pp. (English, French, Spanish, Russian)

No.	Title
18	User Guide for the Exchange of Measured Wave Data. 1987. 81 pp. (English, French, Spanish, Russian)
19	Guide to IGOSS Specialized Oceanographic Centres (SOCs). 1988. 17 pp. (English, French, Spanish, Russian)
20	Guide to Drifting Data Buoys. 1988. 71 pp. (English, French, Spanish, Russian)
21	*(Superseded by IOC Manuals and Guides No. 25)*
22 rev.	GTSPP Real-time Quality Control Manual, First revised edition. 2010. 145 pp. (English)
23	Marine Information Centre Development: An Introductory Manual. 1991. 32 pp. (English, French, Spanish, Russian)
24	Guide to Satellite Remote Sensing of the Marine Environment. 1992. 178 pp. (English)
25	Standard and Reference Materials for Marine Science. Revised Edition. 1993. 577 pp. (English)
26	Manual of Quality Control Procedures for Validation of Oceanographic Data. 1993. 436 pp. (English)
27	Chlorinated Biphenyls in Open Ocean Waters: Sampling, Extraction, Clean-up and Instrumental Determination. 1993. 36 pp. (English)
28	Nutrient Analysis in Tropical Marine Waters. 1993. 24 pp. (English)
29	Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. 1994. 178 pp . (English)
30	MIM Publication Series:
	Vol. 1: Report on Diagnostic Procedures and a Definition of Minimum Requirements for Providing Information Services on a National and/or Regional Level. 1994. 6 pp. (English)
	Vol. 2: Information Networking: The Development of National or Regional Scientific Information Exchange. 1994. 22 pp. (English)
	Vol. 3: Standard Directory Record Structure for Organizations, Individuals and their Research Interests. 1994. 33 pp. (English)
31	HAB Publication Series:
	Vol. 1: Amnesic Shellfish Poisoning. 1995. 18 pp. (English)
32	Oceanographic Survey Techniques and Living Resources Assessment Methods. 1996. 34 pp. (English)
33	Manual on Harmful Marine Microalgae. 1995. (English) [superseded by a sale publication in 2003, 92-3-103871-0. UNESCO Publishing]
34	Environmental Design and Analysis in Marine Environmental Sampling. 1996. 86 pp. (English)
35	IUGG/IOC Time Project. Numerical Method of Tsunami Simulation with the Leap-Frog Scheme. 1997. 122 pp. (English)
36	Methodological Guide to Integrated Coastal Zone Management. 1997. 47 pp. (French, English)
37	International Tsunami Survey Team (ITST) Post-Tsunami Survey Field Guide. 2nd Edition. 2014. 120 pp. (English) Post-Tsunami Survey Field Guide. First Edition. 1998. 61 pp. (English, French, Spanish, Russian)
38	Guidelines for Vulnerability Mapping of Coastal Zones in the Indian Ocean. 2000. 40 pp. (French, English)
39	Manual on Aquatic Cyanobacteria – A photo guide and a synopsis of their toxicology. 2006. 106 pp. (English)
40	Guidelines for the Study of Shoreline Change in the Western Indian Ocean Region. 2000. 73 pp. (English)
41	Potentially Harmful Marine Microalgae of the Western Indian Ocean Microalgues potentiellement nuisibles de l'océan Indien occidental. 2001. 104 pp. (English/French)

No.	Title
42	Des outils et des hommes pour une gestion intégrée des zones côtières - Guide méthodologique, vol.II/ Steps and Tools Towards Integrated Coastal Area Management – Methodological Guide, Vol. II. 2001. 64 pp. (French, English; Spanish)
43	Black Sea Data Management Guide *(Cancelled)*
44	Submarine Groundwater Discharge in Coastal Areas – Management implications, measurements and effects. 2004. 35 pp. (English)
45	A Reference Guide on the Use of Indicators for Integrated Coastal Management. 2003. 127 pp. (English). *ICAM Dossier No. 1*
46	A Handbook for Measuring the Progress and Outcomes of Integrated Coastal and Ocean Management. 2006. iv + 215 pp. (English). *ICAM Dossier No. 2*
47	TsunamiTeacher – An information and resource toolkit building capacity to respond to tsunamis and mitigate their effects. 2006. DVD (English, Bahasa Indonesia, Bangladesh Bangla, French, Spanish, and Thai)
48	Visions for a Sea Change. Report of the first international workshop on marine spatial planning. 2007. 83 pp. (English). *ICAM Dossier No. 4*
49	Tsunami preparedness. Information guide for disaster planners. 2008. (English, French, Spanish)
50	Hazard Awareness and Risk Mitigation in Integrated Coastal Area Management. 2009. 141 pp. (English). *ICAM Dossier No. 5*
51	IOC Strategic Plan for Oceanographic Data and Information Management (2008–2011). 2008. 46 pp. (English)
52	Tsunami risk assessment and mitigation for the Indian Ocean; knowing your tsunami risk – and what to do about it. 2009. 82 pp. (English)
53	Marine Spatial Planning. A Step-by-step Approach. 2009. 96 pp. (English; Spanish). *ICAM Dossier No. 6*
54	Ocean Data Standards Series:
	Vol. 1: Recommendation to Adopt ISO 3166-1 and 3166-3 Country Codes as the Standard for Identifying Countries in Oceanographic Data Exchange. 2010. 13 pp. (English)
	Vol. 2: Recommendation to adopt ISO 8601:2004 as the standard for the representation of date and time in oceanographic data exchange. 2011. 17 pp. (English)
55	Microscopic and Molecular Methods for Quantitative Phytoplankton Analysis. 2010. 114 pp. (English)
56	The International Thermodynamic Equation of Seawater—2010: Calculation and Use of Thermodynamic Properties. 2010. 190 pp. (English)
57	Reducing and managing the risk of tsunamis. Guidance for National Civil Protection Agencies and Disaster Management Offices as Part of the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas Region – NEAMTWS. 2011. 74 pp. (English)
58	How to Plan, Conduct, and Evaluate Tsunami Exercises / Directrices para planificar, realizar y evaluar ejercicios sobre tsunamis. 2012. 88 pp. *(*English, Spanish*)*
59	Guía para el diseño y puesta en marcha de un plan de seguimiento de microalgas productoras de toxinas. 2011. 70 pp. (Español solamente)
60	Global Temperature and Salinity Profile Programme (GTSPP) — Data user's manual, 1st Edition 2012. 2011. 48 pp. (English)
61	Coastal Management Approaches for Sea-level related Hazards: Case-studies and Good Practices. 2012. 45 pp. (English)

No.	Title
62	Guide sur les options d'adaptation en zone côtières à l'attention des décideurs locaux – Aide à la prise de décision pour faire face aux changements côtiers en Afrique de l'Ouest / A Guide on adaptation options for local decision-makers: guidance for decision making to cope with coastal changes in West Africa / Guia de opções de adaptação a atenção dos decisores locais: guia para tomada de decisões de forma a lidar com as mudanças costeiras na Africa Ocidental. 2012. 52 pp. (French, English, Portuguese). *ICAM Dossier No. 7*.
63	The IHO-IOC General Bathymetric Chart of the Oceans (GEBCO) Cook Book. 2012. 221 pp. (English). *Also IHO Publication B-11*
64	Ocean Data Publication Cookbook. 2013. 41 pp. (English)
65	Tsunami Preparedness Civil Protection: Good Practices Guide. 2013. 57 pp. (English)
66	IOC Strategic Plan for Oceanographic data and Information Management (2013-2016). 2013. 54 pp. (English/French/Spanish/Russian)
67	IODE Quality Management Framework for National Oceanographic Data Centres *(in preparation)*
68	An Inventory of Toxic and Harmful Microalgae of the World Ocean *(in preparation)*
69	A Guide to Tsunamis for Hotels: Tsunami Evacuation Procedures *(in preparation)*
70	A guide to evaluating marine spatial plans. 2014. 96 pp. (English)