TsuInfo Alert

Prepared and published bimonthly by the Washington State
Department of Natural Resources, Washington Geological Survey,
on behalf of the National Tsunami Hazard Mitigation Program (NTHMP),
a state/federal partnership led by the National Oceanic and Atmospheric Administration (NOAA).
This publication is free upon request and is available in print by mail and online at:
http://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/tsunamis/tsuinfo-alert

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NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM LIBRARY CATALOG:
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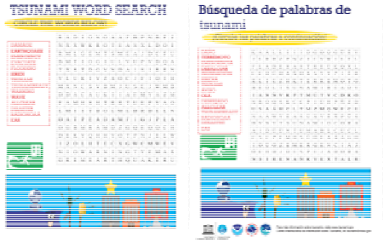
Vertical Evacuation Best Practices for the International Community

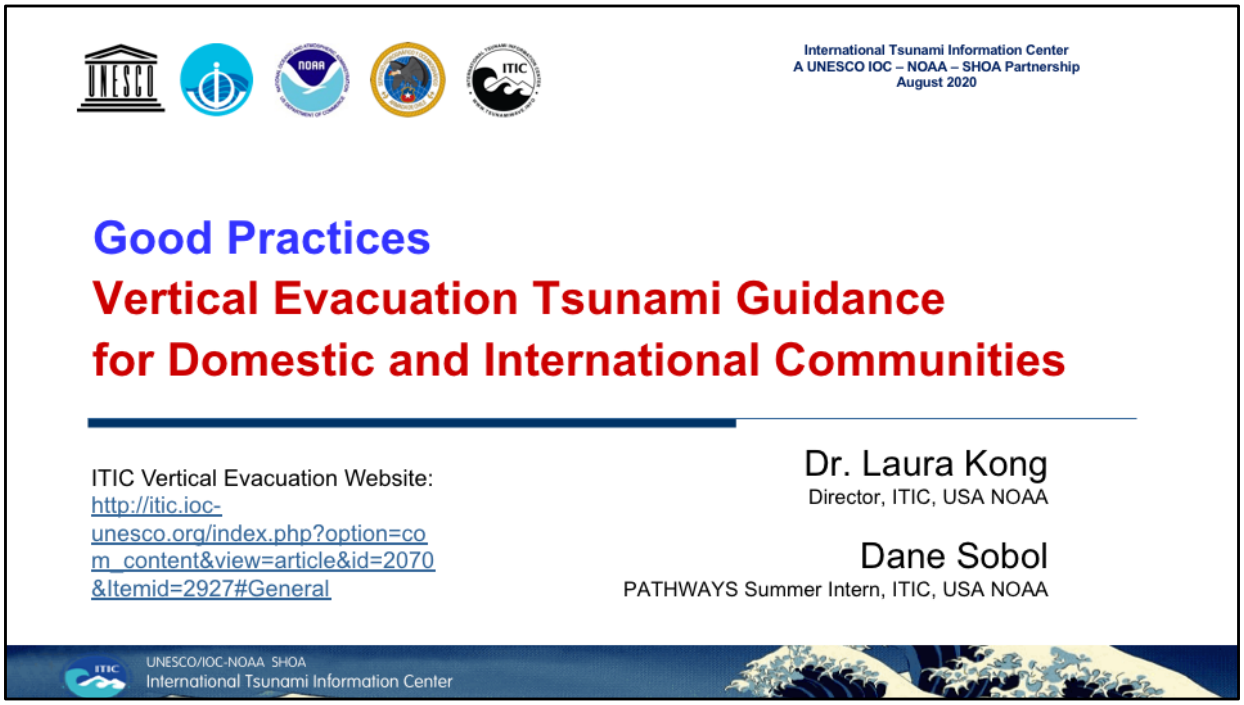
By Dane Sobol and Laura Kong, International Tsunami Information Center (ITIC)

Vertical evacuation may be a life-saving solution where natural high ground does not exist, or a local tsunami does not allow sufficient advance warning time to enable evacuation to high ground. Strong vertical evacuation buildings should provide a safe refuge for people to escape a tsunami. By simple definition, a vertical evacuation building is a structure with sufficient height and strength to resist tsunami wave effects. The 2018 International Building Code for structures references the ASCE/SEI 7-16 standard, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, Chapter 6, "Tsunami Loads and Effects," to design structures for tsunamis.



In response to a request from the UNESCO Intergovernmental Oceanic Commission Working Group on Tsunamis and Other Hazards related to Sea Level Warning and Mitigation Systems (IOC TOWS) Task Team on Disaster Management and Preparedness, ITIC has compiled international best practices in tsunami vertical evacuation. Highlights have been posted to the ITIC Vertical Evacuation web site http://itic.ioc-unesco.org/index.php?option=com_content&view=article&id=2070&Itemid=2927. Best practices were categorized by country and the following keywords: engineering assessment, building code, mitigation, and response. Each reference contains a brief summary for rapid comprehension. A total of 117 references were found. USA, Japan, and Indonesia had the most references. Tsunami awareness activities were also created for children to reinforce vertical evacuation guidance.

ITIC welcomes additional contributions to this compilation (please send to itic.tsunami@noaa.gov).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A UNESCO IOC – NOAA – SHOA Partnership
August 2020
Good Practices
Vertical Evacuation Tsunami Guidance
for Domestic and International Communities
ITIC Vertical Evacuation Website:
http://itic.ioc-unesco.org/index.php?option=com_content&view=article&id=2070&Itemid=2927#General
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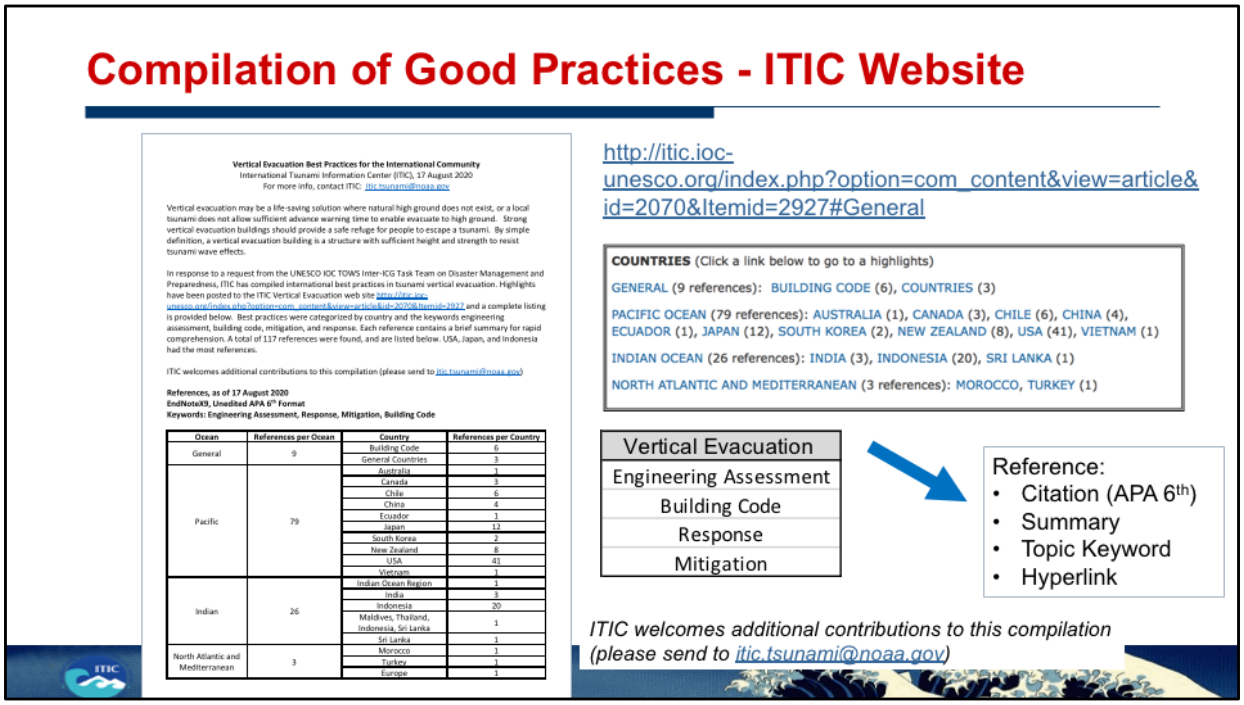

http://itic.ioc-unesco.org/images/stories/vertical_evac/Vert%20Evac%20Endnote_20200817_draft.pdf

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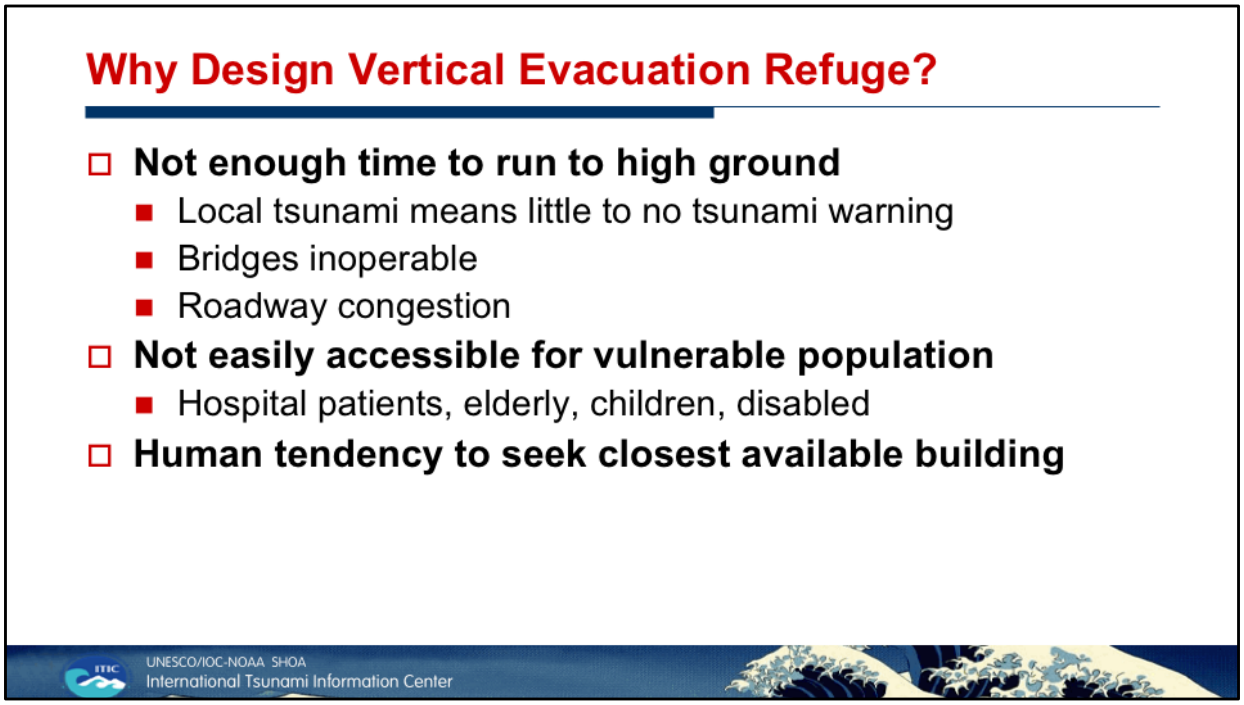
RESOURCE MATERIALS ON VERTICAL EVACUATION STRUCTURES
KEYWORDS: Engineering Assessment, Building Code, Mitigation, Response



Vertical Evacuation Refuges must be tall enough in height and structurally adequate

In some locations, high ground may not exist, or tsunamis triggered by local events may not allow sufficient warning time to evacuate to high ground. A potential solution is vertical evacuation above rising waters into buildings and other structures that have the strength and resilience necessary to resist the effects of tsunami waves. A *vertical evacuation refuge* is a structure or earthen mound designated as a place of refuge in the event of a tsunami. The refuge is designed for short-term protection (12-24 hours), has sufficient height to elevate evacuees above the tsunami inundation level, and has been designed and constructed to withstand an earthquake and resist tsunami load effects. An evacuation shelter is designed for longer-term use; it provides a safe, sanitary, and secure environment and life-sustaining services to disaster survivors displaced from their primary residences due to natural or man-made disasters.

Vertical evacuation should not be chosen over safe, solid, nearby high ground that is out above the tsunami hazard zone. However, if you cannot evacuate inland and there are no multi-story, reinforced concrete or steel refuge structures nearby, then you should find the tallest, sturdy structure and climb up and cling to it until the wave passes. In some cases, this might only be a strong tree or utility pole. If you are swept up by a tsunami, look for something to help you stay afloat, and to protect you from dangerous floating debris such as houses, cars, and trees.

Vertical Evacuation – Building Code

- 2018 International Building Code
  - American Society of Civil Engineers 7-16 Standard, Chapter 6 “Tsunami Loads and Effects”
- ASCE 7-16 only applicable to states of Alaska, Washington, Oregon, California, and Hawaii because tsunami hazards are quantifiable

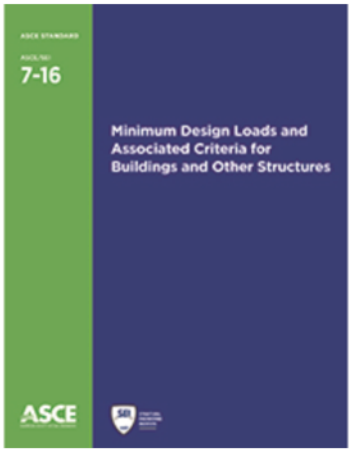


Image credit: https://www.asce.org/asce-7/

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Tsunami design was incorporated by reference into the 2018 International Building Code for structures in risk category III and IV (large occupancy, such as for shelters, and essential facilities). The reference is Chapter 6, “Tsunami Loads and Effects,” of the ASCE/SEI 7-16 standard, *Minimum Design Loads and Associated Criteria For Building and Other Structures*

The 2018 International Building Code references ASCE 7-16 Standard Chapter 6 “Tsunami Loads and Effects.” https://www.asce.org/asce-7/ provides information on ASCE 7 Online, ASCE 7 Hazard Tool, ASCE 7-16 Provisions and Commentary, and Guides.

ASCE 7-16 may be purchased from https://sp360.asce.org/PersonifyEbusiness/Merchandise/Product-Details/productId/233133882?_ga=2.22667570.804265669.1600718001-2010903741.1600718001.

Vertical Evacuation – Search Tool

- **American Society of Civil Engineers database to find current research on vertical evacuation for a specific country. https://ascelibrary.org**
  - Technical Reports
  - ASCE 7-16 Standard
  - Proceedings
- **ASCE 7-16 Tsunami Design Zone Maps for Selected Locations:**
  - Alaska, California, Hawaii, Oregon, and Washington
  - https://ascelibrary.org/doi/book/10.1061/9780784480748

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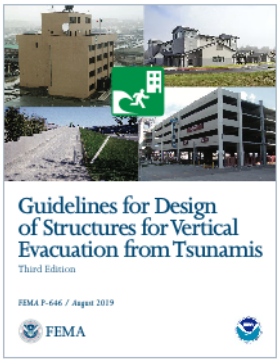
Many search tools exist to find current research on vertical evacuation, but this database contains more current research on vertical evacuation. The IBC 2018 references ASCE 7-16 for tsunami design, so this database is a great resource.

Guidelines for Design of Structures for Vertical Evacuation from Tsunamis (FEMA, 2019, 3rd ed) - Guidance

- **Guidance on planning, location, operation, design, and construction of structures that could be used as a vertical evacuation refuge**
  - Provides information to technical and lay audiences
  - Additional technical design in ASCE/SEI 7-16
- **Intended for…**
  - State and Local Government Officials
  - Community Planners
  - Engineers
  - Architects
  - Building Officials
  - Emergency Managers
  - Tsunami Planning Activists
  - Building Owners



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https://www.fema.gov/media-library-data/1570817928423-55b4d3ff4789e707be5dadef163f6078/FEMAP646_ThirdEdition_508.pdf

"This report is intended as a resource for state and local government officials, community planners, engineers, architects, building officials, emergency managers, tsunami planning activists, and building owners who are considering the construction and operation of tsunami-resistant structures that are intended to provide a safe haven for evacuees during short-term, high-risk tsunami events. It provides guidance on the planning, location, operation, design, and construction of structures that could be used as a refuge for vertical evacuation above rising waters associated with tsunami inundation. Much of the information contained in a report originally published as a companion to the first edition, FEMA P-646A, *Vertical Evacuation from Tsunamis: A Guide for Community Officials* (FEMA, 2009) has now been incorporated directly into this third edition." (FEMA, 2019).

"This third edition serves the dual purpose of providing information for both technical and lay audiences. Information to assist in planning, funding, locating, operating, and maintaining vertical evacuation refuge structures is provided in the first six chapters of this report. Information providing additional background, guidance, and

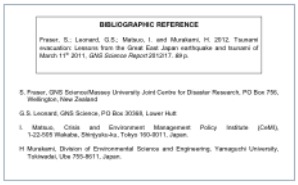
commentary on the technical design provisions now contained in ASCE/SEI 7-16 is provided in the last three chapters of this report." (FEMA, 2019).

Key changes in 3rd edition:
-Additional loading expressions (debris loads, tsunami loads, etc.) removed and moved to ASCE 7-16.
-P646 Design Guide and P646A Community guide combined into 3rd edition.

Non-structural issues discussed:
Where to put vertical evacuation building?
How to space buildings?
Entry and exit requirements?
How to finance buildings?

Tsunami Evacuation: Lessons from the Great East Japan earthquake and tsunami of March 11th 2011 (NZ GNS, 2012)

- **Documents performance of vertical evacuation structures affected by the Great East Japan Earthquake and Tsunami of 2011**
  - Analysis of evacuation preparedness and response from interviews with local disaster prevention officials and emergency service officials with tsunami mitigation recommendations
  - Report shows examples of hazard and evacuation maps and signs in Tōhoku region.
  - Investigated locations within Iwate and Miyagi prefectures


BIBLIOGRAPHIC REFERENCE

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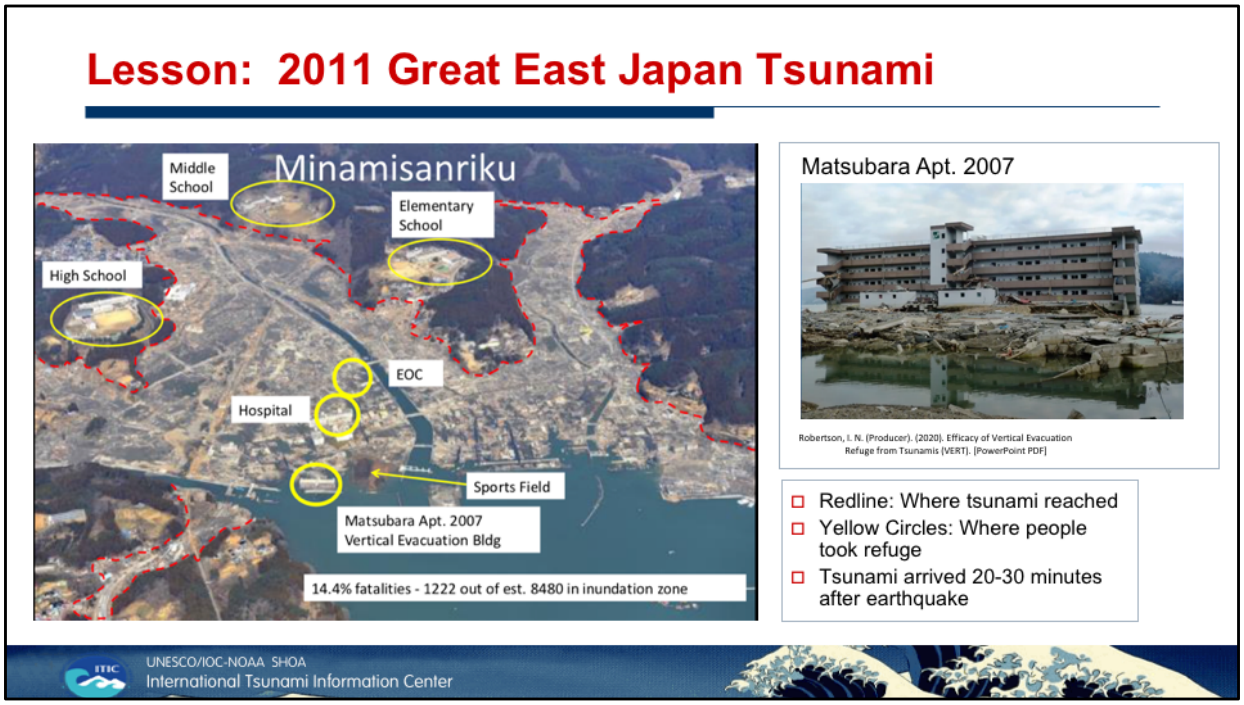
During the 2011 Japan tsunami, vertical evacuation structures saved many lives. Based on lesssons learned, *Guidelines on Structural Requirements for Tsunami Evacuation Buildings Considering the Great East Japan Earthquake* were issued by the Ministry of Land, Infrastructure, Transportation and Tourism (MLIT).



Redline is runup line in Minamisanriku, Japan 3/2011
Run-up is the maximum vertical height of tsunami wave
Yellow circle: Buildings people used to evacuate. Some weren't designated as a vertical evacuation building, but people used these regardless to escape the tsunami.
20 – 30 minutes warning right after Earthquake

Lesson: 2011 Tsunami Japan

- **Historical records alone do not adequately measure a future tsunami's potential height**
  - For 2011 Japan Tsunami, designated vertical evacuation structures not tall enough, e.g., 2 ft of water above roof observed
  - Building structurally survived, but not tall enough

http://itic.ioc-unesco.org/images/stories/vertical_evac/ITIC-ASCE%207-16_2016.pdf

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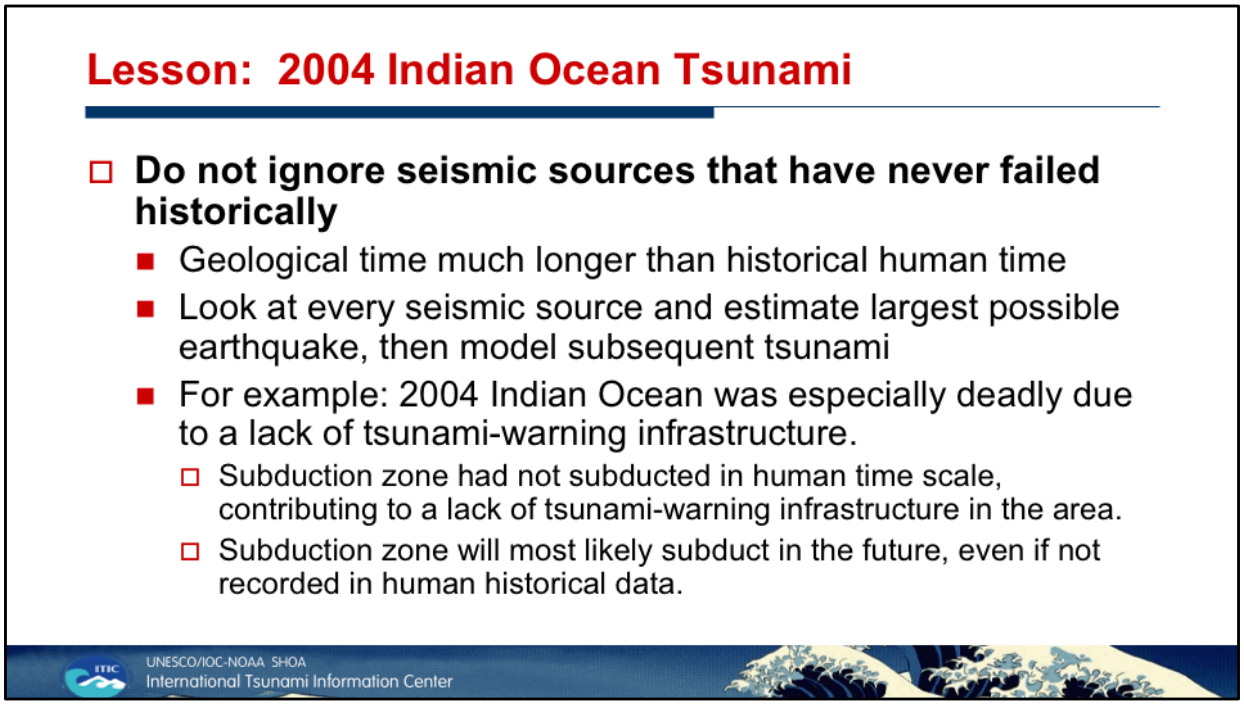

The 365 A.D. Crete earthquake occurred in the Eastern Mediterranean with an epicenter near Crete. The undersea Earthquake a magnitude 8.0 or higher, and generated a large and devastating tsunami that destroyed ancient coastal cities along the Mediterranean sea. The Earthquake may strike the Mediterranean region every 800 years. Cities along the Mediterranean region are advised to prepare their infrastructure for a large tsunami, even if data is not recorded from human time scales.

Source: https://pubs.geoscienceworld.org/gsa/geology/article-abstract/44/3/191/132011/Did-the-A-D-365-Crete-earthquake-tsunami-trigger?redirectedFrom=fulltext

Source: https://www.q-mag.org/what-happened-on-july-21-365-a-d.html

Recommendations

- **Adopt IBC 2018, referencing ASCE 7-16 Standard Chapter 6 "Tsunami Loads and Effects," for the design of vertical evacuation structures. Ensure compliance with local building codes.**
  - Design for Maximum Considered Tsunami, with a 2% probability of being exceeded in a 50-year period, or a 2500 year average return period. source: link
  - Do not rely only on historical records to estimate tsunami wave height
- **Dedicate funding to generate new maps based on probabilistic tsunami hazard analysis that are required by IBC 2018 / ASCE 7-116**
- **Expand tsunami education in school and include tsunami response and vertical evacuation in lesson plans.**
  - Ensure children understand what vertical evacuation is
    - When to select a natural versus man-made vertical evacuation building refuge,e.g., minimum total building stories, which floor to evacuate to, ideal building material, etc.
    - Example: Waikiki, Oahu permits evacuation to the fourth floor or higher in structural steel or reinforced concrete buildings that are 10 stories or higher

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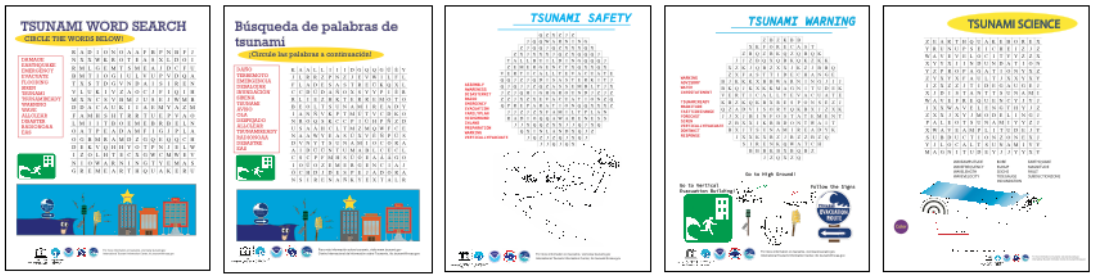
Example of tsunami education

- **Word Search and Coloring Book that teaches key terms related to vertical evacuation.**
  - Word Search Artwork By: Dane Sobol



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Word searches created with a focus on tsunami science, warning, and safety for elementary children.

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August 2020

Thank You

ITIC Vertical Evacuation Website:
http://itic.ioc-unesco.org/index.php?option=com_content&view=article&id=2070&Itemid=2927#General

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