Affordable Tsunami Mitigation

by

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ABSTRACT

Thirty-five years have passed since tsunamis caused loss of life at distances of more than one thousand kilometers from the tsunamis' source areas. During that time the primary cause of the fatalities and the destruction is due to the locally generated tsunami. Japan has a highly developed program to mitigate the effects of local tsunamis. The United States, following the very great Alaska earthquake of 1964, has developed local or regional tsunami warning systems for Alaska, the Pacific coast States, and British Columbia of Canada, as well as for Hawaii. Tsunami mitigation involves three aspects: assessment, emergency management (warning and evacuation), and education. Tsunami assessment addresses past tsunami occurrence, both historical and paleotsunamis. It also involves tsunami inundation modeling and the definition of tsunami hazard zones. Tsunami emergency management involves a system of rapid earthquake characterization and communication of that information to appropriate emergency management authorities that, in turn, undertake appropriate evacuation procedures. Tsunami education involves a system of ongoing programs that reinforce tsunami awareness. These may consist of annual awareness programs centered on the date of some significant tsunami event. They may also take the form permanent signs or structures indicating tsunami evacuation routes or havens of safety. Japan and the United States should adapt their successful methods of tsunami mitigation and make them affordable to all nations in need of tsunami mitigation systems.

KEYWORDS

affordable; assessment; education; emergency management; mitigation; tsunami

1. INTRODUCTION

Thirty-five years have passed since tsunamis caused loss of life at distances of more than one thousand kilometers from the tsunamis' source areas. Damage in this far field was also minimal. Nevertheless, the number of people killed by tsunamis during this interval of time is in the thousands. The primary cause of the fatalities and the destruction is due to the locally generated tsunami.

Local tsunamis, or even regional tsunamis, are difficult natural hazards to deal with from an emergency management viewpoint. Cyclonic storms- hurricanes, typhoons, or cyclones- that build up to destructive force and follow relatively predictable paths over periods of days, give emergency managers time to prepare for their possible passage through the managers' areas of responsibility. Earthquakes' destructive ground shaking is usually over in a matter of minutes. The emergency managers' tasks are primarily focussed on search and rescue of victims and recovery of lifelines. Automatic systems that can detect the onset of the quake can shutdown critical facilities and thus mitigate some of the effects of earthquakes, but this is typically a small portion of all the destruction. Near source tsunamis, however, often allow you minutes or even several tens of minutes after the earthquake before they deliver their destructive force. This gives emergency managers a tantalizingly brief period of time to take some action to reduce the effect. In addition, measures may be implemented prior to the seismic event that can dramatically mitigate the potential tsunami destruction.

Japan and the United States are perhaps the

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leaders among nations in the area of tsunami mitigation. Japan, with its dense population concentrated on its coastlines, is relentlessly attacked by tsunamis arising from nearby sources that wreak havoc on this population. It is no wonder that it has developed some of the world's best tsunami counter measures, an excellent local warning system, and an ongoing educational program that keeps its population aware of how to respond to earthquakes that have the potential to generate deadly tsunamis. The tsunami threat in the United States has been mainly from the distant tsunami. In response to this threat it established a warning system that in fifty years has not allowed a single destructive tsunami from a distant source to reach an American coast without giving emergency managers some amount of time to undertake evacuation measures. The very great earthquake in Alaska in 1964 and the major earthquakes in Hawaii in 1975 and California in 1992 focussed the attention of the United States on the local and regional tsunami threat as well. A regional warning system was established in Alaska, with responsibility for the western U.S. States and British Columbia in Canada. A regional system for Hawaii was also incorporated into the Pacific Tsunami Warning Center. Although these Regional Warning Centers have yet to be tested by a truly destructive local tsunami since their establishment, they continue to put much money and effort into their systems to be ready to respond to the local tsunami when it does occur.

This paper will look at some of the measures undertaken in Japan and the United States in an effort to see which measures may be suitable for countries with very small budgets for tsunami mitigation. Tsunami mitigation can be divided into three aspects. The first aspect is essentially an assessment of the hazard and the risk. Some easily affordable actions may be taken upon completion of such an assessment. The second aspect is the establishment of a warning system. The key to a warning system is communications. With the explosion in the types and methods of communications going on today, ways are evolving that can allow even the most financially strapped nation to have some degree of a local tsunami warning system. The third aspect of tsunami mitigation is education. Raising public awareness of the threat of tsunamis and providing them with instruction on what to do when one is bearing down upon them is perhaps the most affordable of all the aspects of tsunami mitigation.

2. TSUNAMI ASSESSMENT

The Tsunami Inundation Modeling Exchange (TIME) program, originally developed by Noburo Shuto when he was at the Tohoku University, is a fine example of tsunami hazard assessment procedure that can be implemented at relatively low costs to the users. TIME is a modeling procedure that enables the user to make estimates of the expected tsunami runup that may occur on a coastline, given the bathymetry and topography in the vicinity of the coastline. The procedure provides emergency managers and planners with basic information necessary to develop evacuation and zoning plans for their coastlines that are vulnerable to tsunami inundation. TIME software has been distributed to many tsunami-prone countries and training has been given to scientists on how to use the software to determine reasonable inundation models. The procedure is currently being applied to many coastal population centers in Central and South America, in particular, and at a number of other sites in the Pacific basin.

In the United States there has been a growing awareness in recent years of the magnitude of the potential threat of a local tsunami along the northern California, Oregon, and Washington coastlines where the Juan de Fuca tectonic plate is being subducted beneath the North American plate. Paleotsunami studies revealed repeated episodes of extensive tsunami inundation in a number of areas along this coastline. A major earthquake that spawned a small local tsunami near the southern end of this subduction zone in the early 1990's brought about an inundation modeling effort by the U.S. NOAA's Pacific Marine Environmental Laboratory. This effort produced tsunami inundation hazard maps for the communities of Crescent City and Eureka in northern California. The project has since developed into multimillion dollar program that not only involves tsunami hazard assessment, but also improving timely tsunami detection and

warning, and raising public awareness of the tsunami hazard through a variety of educational projects.

3. TIMELY TSUNAMI DETECTION AND WARNING

To provide timely warnings for local or regional tsunamis the key elements involved are a rapid characterization of the causative earthquake and communication of that information quickly to emergency managers at any time. Systems developed by the Japan Meteorological Agency (JMA) and the United States Pacific Tsunami Warning Center (PTWC) are exemplary. They automatically determine the location and size of earthquakes in reasonably sized areas of responsibility within minutes of their occurrence and pass that information on to the public directly or through emergency management systems in about five minutes or less.

Both of these systems are, however, expensive to operate and budget planners continually need to be reminded of the savings in human lives that are made through their existence. What sort of a system can be developed for a country or state with limited financial resources? How can one incorporate elements of the JMA and PTWC systems into a less expensive tsunami warning system?

Both systems recognize that it is impossible to successfully warn the public before all tsunamis strike a coastline. Therefore they encourage and support an educational effort to make the public aware of what actions can be taken to avoid becoming victims of a tsunami. The systems believe that persons who are within about ten minute's travel-time of a tsunami need to act on their own. A warning issued within five minutes of the causative earthquake becomes effective when a population is informed that the earthquake they may, or may not, have just felt has the potential to generate a destructive tsunami. The warning answers the question running through the minds of the public, "Was that earthquake severe enough for me to get to high ground or away from the coast?"

The systems of the JMA and PTWC use networks of relatively closely spaced seismic stations to determine the exact location of the starting point of an earthquake. They use the level of excitation of the seismic instruments of these stations to determine a size for the earthquake. They base their decision on the type of information to disseminate regarding the earthquake on this information. How can this be done at a lowered cost? One way is to make multiple use of seismic data. If some funded institution is operating a network of seismic stations for research or some other purpose, it may be possible to simply tap that data and feed it to a relatively low cost automated earthquake-processing system. The warning system would not have to maintain seismic stations and the research institution would have additional justification to seek funding for operating its seismic network.

What if there is no seismic network available in area of responsibility of a warning system? It may be possible to use data from a single three-component seismic station to obtain an earthquake location satisfactory for warning purposes. If the seismic system has a relatively broad response band and high dynamic range, it may also provide adequate information on the earthquake's size. France's Laboratorie d'Geophysique has developed in recent years a single station detection system, TREMORS, which fulfills the requirements for a tsunami warning system. While TREMORS may become saturated for the largest of earthquakes, it can yield sufficient information to make a decision on whether or not to issue a tsunami warning. Although the complete TREMORS package including the seismometers may be somewhat expensive, the system without the seismometers is affordable. The PTWC worked with the French to modify TREMORS so that it would except data from broadband stations deployed around the world by the IRIS consortium. Thus the possibilities of using TREMORS affordably has increased many fold.

4. TSUNAMI HAZARD EDUCATION

Raising the awareness of the public to the threat of tsunamis is perhaps the most affordable

element in a tsunami warning system. The Tsunami Warning System in the Pacific (ITSU) has developed educational materials for all levels of a school curriculum. Many innovative educational techniques that may be adapted for other countries are coming out the United States' National Tsunami Mitigation Program.

Perhaps the most important element of any tsunami awareness program is that it be ongoing. If a region has been struck by a particularly devastating tsunami, a period of time around the anniversary of that event can be used as a time of renewed effort to make the public aware of the tsunami hazard. In addition, signs delimiting tsunami danger areas, tsunami evacuation routes, and tsunami safety areas act as constant reminders to the public of the tsunami hazard potential.

An ongoing public education program can lead to an acceptance of perhaps the most important tsunami mitigation activity, namely, hazard zoning. Unfortunately in most instances hazard zoning comes about through repeated events of devastation. The goal in tsunami zonation should be to reduce exposure time to tsunamis. The ultimate zonation is to free inundation areas of any permanent occupancy by persons or facilities. This is often impossible because certain facilities such as harbors are needed for commercial and recreational activities. Permanent residency could be reduced through a program of resettlement. All such efforts may need to be accomplished gradually in order to be affordable.

In situations where there is no alternative but to live and work by the sea some readily accessible haven of safety is needed. The situation in Papua New Guinea that was the site of the devastating tsunami in July 1998 may be considered as an example. The affected areas had the sea on one side and a barrier to escape, in this case a lagoon, inland. Affordable safety havens for these situations could be artificial mounds rising to heights above projected tsunami on land depths. Perhaps a bit more expensive would be tsunami resistant structures that could be temporarily sealed during the passage of tsunami waves. These could vary from simple block structures to more elaborate, monument-like structures. Perhaps an old ship, rather than being converted into scrap metal, could even be used if the beaching operation and subsequent maintenance costs were not excessive. The basic principle would be to have a readily accessible haven available to those who have no choice but to live next to the sea. These havens would also act as a constant reminder of the tsunami threat as well.

5. CONCLUSIONS

Japan and the United States have demonstrated that they are the world's leaders in the area of tsunami mitigation. These countries have developed and implemented many impressive measures of tsunami mitigation that span the tsunami assessment, emergency management, and education spectrum. Many of these measures, however, are quite expensive and may not be affordable in countries lacking the financial resources that can be budgeted for tsunami mitigation. Japan and the United States should continue to demonstrate their leadership by seeking ways to make their successful tsunami mitigation programs affordable to all nations that need them.

6. REFERENCES

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