Tsunami Mitigation Strategies

Introduction

While tsunamis can not be prevented, or their destructive effects entirely avoided, actions can be taken to mitigate the risks of this hazard, thereby reducing the impacts on life, physical structures and livelihoods. The first step in mitigating the tsunami hazard and reducing vulnerability is to gain an understanding of the threat and potential effects should a tsunami occur.

Some of the more *direct physical effects* of tsunami include:

- Loss of life;
- Damage to, or destruction of buildings, boats, critical facilities and coastal infrastructure;
- Loss of coastline; and
- Excessive scattered debris.

Less direct effects, and those with sometimes long-term consequences, can include:

- Contamination of coastal soils;
- Diminished domestic water supply due to contamination of shallow wells and aquifers (with salt water and other toxic substances);
- Disease outbreaks;
- Interruption of business and economic processes; and
- Disruption of education and social services.

It can take many years for communities to recover from the effects of tsunamis, rebuild homes and physical infrastructure, and regain economic stability. Oftentimes disasters and subsequent recovery processes reveal complex inter-relationships and dependencies. For example, seawater over inland areas due to a tsunami increases salinity of soils and can render land unsuitable for cultivation. If arable land is reduced, food supply is diminished and farmers must seek other employment, which dramatically affects their livelihoods.

Tsunami risks can be mitigated through many of the same actions that minimize the effects of other coastal hazards such as flooding, storm surge and high surf. By no means an exhaustive list of all possible mitigation strategies, those outlined here serve as a starting point for consideration. Additionally, because the Tsunami Awareness Kit was developed specifically for the Pacific Islands, this document presents a number of strategies unique to the island environments.

- Land use management to minimize development in areas of potential tsunami inundation.
- Preservation of natural barriers or dunes along coastlines.
- Establishment of design standards, building codes, or guidelines for construction of buildings within coastal areas.
- Increased public awareness and education about tsunami risks, warning signs and preparedness actions.
- Development of a warning system to alert people to evacuate to higher ground or to upper stories of sturdily built structures.

Strategy 1: Land Use Management

Building Placement

The late seismologist, Ian Everingham conducted extensive research and wrote numerous publications concerning earthquake and tsunami phenomena and their effects in the Pacific Islands. Concerning building placement, he suggests:

- A simple precaution against damage from most tsunamis is for all buildings to be placed 2-3 metres above the high tide level (Everingham, 1976). Special precautions should be made for buildings supplying essential services, however, as is seen by the $300,000 damage caused to a government communications station at Torokima, on the west coast of Bougainville by a 2 metre tsunami following a magnitude 7.7 earthquake in the east Solomon Sea on 20 July, 1975 (Everingham, et al, 1977).

The International Tsunami Survey Team (ITST) deployed after the 1998 Aitape, Papua New Guinea tsunami recommended the following land use considerations:

- Residents should not be relocated in locales fronted by water and backed by rivers or lagoons; and

- Schools, churches, and other critical facilities should never be located closer than 400m from the coastline, and preferably 800m in at-risk areas.

Strategy 2: Planting and Environmental Preservation

Preserve Dunes And Other Natural Barriers

Professor Hugh Davies outlined several environmental mitigation measures in *Tsunami PNG 1998* excerpts from Earth Talk:

- Sand dunes and sandy berms topped with shrubs and grasses offer some protection from tsunamis depending upon the height and force of the wave. Once the wave crosses a berm and moves inland it may encounter obstructions or ground features that will cause it to lose energy. Ideally, the ground behind the berm would have an uphill slope to further deter the wave. Conversely, if the ground behind the berm has a gentle or downhill slope, the wave will maintain its energy, and may even gain momentum.

- Mangroves, and stands of dense vegetation can offer some protection from tsunami by not only providing holding capacity for near-shore areas, but by absorbing some of the energy of the waves, catching and holding logs and other debris, and diverting the flow of water.

Ecologist and wetlands specialist Faizal Parish was quoted in a 16 January 2005 article in the New Straits Times:

- During the 26 December 2005 tsunami, the Malaysia Forestry Department found that the "mangrove swamps had acted as an effective buffer zone against the full impact of the tsunami." Based on observations of this tsunami, "it was estimated that a mangrove belt 100 meters wide with a density of two to three trees every three meters could have reduced the height [of a tsunami] by 70%, assuming the wave was created by a 7.5 Richter earthquake. Instead of a wave, the water would have reached land like a rising flood. Such a green belt would have also reduced the power of the wave by about 90%."

- Manmade or enhanced natural channels may divert tsunami flooding away from surrounding areas and should not be overlooked as potential mitigative strategies.

Strategy 3: Structural and Design Considerations

Building Construction Practices

Vertical evacuation is a consideration for near-source tsunamis, where time is a limiting factor, or in densely populated areas, where time or horizontal evacuation is not feasible. While it is recognized that most buildings cannot withstand extreme tsunami loads, multi-story buildings of reinforced concrete and structural steel that are built to withstand local seismic forces and/or extreme wind conditions with limited structural damage, may offer protection from smaller tsunami waves. Research (Pacheco, et al. 2005) is underway to validate design considerations for buildings within inundation areas that:

- Allow flow of water through the ground floor;
- Allow non-structural elements at lower levels to break away; and
- Position bearing or structural walls perpendicular to water flow.

The following table, from the booklet *Designing for Tsunamis*, page 35, lists the possible effects of tsunamis on physical structures, and suggests design solutions for each of the potential effects. It is important that design measures be based on the local hazard study so that expected forces determine the design solutions.

Tsunami Effects and Design Solutions

Phenomenon	Effect	Design Solution
Inundation	• Flooded basements. • Flooding of lower floors. • Fouling of mechanical, electrical and communication systems and equipment. • Damage to building materials, furnishings, and contents (supplies, inventories, personal property). • Contamination of affected area with waterborne pollutants.	• Choose sites at higher elevations. • Raise the building above the flood elevation. • Do not store or install vital material and equipment on floors or basements lying below tsunami inundation levels. • Protect hazardous material storage facilities that must remain in tsunami hazard areas. • Locate mechanical systems and equipment at higher locations in the building. • Use concrete and steel for portions of the building subject to inundation. • Evaluate bearing capacity of soil in a saturated condition.
	• Hydrostatic forces (pressure on walls caused by variations in water depth on opposite sides).	• Elevate buildings above flood level. • Anchor buildings to foundations. • Provide adequate openings to allow water to reach equal heights inside and outside of buildings. • Design for static water pressure on walls.
	• Buoyancy (flotation or uplift forces caused by buoyancy).	• Elevate buildings • Anchor buildings to foundations.
	• Saturation of soil causing slope instability and/or loss of bearing capacity.	• Evaluate bearing capacity and shear strength of soils that support building foundations and embankment slopes under conditions of saturation. • Avoid slopes or provide setback from slopes that may be destabilized when inundated.
Currents	• Hydrodynamic forces (pushing forces caused by the leading edge of the wave on the building and the drag caused by flow around the building and overturning forces that result).	• Elevate buildings. • Design for dynamic water forces on walls and building elements. • Anchor building to foundations.
	• Debris impact	• Elevate buildings. • Design for impact loads.
	• Scour	• Use deep piles or piers. • Protect against scour around foundations.
Wave break and bore	• Hydrodynamic forces	• Design for breaking wave forces.
	• Debris Impact	• Elevate buildings. • Design for impact loads.

Phenomenon	Effect	Design Solution
	• Scour	• Design for scour and erosion of the soil around foundations and piers.
Drawdown	• Embankment instability	• Design waterfront walls and bulkheads to resist saturated soils without water in front. • Provide adequate drainage.
	• Scour	• Design for scour and erosion of the soil around foundations and piers.
Fire	• Waterborne flammable materials and ignition sources in buildings.	• Use fire-resistant materials. • Locate flammable material storage outside of high-hazard areas.

Strategy 4: Increase Hazard Awareness

Public Outreach and Education

By educating the public about the tsunami hazard, communities become informed and empowered to take actions that prepare them for tsunamis. People are taught to recognize the warning signs of an impending tsunami. They can also plan and maintain escape routes to higher ground, and discuss ways to assist children and persons with limited mobility. In remote areas there may be no mechanism to receive advance warning of a tsunami. In situations like these, public awareness of hazard warning signs and preparedness can save lives.

In *Seismicity and Tsunami Warning in Papua New Guinea*, I.D. Ripper indicates, “The best warning of the approach of a tsunami following a large local earthquake is the earthquake itself. Should a strong earthquake be felt at medium strength for what seems to be a long period, coastal people should prepare for a tsunami. The tsunami may follow immediately after the earthquake, or up to about an hour later. Sometimes, the first indication of the tsunami is the sea receding from the shore, exposing normally covered coral reefs. The rise in sea level then follows.”

Hazard awareness and education programs that make scientifically credible information understandable and available, and that are consistent and persistent in delivery of information prove most effective. Several successful educational activities include:

- Presentations, lectures, and informal talks offered by local experts that describe the tsunami hazard, identify risk areas, and recommend safety precautions.

- Leave-behind materials such as brochures and preparedness guidelines that encourage people to seek additional information and take action to safeguard their homes and communities.

- Hazard warning signs placed in recognized risk areas; and other signs that direct residents toward established evacuation routes leading to areas of safety.

- Evacuation drills practiced in schools and other establishments.

- Articles concerning the tsunami hazard and safety precautions periodically posted in newspapers, newsletters or popular magazines.

- Information booths set up during festivals or other community events to educate the public.

The ITST deployed after the 1998 Aitape, PNG tsunami recommended the following community planning activities:

- Every family in an at-risk area should have a designated Casuarina tree (also known as sheoak, ironwood, or Australian pine) with a ladder or carved steps to allow vertical evacuation of the able, when there is no other option. The local Casuarina species withstands the wave attack significantly better than palm trees, and should therefore be planted in front of coastal communities wherever possible.

- Establish evacuation routes. Evacuation drills should be practiced annually on the anniversary of a previous tsunami disaster to reinforce that all people in at-risk areas know that if they feel the ground moving they should run as far from the beach as possible.

- Memorials should be built at worst-stricken locales to remind future inhabitants of the disaster, and discourage future habitation of high risk locations. A memorial can be as simple as erecting a large sign or placard.

Strategy 5: Tsunami Warning

Systems and Notification Procedures

Tsunami warning is a critical element in saving lives, as recent and historical events have so devastatingly pointed out. Locally generated tsunamis afford little or no time for warning, and in these cases the most effective warning may be ground shaking, or an observed withdrawal of the sea. In coastal areas where communication systems are limited, it is the recognition of these warning signs and preparedness to act that may prove indispensable in saving lives.

Tsunamis generated from distant sources allow greater warning time, provided there are systems and procedures in place that allow for receipt of warning messages, analysis of the information, and notification mechanisms established to warn communities.

Numerous resources in the Tsunami Awareness Kit discuss new and existing systems and technologies for tsunami detection and warning. Guidance documents for development of emergency plans and procedures are also included. See Resources for Disaster Managers: Tsunami Detection and Warning Systems, and Emergency Planning and Procedures. To find out more information about the NOAA Pacific Tsunami Warning Center, visit: http://www.weather.gov/ptwc/

In the aftermath of the 26 December 2004 tsunami international agreements were forged to improve tsunami detection and warning. With collaboration and foresight, warning systems that engage communities as active participants, employ sound scientific and technical monitoring and expertise, disseminate timely and understandable warnings, and integrate other hazards where appropriate, will result.

References

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