

Originally published by A.C. Yalçiner, E. Pelinovsky, E. Okal, C.E. Synolakis (eds.)  
Submarine Landslides and Tsunamis 267-276  
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## **A TSUNAMI MITIGATION PROGRAM WITHIN THE CALIFORNIA EARTHQUAKE LOSS REDUCTION PLAN**

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### **Abstract**

Tsunami assessment, education, warning, and mitigation efforts are intended to reduce losses related to tsunamis. California is participating in an effort with the states of Alaska, Hawaii, Oregon and Washington as well as the Federal Emergency Management Agency, the National Oceanic and Atmospheric Administration, and the United States Geological Survey in developing tsunami hazard risk reduction techniques under the National Tsunami Hazards Mitigation Program. This program supports the California Earthquake Loss Reduction Plan through the geosciences, landuse, and (indirectly) education elements of the Plan. This paper briefly describes the relationship between the National Tsunami Hazard Mitigation Program and the California Earthquake Loss Reduction Plan and highlights tsunami hazards assessment, education, warning, and mitigation in California.

### **1. Introduction**

#### *1.1. WHY WORRY ABOUT TSUNAMIS?*

California has been subjected to fourteen known locally generated tsunamis dating back to 1800 which have not been assessed and mitigated to the same level, as have earthquakes. This is because over the last 200 years earthquakes have caused more damage and loss of life than tsunamis in California. Tsunamis, however, have caused significant damage in California in both Santa Barbara and Crescent City.

#### *1.2. FOUNDING OF THE CALIFORNIA SEISMIC SAFETY COMMISSION AND THE ESTABLISHMENT OF THE CALIFORNIA EARTHQUAKE LOSS REDUCTION PLAN.*

California's Seismic Safety Commission (Commission) was established, as a direct result of the 1971 San Fernando earthquake, by legislation that took effect on January 1, 1975. The legislation directed the commission to engage in the following activities:

- Set mitigation goals and priorities in the public and private sectors
- Request state agencies to devise criteria to promote earthquake and disaster safety
- Recommend program changes to state agencies, local agencies, and the private sector to further seismic safety
- Provide incentives for research
- Coordinate earthquake safety activities of government at all levels

Because of its desire to maintain the momentum of a goal and policy-setting process, the State established the *California Earthquake Hazard Reduction Act of 1986*. Enactment of the Act followed the devastating Mexico City earthquake of 1985, which brought home the specter of massive urban losses. The 1986 law also required the Commission to develop a series of five-year strategic plans that focused on reducing earthquake losses and speeding recovery.

The *California Earthquake Loss Reduction Plan* (Plan) continues a planning process that began over 25 years ago. Although the Commission has taken an appropriate new look and a somewhat different emphasis, it has done so with a continued commitment to the original goals and the intent that the Plan serves multiple purposes:

- First, it continues to be the Commission's policy statement about what needs to be done to reduce earthquake risk over the long term
- Second, it is the state's strategic plan guiding the Executive Branch agencies in their overall implementation strategies and priorities for seismic safety
- Third, it complies with the Federal Emergency Management Agency's *National Hazards Mitigation Strategy* and serves as the state's federally required hazard mitigation plan for earthquakes.

The Plan is a roadmap to achieve a safer California. The Plan contains 11 elements, each addressing a distinct but interrelated area of concern. The Plan sets forth statewide objectives and strategies to support the goals of learning from earthquakes, advancement in building for earthquakes, and advancement in living with earthquakes. The goals, objectives, and strategies presented in the Plan address the state's most pressing seismic issues through the following 11 elements:

- Geosciences
- Research and Technology
- Education and Information
- Economics
- Land Use
- Existing Buildings
- New Construction
- Utilities and Transportation
- Preparedness
- Emergency Response
- Recovery

Until the early 1990s, the tsunami risk to the California coast focused on the hazards presented by distant sources (Japan, Alaska, and South America). However, in 1992, the Commission began to identify potential tsunami hazards from coastal California sources and, after reviewing historical data, determined that a policy must be developed and implemented to address hazards presented from near shore tsunami sources. In response to the determination, the Commission included the tsunami hazard in the *California Earthquake Loss Reduction Plan* and proposed specific questions to be addressed. The questions listed below were selected to be addressed so that a framework for assessing tsunami hazard and preparing strategy for tsunami risk mitigation could be developed. The answers to the questions are still being developed.

### *Risk Issues*

- What is the current risk to California from distant and locally generated tsunamis?
- Are the current mitigation actions by federal and state government appropriate to the level of risk?
- Are there better or more effective ways to assess tsunami risk given the scarcity of data?
- How can the acceptable levels of tsunami risk be determined?
- What should be the highest priority for run-up studies? (Ports and harbors or developed beach areas with high populations)?

### *Preparedness Issues*

- Does the current tsunami warning system operated by the National Oceanic and Atmospheric Administration meet California's needs?
- Could the present warning system provide sufficient notice to alert coastal residents that a tsunami has been generated from a local offshore source?
- What is the least amount of time that a warning can be issued?
- How is a tsunami warning issued?
- How is the information released to the public?
- Could the present seismic networks in California be modified to function as or form the foundation of a local tsunami warning center?

### *Education Issues*

- What should people know about tsunamis?
- What methods have been most effective in educating the public to the tsunami hazard in the United States and other countries?
- In countries with public information programs, do residents resist evacuating? If so, why?

### *Recovery Issues*

- Are there unique circumstances presented by tsunamis that impact recovery?
- What federal programs and insurance coverage apply to tsunami damage?
- If tsunami run-up areas were identified for California, how would the insurance industry respond?

### *Land Use Issues*

- If tsunami run-up areas were identified for California, should there be specific design requirements for structures located in the inundation zone? How have other states and countries approached this problem?
- Design or avoidance, which is the best tsunami mitigation for a development proposed in an inundation zone?
- Are there classes of use that should be prohibited from locating within an inundation zone (hospitals, schools, essential services)?
- Are there classes of use that cannot avoid being located in inundation zones (ports, marinas, water dependent industries)?

Addressing the questions presented above represents a major step in moving the State's tsunami mitigation program in a direction similar to land use laws that require mitigation for development located within liquefaction and earthquake induced landslide zones. This paper is not intended to address all of the questions.

Regrettably, tsunami inundation areas were not included in the liquefaction, and earthquake induced landslides in the development of seismic hazard zone maps mandated by the state in the early 1990s. Incorporation of all three hazards into one overall land use policy is the most practical, efficient, and cost effective way to identify and mitigate these hazards. Today, the tsunami hazard and associated mitigation activities of the National Tsunami Hazard Mitigation Program are a major part of the *California Earthquake Loss Reduction Plan*. This fact, along with recognition and funding assistance by the Federal Emergency Management Agency and the National Oceanic and Atmospheric Administration has fostered a major tsunami risk reduction program for California and other states in or along the Pacific Ocean.

## **2. Discussion**

### **2.1. STATE AND FEDERAL ACTIVITIES REGARDING TSUNAMI AND LOSS REDUCTION**

The West Coast and Alaska Tsunami Warning Center and the Pacific Tsunami Warning Center, have been providing tsunami warnings for California from distant and local tsunamis. The current tsunami warning system operated by the National Oceanic and Atmospheric Administration does not fully meet California's needs. This is due to California being vulnerable to both local and distant source tsunamis. There are areas along the California Coast that are considered to be tsunami generation regions (see table 1 and figure 1). A locally generated tsunami may not be detected in sufficient time for one of the tsunami warning centers to provide adequate warning time for local authorities to evacuate areas impacted by the tsunami. The National Tsunami Hazards Mitigation Program (NTHMP) has identified the need for additional data collection capability (filling of data gaps), data analysis, tsunami modeling, and continued development, deployment, and implementation of tsunami warning guidance tools.

# Near-Shore Potential Tsunami Sources Along the California Coast



Figure 1. Near-Shore Potential Tsunami Sources Along the California Coast

The NTHMP tsunami detection and data collection efforts include: deploying additional tidal gauges, or replacing tidal gauges, deep water tsunami buoys, seismometers, and tsunami damage observations. The collection and analysis/interpretation of tsunami data and tsunamigenic data is needed in order to develop new or revise existing tsunami models. With better data, models, and mapping of tsunami inundation zones, area and site specific mitigation needs can be better

assessed. The NTHMP is an excellent vehicle to continue to use to develop and deploy tsunami hazards monitoring and warning systems and to develop tsunami hazard mitigation schemes.

TABLE 1. Local Tsunami Source Regions of California (from McCarthy et. al. 1993)

SOURCE ZONE	MAJOR OFFSHORE FAULTS	MAJOR SUBMARINE CANYONS	EARTHQUAKE MAGNITUDE AND YEAR	HISTORICAL TSUNAMI RUNUP AND YEAR
Crescent City to Cape Mendocino	Little Salmon Fault(T) Mad River Fault(T) Mendocino Fault(S) Cascadia Subduction Zone(T)	Trinity, Eel, Mendocino, Mattole	Ms=7.4 (1923) M=7.2 (1923)	1.1-m (1992)
Cape Mendocino to San Francisco	San Andreas Fault(S) Point Reyes Fault(T)	Spanish, Delgada, Vizcaino, Noyo, Navarro, Arena, Bodega	M=7.7 (1906)	0.1-m (1906)
San Francisco to Monterey	San Gregorio Fault(S)	Pioneer, Ascension, Monterey	M=7.1 (1989)	0.3-m (1989)
Monterey to Point Arguello	Hosgri Fault Zone(RS) Santa Lucia Bank Fault(RS?)	Sur, Lucia	Ms=7.3 (1927)	0.6-m (1927)
Point Arguello to Los Angeles (Santa Barbara Channel and Santa Monica Bay)	Santa Barbara Channel Faults(T) Anacapa-Dume Fault Zone(RS) Santa Monica Fault(T)	Arguello, Huename, Mugu, Dume, Santa Monica, Redondo	MI=7.7 ½ (1812)	3-4m (1812)
Los Angeles to San Diego (Inner Borderland)	San Clemente(R) Catalina-San Diego Trough(S-RS?) Palos Verdes(RS) Coronado Bank (NS) Newport-Inglewood-Rose Canyon(S)	San Gabriel, Newport, Carlsbad, La Jolla, Coronado	M-6.25 (1933)	Uncertain (1862, 1933)
Northern Channel Islands to San Nicolas Island (Northern Outer Borderland)	East Santa Cruz Basin Fault Zone(S) Ferrelo Fault Zone(S) San Nicolas Island Escarpment(T?)	Santa Cruz	ML-5.1 (1969)	?
San Nicolas Island to Mexican Border (Southern Outer Borderland)	East Santa Cruz Basin Fault Zone(S) Ferrelo Fault Zone(S)	Unnamed	ML=5.3 (1948)	?

The California Public Resources Code also includes tsunamis as a subset of seismic hazards (Public Resources Code Section 2692.1) within the State of California Seismic Hazards Mapping Act. Development of tsunami inundation maps for California is underway by the University of Southern California Tsunami Research Center and the Tsunami Inundation Mapping Effort (TIME) Center in Newport, Oregon. The State of California, the National Oceanic Atmospheric Administration, and the Federal Emergency Management Agency are supporting the development of these tsunami inundation maps. Tsunami inundation maps for California outside of Crescent City and Humboldt Bay have not been developed for use in other than evacuation planning in California.

California is a subscriber to the West Coast and Alaska Tsunami Warning Center, located in Palmer, Alaska and in the Pacific Tsunami Warning Center in Ewa Beach, Hawaii. Other states subscribing to the Alaska Tsunami Warning Center and the Pacific Tsunami Warning Center include Oregon, Washington, Alaska, and Hawaii. California is also a partner in the NTHMP. California does not have a separate tsunami hazard mitigation plan. Instead of developing a stand-alone tsunami hazard assessment, warning and mitigation program the State elected to partner with the NTHMP. The NTHMP consists of three interdependent components (1):

- Hazard assessment
- Warning guidance
- Mitigation.

The three components fit into the Plan under the geosciences and land use elements. The geosciences element calls for the development of data to provide accurate and useful planning scenarios to reduce the risk from the hazards of seiches and tsunamis. The land use element of the Plan calls for the identification of all areas subject to potential inundation from dam or levee failure or tsunami run-up, and the incorporation of appropriate loss reduction strategies to be incorporated into general plans ([2] page 12). The tsunami run-up identification effort is well underway by the University of Southern California Tsunami Research Center and the TIME Center.

#### *2.1.1. California Tsunami Assessment, Warning Guidance, and Mitigation Activities for California*

The following tsunami assessment, warning guidance, and mitigation activities are underway or in planning and research stages in California:

##### *2.1.1.1. Assessment*

The geosciences initiative is directly related to tsunami assessment activities. The geosciences initiative regarding tsunamis is carried out by the collection and processing of data, the development of tsunami generation and propagation models, and the development of tsunami inundation maps. The collection, processing, and analysis of data is done not only for tsunamis that have affected California but is also reviewed for tsunamis in other parts of the world. Recent tsunamis generated by the Manzanillo, Mexico earthquake of 1995, the Papua New Guinea earthquake of 1998, and the Kocaeli, Turkey earthquake of 1999 have been evaluated. The installation of tidal gauges, seismometers, and collection of first hand accounts, has also helped to fill in data gaps. Modeling of tsunamis has led to a beginning in the understanding of tsunamigenic events. A better understanding of sea floor topography has led to a refinement in the estimate of California coastal areas that are prone to tsunami inundation. So far, the majority of information regarding marine geology has been provided by the USGS. Future activities may also include data provided by the United States Navy, oil companies, and project Earthscope (if funded).

*2.1.1.2.* Several tsunami inundation maps covering portions of the Southern California Coast have been completed and several more are under development in both Southern and Northern California.

2.1.2.1. The warning guidance effort of California follows that of the NTHMP. However, not all of the 15 coastal counties of California have adopted the NTHMP tsunami warning guidance in their general plans. Areas of California such as Crescent City, Del Norte County, and Humboldt County have adopted a more visible warning guidance stance. Tsunami hazard inundation posting has been established in Crescent City and in the Eureka/Arcata Bay areas of Northern California. The California Department of Transportation is assessing the use of the national tsunami hazard and evacuation signs. The Crescent City draft publication entitled “Tsunami” is under consideration for revision by OES for applicability on a statewide basis. OES, the California Coastal Commission, and Humboldt State University are planning to develop a tsunami curriculum for kindergarten through twelfth grade students. The curriculum will enable children to understand what tsunamis are, what hazards are associated with tsunamis, in general, when they may be expected, and finally how to protect oneself from tsunami hazards. The curriculum is to be partially based upon a similar program developed by the State of Washington. Another useful education tool is United States Geological Survey Circular No. 1187 [3] entitled “Surviving a Tsunami-Lessons from Chile, Hawaii, and Japan”. This document contains strategies that an individual may follow when a tsunami is expected.

### 2.1.3. Mitigation

The completed maps are to be used in the planning of evacuation routes and posting of areas that are in a tsunami hazard inundation area. Tsunami mitigation has included the development of tsunami evacuation plans for several communities. So far, no significant County or City ordinances have been adopted restricting coastal development in California with respect to tsunami hazard. There are four documents that are useful in understanding the disposition of the tsunami risk reduction activities implemented in California. The documents are briefly described below:

*Designing for Tsunamis Seven Principles for Planning and Designing for Tsunami Hazards*, National Tsunami Hazard Mitigation Program, dated March 2001. The document is a guideline to help coastal communities understand tsunami, their hazard potential and risks in addition to providing guidance for the mitigation of tsunami risk through land use planning and building design.

*Local Planning Guidance on Tsunami Response, Second Edition, A Supplement to the Emergency Planning Guidance of Local Governments*, dated May 2000, State of California Office of Emergency Services. [4] The guidance document contains a template for developing planning activities to mitigate tsunamis and a sample tsunami warning checklist based upon efforts of the County of San Mateo, California.

*Findings and Recommendations for Mitigating the Risks of Tsunamis in California*, dated September 1997, State of California Office of Emergency Services. [5] This document called for the development of tsunami inundation maps for California which are to be used for planning evacuation routes.

*Planning Scenario in Humboldt and Del Norte Counties, California for a Great Earthquake on the Cascadia Subduction Zone*, California Division of Mines and Geology, Special Publication No. 115, dated 1995. [6] The scenario contains information regarding the 1964 Crescent City tsunamis as well as graphics regarding potential tsunami runup zones.

## 3. Summary

3.1. The 1992 Cape Mendocino earthquake demonstrated that in addition to being susceptible to distant source tsunamis, California is also susceptible to locally generated tsunamis and to tsunamis generated from earthquakes along the Cascadia Subduction zone. Although California had been subjected to other more destructive tsunamis in the past, the Cape Mendocino event led to the inclusion of tsunami hazard initiatives in California’s Earthquake Loss Reduction Plan. Instead of implementing a stand alone tsunami hazard assessment and mitigation program, California’s Office of Emergency Services has been able to share in the collection, processing, and analysis of data, the development of tsunami modeling, the cost of mapping tsunami inundation zones, the development of tsunami



hazard warning guidance materials, as well as the development of tsunami hazard mitigation techniques by working with universities, federal, state (including Washington, Oregon, Alaska, and Hawaii) and local agencies. The NTHMP supports the Plan's initiative with respect to geosciences, land use and education. State activities regarding tsunami education are being planned and is expected to be partially based on the State of Washington's tsunami hazard education program.

The successful interaction of the NTHP and *California's Earthquake Loss Reduction Plan* points to the value of incorporation of tsunami risk reduction activities into existing or developing earthquake loss reduction programs or national hazard reduction programs. It is the intent of the authors to encourage the incorporation of tsunami risk reduction activities into national and or local earthquake risk reduction or natural hazard reduction programs for countries that have potential tsunami exposure.

## **1. Acknowledgements**

1.1. The authors acknowledge the invaluable assistance of Mr. James Godfrey from the State of California, Office of Emergency Services, who provided invaluable background information regarding current tsunami hazard assessment, warning guidance, and mitigation activities and Mr. Vincent Vibat of the California Seismic Safety Commission who provided graphics and formatting support for the paper.

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