State of California
Seismic Safety Commission

THE TSUNAMI THREAT TO CALIFORNIA

FINDINGS AND RECOMMENDATIONS
ON TSUNAMI HAZARDS AND RISKS

December 2005

CSSC 05-03

I. EXECUTIVE SUMMARY

Damaging tsunamis are rare but potentially catastrophic events that present a danger to the people and economy of California. Over 80 tsunamis have been observed or recorded along the coast of California in the past 150 years, 9 causing minor damage in ports and harbors and 2 with major impacts. Four events caused deaths; the worst occurred in 1964 when 12 people died in California from the tsunami generated by the Great Alaska earthquake. Local earthquakes can produce damaging tsunamis that will provide very little warning time.

On Sunday, December 26, 2004, a strong earthquake of magnitude 9.3 occurred off the coast of northern Sumatra, triggering a giant tsunami that propagated throughout the Indian Ocean Basin, causing massive casualties and destruction. As a result of the Sumatra event and past damaging California tsunamis, the Seismic Safety Commission created a Tsunami Safety Committee to evaluate the state of tsunami readiness in California. This committee held six meetings, took testimony from representatives of local governments and the scientific community. Based on this testimony, the Seismic Safety Commission made the following Findings and Recommendations:

Findings

1 Tsunamis, generated either locally or from events elsewhere in the Pacific Basin, pose a significant threat to life and property in California.

2 Tsunamis present a substantial risk to the economy of the State and Nation, primarily through the impact on our ports.

3 Californians are not adequately educated about tsunamis and the risk they pose; consequently, many are unaware how to respond to natural or official tsunami warnings.

4 The existing tsunami warning system has not achieved all of its objectives for several reasons including problems with communications, agency coordination and protocols.

5 Present building codes and guidelines do not adequately address the impacts of tsunamis on structures. Currently available tsunami inundation maps are not appropriate for code or guideline applications.

6 Federal programs have provided resources to initiate tsunami hazard mapping and mitigation programs. However, more effort and a better understanding of the risk is required to bring the treatment of tsunamis to a level comparable to other State hazards such as earthquakes.

Devastation from the 2004 Sumatran tsunami.

7 The Governor's Office of Emergency Services and many local governments have been proactive in addressing the State's tsunami risk and, since the Sumatran tsunami and the June 14, 2005 tsunami warning in northern California, have renewed interest in improving warning dissemination and other aspects of tsunami planning and preparedness.

Recommendations

The State of California should:

1. Improve education about tsunami issues in the State:

    a. Include multi-language education about tsunami hazards and how to respond to large coastal earthquakes, sudden water level changes and official tsunami warnings in all California schools.

    b. Actively educate coastal populations about tsunami hazard zones, evacuation routes and install signage consistent with other west coast states as soon as possible.

    c. Update State and local earthquake preparedness materials to include tsunami safety. Incorporate tsunamis in safety training for workplaces in inundation zones, especially ports.

    d. Develop multi-language tsunami information and educational materials and make them available to visitors to coastal areas.

2. Work with other coastal states to obtain an external expert review of the NOAA tsunami warning system criteria for issuing and canceling warnings as well as the format and procedures for distribution.

3. Continue to work with federal agencies to develop guidelines for structures to resist both strong ground motion and tsunami wave impact.

4. Support and provide matching funds for tsunami mitigation programs in coastal counties and in OES, including improvements to the communications and emergency response systems. These funds will leverage federal support for tsunami mitigation programs.

5. Support and provide matching funds for the development of improved technologies and methodology to assess the tsunami risk. These new technologies and risk assessments should be used to support better long-term and emergency response planning. Develop probabilistic tsunami hazard maps appropriate for building code and land-use regulations.

II. THE TSUNAMI HAZARD IN CALIFORNIA

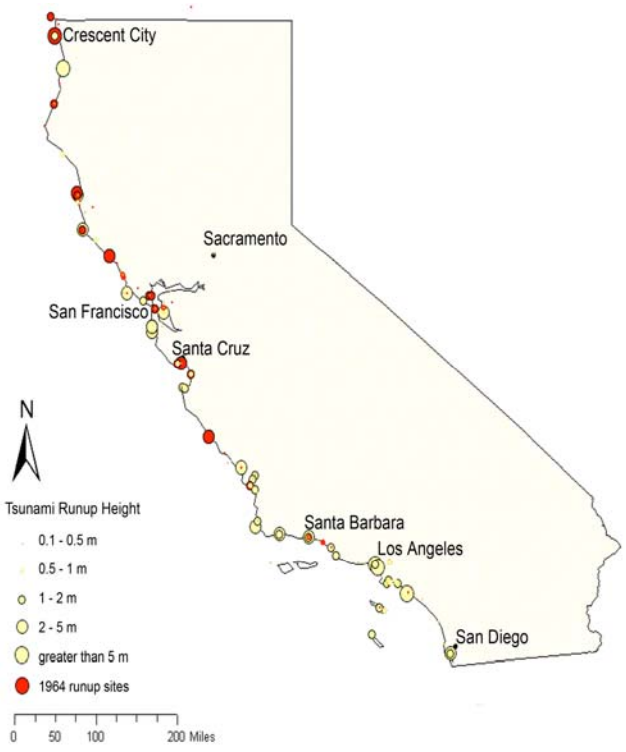
What is a tsunami?

A tsunami is a series of waves most commonly caused by the deformation of the sea floor during a submarine earthquake. They are also generated by landslides, volcanic eruptions or more rarely by asteroid impact. Tsunamis are extremely long waves with the distance between successive peaks or troughs on the order of 10's to 100's of miles. As the waves enter shallow water, they slow down and rise in height, in the largest cases, by tens of feet. Large tsunamis can cause great loss of life and property damage where they come ashore. Tsunamis are always largest closest to the source region where they may strike the closest coastlines only minutes after the triggering event. The largest tsunamis travel across the ocean with sufficient energy to cause damage thousands of miles away and many hours after the source event occurred. When the coastal area is close to the source region and the first waves to arrive take less than an hour to travel, the tsunami is called a local or near-field tsunami. For travel times of several hours or longer, the tsunami is a distant or far-field tsunami.

Crescent Beach Motel, Crescent City, California damaged by the 1964 tsunami. A core taken from the pond shown by the star. Deposits of sand from the 1964 and 1960 tsunamis marked by the red arrows are much smaller than the 1700 deposit marked by the green arrow.

Does California have tsunamis?

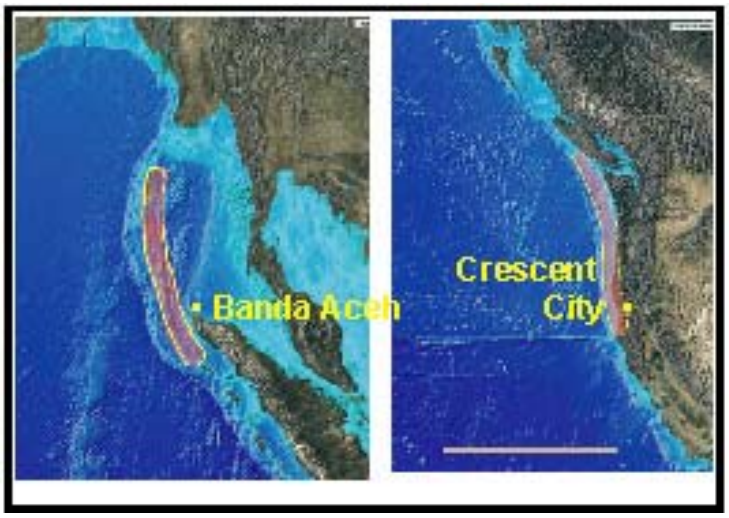
California is at risk from both local and distant tsunamis. Eighty-two possible or confirmed tsunamis have been observed or recorded in California during historic times. Most of these events were small and only detected by tide gages. Eleven were large enough to cause damage and four events caused deaths. Two tsunami events caused major damage. The 1960 Chilean earthquake produced a great tsunami that impacted the entire Pacific basin. Damage was reported in California ports and harbors from San Diego to Crescent City and losses exceeded one million dollars. The worst event was the 1964 tsunami generated by the M 9.2 Alaska earthquake that killed 12 in Northern California and caused over $15 million in damages. The peak wave height was 21 feet in Crescent City and 29 city blocks were inundated. Wave oscillations in San Francisco Bay lasted more than 12 hours causing nearly $200,000 in damages to boats and harbor structures.



What is the greatest risk to California?

The Cascadia subduction zone will produce the State's largest tsunami. The Cascadia subduction zone is similar to the Alaska-Aleutian trench that generated the magnitude 9.2 1964 Alaska earthquake and the Sunda trench in Indonesia that produced the magnitude 9.3 December 2004 Sumatra earthquake. Native American accounts of past Cascadia earthquakes suggest tsunami wave heights on the order of 60 feet, comparable to water levels in Aceh Province Indonesia. Water heights in Japan produced by the 1700 Cascadia earthquake were over 15 feet, comparable to tsunami heights observed on the African coast after the Sumatra earthquake.

The Cascadia subduction zone last ruptured January 26, 1700, creating a tsunami that left markers in the geologic record from Humboldt County, California to Vancouver Island, Canada and is noted in written records in Japan. At least seven ruptures of the Cascadia subduction zone are observed in the geologic record.



Comparison of the December 26, 2004 Sumatra rupture and the estimated rupture of the 1700 Cascadia Subduction zone at the same scale. Scale bar is 700 mi.

Distant and local tsunamis.

Tsunamis that damaged California's coast have come from all around the Pacific basin including South America and Alaska. Nearly two thirds of California's historic tsunami events and all but one damaging event were generated by distant sources.

In addition, local tsunamis can be caused by offshore faults or coastal and submarine landslides and have the potential to cause locally greater wave heights and do pose a threat to the state. The largest historic local-source tsunami on the west coast was caused by the 1927 Point Arguello, California, earthquake that produced waves of about 7 feet in the nearby coastal area.

What government agencies are responsible?

The National Oceanic and Atmospheric Administration (NOAA) has statutory responsibility to provide tsunami warnings, which are disseminated in California through the Governor's Office of Emergency Services. Local jurisdictions have the responsibility for ordering and canceling evacuations.

FINDING: **Tsunamis, generated either locally or from events elsewhere in the Pacific Basin, pose a significant threat to life and property in California.**

The California Geological Survey has statutory authority to conduct tsunami inundation mapping, contingent on State funding that has not yet been appropriated. The Governor's Office of Emergency Services (OES) has contracted with the University of Southern California for preliminary tsunami inundation mapping with funding from NOAA through the National Tsunami Hazard Mitigation Program (Program). This Program supports tsunami hazard mitigation in the states of California, Oregon, Washington, Alaska and Hawaii. The State of California has representation on the program steering committee by a representative from the Governor's Office of Emergency Services (OES) and a representative from the California Geological Survey (CGS). Coordination with the other four western states and the National Tsunami Hazard Mitigation Program is essential to the success of the Program.

III. THE NATURE OF THE TSUNAMI RISK IN CALIFORNIA

Casualties.

As the 2004 Sumatran tsunami amply demonstrated, a large tsunami poses a major risk to human life, primarily from flooding and debris impact. Evacuation is possible and can save many lives if carried out properly. However, a poorly coordinated evacuation can actually put people in harm's way. Moreover, the short time frame between event and tsunami for local events requires that the local population be aware enough of the appropriate action to evacuate without official notification.

Of the five Pacific states, California has the largest population exposed to tsunami risk. NOAA has estimated that more than one million people in California live within coastal areas vulnerable to tsunami inundation (the rushing in of the water causing flooding and battering by debris). That number does not include one million or more visitors to California's beaches on any given summer day.

Financial losses.

Tsunamis cause damage to man-made structures in several ways, primarily from water currents and the impact of water-borne debris. The incoming waves cause flooding and push vessels into land-based structures. The withdrawing waves causes vessels and boats to hit bottom and damages power plants and other facilities that use sea water for cooling. The strong currents scour foundation material from under structures and carry debris. Debris carried by the water batters people and property, and is responsible for much of the damage from tsunamis. Secondary effects, such as fire and the release of hazardous materials, can escalate the disaster to a greater catastrophe. These effects are difficult to predict.

The exposure of our built environment to possible tsunami damage varies dramatically along the California coast. The flooding produced by the tsunamis depends strongly on local topography. Some areas, such as Crescent City, California have experienced large run-up, whereas other areas have yielded relatively minor impacts. In general, lower areas have always been more vulnerable. The codes that produce buildings resistant to earthquakes do not, in general, address the forces likely to arise from tsunamis. Many structures are designed to resist forces directed towards the structure; however, once water enters the structure and draw-down occurs outside of the structure, walls may collapse or deflect outward, causing serious damage.

Aerial photographs of Banda Aceh, Indonesia, before and after the 2004 tsunami.

Seaports.

Our ports face the greatest exposure for catastrophic losses. The Ports of Los Angeles and Long Beach are the first and second busiest seaports in all the United States. Together these California State-owned but city-managed seaport complexes handle 14 million units of containers annually, which make them the third busiest port in the world. Combined they handle approximately $240 billion worth and 250 million metric tons of cargo, generate $10 billion worth of yearly taxes, and are responsible for approximately $100 billion in direct and indirect business annual sales, and directly and indirectly generate some 600,000 and 2.5 million jobs throughout our State and nation, respectively. Other economically important ports in

California subject to tsunami damage include those in Oakland, Richmond and San Diego.

There is substantial development of apparently well engineered and "permanent" port infrastructure designed only for earthquake forces. They are located largely along the water's edge at the two ports and include the pile supported reinforced concrete wharves, rubble mound retaining structures, and ship-to-shore container cranes. There are also a multitude of potentially loose infrastructure and objects that can become buoyant and/or free floating in the event of flooding from a significant tsunami. These include the millions of tons of open stored dry and break bulk products; mobile equipment, vehicles, railroad infrastructure and tools; approximately 10,000 8,400 pound empty 40-foot containers; about 60 huge simultaneously berthed ocean-going ships; and thousands of smaller pleasure craft and harbor boats. These vessels are secured to their docks by sets of mooring lines that provide security for "normal" ship mooring forces, and not for the tremendous vertical buoyant and hydrodynamic forces that can be induced by major tsunamis.

FINDING: **Tsunamis present a substantial risk to the economy of the State and Nation, primarily through the impact on our ports.**

The ports' docks and terminals operate at a surface level that is, in general, only 9 feet above the mean high seawater level. A 15-foot (or greater) tsunami, for example, arriving at the Inner Harbor would therefore overtop the wharf decks and inundate much of the 7500-acre landside port operations. Without adequate warning, this would cause considerable human casualties, operational disruption, port damage, and economic impact. Based on the ports' own data, a two-month shut down of the two ports would result in a overall total economic loss of $60 billion. In addition to this, there are approximately 8,000 total outdoor personnel on any given port operational day. Unless safely evacuated, these workers can face injury and loss of life directly from drowning, or indirectly by water borne collision into water-borne debris.

The port of Valdez, AK after the tsunami of March 27, 1964.

IV. TWO CASE STUDIES

The devastating Sumatran tsunami of December 26, 2004 and the American tsunami alert of June 14, 2005 each provide insight for where we can improve safety in California.

Sumatra, Indonesia.

The 2004 great Sumatran earthquake occurred on a fault that extends over 1200 kilometers (800 miles) off the coast northern Sumatra. The earthquake triggered a giant tsunami that propagated throughout the Indian Ocean Basin, causing massive casualties, extreme inundation, and destruction along the northern and western coast of Sumatra. Within hours, the tsunami devastated the shores of Thailand to the east as well as Sri Lanka, India and the Maldives to the west. The tsunami also caused deaths and destruction in Somalia and other nations of east Africa. The propagation of the tsunami was worldwide so that it was even detected on the California coast.

Damage at a tourist beach from the 2004 Sumatran tsunami.

One of the strongest lessons learned from the Sumatran tsunami is the power of public education and tsunami awareness. At Jantang, an entire town was destroyed when tsunami waves surged in over 15 m (45 feet). Ninety percent of the villagers were killed and 100% of the structures were destroyed.

In Langi village on the island of Simeulue, the tsunami wave was slightly smaller, but only by a few feet. The surge still destroyed 100% of the town's buildings, yet no one was killed. The difference was the level of tsunami awareness of each community. The people of Langi maintain a strong oral tradition and frequently recount stories of past tsunami disasters to the younger members of the community. The oral history recounted the events of 1812 when a similar tsunami had devastated the area. The people had even prepared gathering points and evacuation routes in anticipation of another tsunami.

A second lesson is that you don't have to live on the coast to be at risk from a tsunami. The Sumatran tsunami was the deadliest natural disaster in the history of Sweden, killing 551 vacationing Swedes in Thailand and Sri Lanka. Anyone who visits the beach is at risk from tsunamis.

June 14th alert in California.

On June 14, 2005 a magnitude 7.2 earthquake occurred offshore of Northern California, in the vicinity of the Cascadia Subduction Zone. Following procedures, the NOAA Tsunami Warning Center issued a tsunami warning 6 minutes after the event for the whole west coast from San Diego to British Columbia. The earthquake generated a small tsunami, which was only detected on tidal gauges and on one of NOAA's Deep Ocean Assessment and Reporting of Tsunamis (DART) buoys and caused no damage. The warning was canceled 78 minutes after the event. This event intensified interest in the tsunami threat to California and identified several gaps in tsunami preparedness and response capability that could pose potentially serious problems. These include the basis for NOAA issuing and canceling warnings, inadequate alert and warning systems at the local, state and federal government levels, a general lack of knowledge of the tsunami threat, needs for public information materials, and jurisdictions without tsunami response plans and procedures.

FINDING: **The existing tsunami warning system has not achieved all of its objectives for several reasons including problems with communications, agency coordination and protocols**

NOAA through the National Weather Service operates two Tsunami Warning Centers, one located in Hawaii (PTWC) and the other in Palmer, Alaska. The West Coast Alaska Tsunami Warning Center in Palmer (WCATWC) is responsible for issuing warnings, watches and tsunami information messages to all regions along the west coast of the United States including California. The Center receives seismic information from a variety of networks coordinated by the US Geological Survey.

The warning was issued by the Alaska center on the basis of internal procedures that call for a warning to all areas within two hours travel time of an earthquake above magnitude 7 off the coast. Many scientists expressed skepticism that the wide spatial coverage of the warning was appropriate in that a tsunami still large enough to be damaging hundreds of miles from the source seemed extremely improbable. The Hawaii center issued a bulletin saying no warning was in effect, because the Hawaii center has responsibility to warn the western Pacific. Some recipients of both messages misinterpreted the Hawaii statement as a cancellation of the Alaskan warning. The warning was canceled, again as specified in the procedures, when the predicted wave recorded on a DART buoy was too small to be damaging. Eleven minutes after the earthquake, seismological data had shown that the earthquake did not result from vertical deformation of the sea floor and was located 30 km west of the Cascadia subduction zone, greatly reducing the likelihood that a tsunami had been generated. NOAA procedures do not use seismological information for canceling warnings.

The California State Warning Center (CSWC) received the warning. The tsunami warning issued by NOAA contained language and format that was unclear or obscured critical information. The CSWS disseminated the warning through the California Warning System (CALWS), the California Law Enforcement Teletype System (CLETS) and the Emergency Digital Information System (EDIS). Not all affected local jurisdictions were aware of the warning from the CSWC. Many who did receive it had difficulty interpreting its impact. The response by local counties varied significantly from evacuations to no response. Some jurisdictions experienced difficulty in ramping up staffing levels that were required for effective notification, activations of emergency operation centers and situation assessment.

FINDING: The Governor's Office of Emergency Services and many local governments have been proactive in addressing the State's tsunami risk and since the Sumatran tsunami and the June 14, 2005 tsunami warning in northern California that renewed interest in improving warning dissemination and other aspects of tsunami planning and preparedness.

This tsunami warning also generated requests from most of the Coastal Counties for training workshops and technical assistance in developing procedures and response plans that cannot be met with current staff resources. Since that time, CSWC staff has reviewed and been re-trained on the tsunami standard operating procedure. CSWC is currently upgrading its automated call system (Dialogic). The upgraded system will be capable of 1,000 one-minute or 2,000 thirty-second calls in 21 minutes. OES conducted a Tsunami Summit on July 19, 2005 with the coastal counties to review state and local procedures and the use of warning communication technologies. The National Weather Service conducted a successful test of the national tsunami system on September 14, 2005, relaying text messages to the coastal cities and the Coast Guard.

V. REDUCING THE RISK

Losses from tsunamis can be reduced in four ways. First, engineering standards can create buildings and port structures more resistant to the damage. Second, public education can train Californians to recognize natural and official tsunami alerts and provide basic instruction as to what to do. Third, warning systems can alert a population to a tsunami coming from a distant source. Fourth, effective evacuation planning can reduce casualties by getting people out of harm's way. On all four fronts, progress has been made and more could be done to increase tsunami safety.

Engineering.

U.S. Building codes generally have not addressed the subject of designing structures in tsunami zones. FEMA's Coastal Construction Manual (FEMA 55), developed to provide design and construction guidance for structures built in coastal areas, addresses seismic loads for coastal structures and provides information on tsunami and associated loads. However, the authors of the Coastal Construction Manual concluded that tsunami loads are far too great and that, in general, it is not feasible or practical to design "normal" structures to withstand these loads. It was acknowledged that special design and construction details would be possible for critical facilities.

A fire triggered by the 1964 Alaskan tsunami in Valdez, AK.

In contrast, the National Tsunami Hazard Mitigation Program Background Paper #5: *Building Design* written for the publication *Designing for Tsunamis* concludes that "good design and engineering can greatly minimize the [destructive] effects of tsunamis on buildings." It points out that the City and County of Honolulu has adopted special requirements for floods and tsunamis such as "Article 11, Regulations within Flood Hazard Districts…" which includes a provision addressing tsunami loads, among other special loading requirements. These loading requirements are in some instances at variance with those in the Coastal Construction Manual.

The initial phase of an ongoing FEMA/NOAA program regarding tsunamis and their potential forces on structures has just been completed. The second phase will concentrate on construction design guidance for tsunami shelter structures (to allow for vertical evacuation) and is being done under contract to the Applied Technology Council. It is thought that the criteria for tsunami shelters could be applied to essential emergency facilities and to structures with large occupancies, such as large seaside resorts.

One conclusion is that, although other states such as Washington and Oregon and local jurisdictions are moving toward developing load and resistance code requirements applicable to general building construction in tsunami zones, considerably more effort, both in re-search related to and development and limitation of such provisions, is required.

FINDING: Present building codes and guidelines do not adequately address the impacts of tsunamis on structures. Currently available tsunami inundation maps are not appropriate for code or guideline applications.

The current inundation maps are estimates of the worst possible tsunami scenario. Knowing only the maximum possible run-up without information about probability of occurrence is insufficient to set engineering guidelines. Probabilistic standards, such as those used for earthquakes, are needed for many planning applications and to prioritize resources.

Education.

Tsunami safety depends first and foremost on personal action. People who move quickly from the inundation zone move themselves to safety. Whether in response to feeling an earthquake or receiving a warning, safety comes from the personal decision to take appropriate action and thus depends on every citizen possibly at risk knowing how to respond appropriately. This knowledge must be conveyed to all our citizens for true safety to be achieved.

A scientist explaining tsunami waves to high school students.

The first step in education begins in schools. At present, public schools have no tsunami or earthquake safety curriculum. All California schools should teach the basic elements of earthquake and tsunami safety to all children. Earthquakes can strike anywhere in the State and anyone could visit the beach. This should include:

- What to expect during an earthquake and how to respond appropriately;
- How to respond to an earthquake near the ocean or a tsunami warning;
- Basic causes of earthquakes and tsunamis;
- Likely sources of earthquakes and tsunamis that could affect California;
- What makes a building earthquake safe.

Because of the 2004 Sumatran event, tsunami safety information has been added to some of the public information materials about earthquakes, such as the Homeowner's Guide to Earthquake Safety (produced by the California Seismic Safety Commission) but there has been no organized effort to ensure our citizens receive the information they need. California should also provide tsunami preparedness information for the general public organized along the lines of the Emergency Survival Program and other emergency preparedness community outreach programs. This should include:

FINDING: Californians are not adequately educated about tsunamis and the risk they pose; consequently, many are unaware how to respond to natural or official tsunami warnings.

- Program Information Sources available to the public that would outline tsunami threat in California as well as outline the alert and warning procedures used by state and local government for tsunamis.
- Local threat information such as tsunami inundation maps, evacuation routes and safe refuge locations.
- Tsunami hazard information and emergency preparedness tips presented using radio and television, printed handouts, Internet and telephone directories.

Evacuations plans.

Effective evacuation planning depends on accurate and meaningful tsunami inundation (flooding) and hazard maps. Under the National Tsunami Hazard Mitigation Program, California has received funding to prepare preliminary Tsunami Inundation Maps for the entire state of California. The State Office of Emergency Services, working with the University of Southern California, has produced inundation maps for most of the coast, which represent the maximum projections for

tsunami inundation. The California Legislature has authorized the California Geological Survey to prepare tsunami hazard maps but has never allocated funding for the task.

Only some communities have completed actual evacuation plans based on these maps. Even fewer have begun the process of educating their residents how to respond and posting signs for evacuation routes. The primary impediment has been the lack of funding for this effort. In addition, the evacuation plans must be created by local government emergency managers. These are the same people who prepare for terrorist incidents and they have often been diverted onto other tasks in the last few years.

Because these maps represent the maximum inundation expected from the largest tsunamis, using these inundation areas for the more common smaller events can cause problems. The computer infrastructure and modeling systems are in place to produce more detailed tsunami inundation that would give emergency planners better information to work with when making a decision on evacuation.

California needs a more consistent effort toward tsunami mitigation in all coastal areas, with resources to support these efforts. The State can support standardization, developing guidance materials that identify a "standard of care" for tsunami response to include maps, directions and conditions for safely evacuating inundation zones. The State should also support development and distribution of standardized public education materials, signage and training for tsunami planning. After many years of uncertainty about tsunami signage because of conflicting objectives between responsible agencies, Caltrans has issued an official notification that local agencies in California may begin installing Tsunami Signs in tsunami inundation areas as defined by the National Oceanic and Atmospheric Agency (NOAA).

FINDING: **Federal programs have provided resources to initiate tsunami hazard mapping and mitigation programs. However, more effort and a better understanding of the risk is required to bring the treatment of tsunamis to a level comparable to other State hazards such as earthquakes.**

Tsunami warning system.

The tsunami warning system in the Pacific Basin is operated federally under NOAA as part of a Pacific Basin system and is not the direct responsibility of California. A significant upgrade to the system is underway with new federal funding approved after the Sumatran tsunami. Tsunami warnings are issued by the center in Palmer, Alaska for the West Coast of the United States and by the Hawaii center for Hawaii and the western Pacific Basin. In some cases, such as the June 14, 2005 Gorda plate event, bulletins issued by the two warning centers may appear contradictory as they are intended for different areas of responsibility. Subsequent bulletins are issued hourly by the Tsunami Warning Centers as water level heights from the DART Buoy network and tide gauges close to the source area become available until the event is ultimately cancelled. If the tide gauges show no unusual wave activity, a bulletin is issued canceling the tsunami warning, watch or advisory. Tsunami bulletins are transmitted to local public agencies that make the decision to evacuate coastal areas if local authorities deem it necessary. The tsunami warning system is only effective if local populations cooperate with authorities and wait for an official "all-clear" before returning to the evacuation zone.

The national tsunami warning system was developed decades ago, in response to a major tsunami in 1946. The criteria for issuing watches, warnings and bulletins are decided internally by NOAA. NOAA issues the warnings and leaves to local communities the decision of how to respond. A significant deficiency is an inability to cancel an alert quickly if further evidence suggests that it is not appropriate. In June 2005, significant financial costs were incurred and the potential for injury was increased because the alert was continued for an hour after most scientists recognized that a potentially damaging tsunami was not underway. Local jurisdictions also need help in understanding whether evacuation is appropriate in a particular situation.

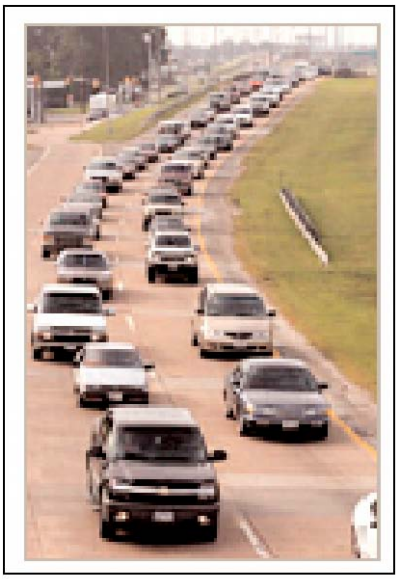
The State of California should encourage the federal government to continue to support and develop the tsunami warning system. The State should work with the other states on the Cascadia Subduction Zone to ensure our needs are being heard and met. Distribution to local jurisdictions is handled through several communication systems. Improvements to these systems

have begun because of the lessons learned from the June 2005 tsunami warning and should be supported by the State.

The inundation maps available to local emergency responders were not suited for the type of event experienced on June 14, 2005. If an evacuation order for the populated areas of southern California had been given for this event, millions of people would have been put into the potentially harmful situation of a mass evacuation. It is clear that a worst case scenario inundation map for an extreme local tsunami in southern California is not appropriate for a warning induced by a moderate earthquake in northern California.

False alarms.

An evacuation based on a false alarm can cost lives in addition to incurring unnecessary expenses in personnel time and a depletion of other resources. An evacuation has its risks and should not be undertaken lightly. The recent, sad case of the elderly patients in Houston who died in a bus fire while being evacuated from Hurricane Rita is a vivid example. At present, the NOAA warning system issues a warning whenever a tsunami occurs, even if the impact would be inconsequential.. For instance, the warning on June 14, 2005 was issued for the entire coast of the western U.S., even though no damage from a tsunami generated by a M<7.5 earthquake has ever been recorded more than 100 miles from the event. The decision on whether an evacuation is needed is left to local jurisdictions that rarely have the expertise to estimate the probable consequences of a tsunami. The local jurisdictions need more information to support this decision making.



Traffic jam caused by evacuation from Hurricane Rita in Texas.

New technologies.

The dissemination of tsunami warnings use a system developed in the 1950s and makes only limited use of present day methods of rapidly disseminating information. Other countries, particularly Japan, have developed modern dissemination systems that should be examined for applicability here. Our mass media capabilities are vastly improved and, in addition to accessing hundreds of television stations, we should also tap on-line news outlets for instant alerts and utilize text message alerts for cell phones, portable email devices and other hand-held communication devices. Accuracy of disseminated information must be a top priority.

VI. SEISMIC SAFETY COMMISSION RECOMMENDATIONS

Recommendation 1: The State of California should improve education about tsunami issues in the State, by:

a. Include multi-language education about tsunami hazards and how to respond to large coastal earthquakes, sudden water level changes and official tsunami warnings in all California schools.

b. Actively educate coastal populations about tsunami hazard zones, evacuation routes and install signage consistent with other west coast states as soon as possible.

c. Update State and local earthquake preparedness materials to include tsunami safety. Incorporate tsunamis in safety training for workplaces in inundation zones, especially ports.

d. Develop multi-language tsunami information and educational materials and make them available to visitors to coastal areas.

Justification. Technological improvements in detection, hazard assessment and warning dissemination are of little use if the people do not understand the information. While tens of thousands of Indonesians died in the 2004 tsunami, every one of the 800 residents of Langi survived the complete destruction of their village because they knew to evacuate to higher ground. Education is the foundation of all the safety plans.

Recommendation 2: Work with other coastal states to obtain an external expert review of the NOAA tsunami warning system criteria for issuing and canceling warnings as well as the format and procedures for distribution.

Justification: The present warning system leads to significant costs to the states through false alarms and delays in cancellation. The local jurisdictions are forced to evaluate tsunami risk to decide on appropriate actions with insufficient information or knowledge base. The concerns of the states need to be included in the process of developing the warning system.

Recommendation 3: Continue to work with federal agencies to develop guidelines for structures to resist both strong ground motion and tsunami wave impact.

Justification. The financial losses in the seaports could have a major impact on the economy of the United States. Investment in better structures when they are built could lead to significant savings in the long run. Earthquake risk is large in California so tsunami engineering must also take strong ground motions into account.

Recommendation 4: Support and provide matching funds for tsunami mitigation programs in coastal counties and in OES, including improvements to the communications and emergency response systems. These funds will leverage federal support for tsunami mitigation programs.

Justification. The events of June 14, 2005, showed us that not all of California is ready to respond to the tsunami warnings that we will be receiving. It is important that all responding agencies at both the local and state level have had the opportunity to work together before the event.

Recommendation 5: Support and provide matching funds for the development of improved technologies and methodology to assess the tsunami risk. These new technologies and risk assessments should be used to support better long-term and emergency response planning. Develop probabilistic tsunami hazard maps appropriate for building code and land-use regulations.

Justification. The level of understanding of the tsunami risk is significantly less complete than we have for other hazards such as earthquakes. The long-term losses expected from tsunamis can be significantly reduced through application of our knowledge.

California Seismic Safety Commission

1755 Creekside Oaks Drive, #100
Sacramento, California 95833
(916) 263-5506

Lawrence T. Klein, *Chair*
Utility Planning

Andrew A. Adelman
Cities/Building Official

Hon. Richard Alarcon
Alternate: Chris Modrzejewski
State Senate

Mark Church
Local Government

Dr. Bruce R. Clark
Geology

Dr. Lucile M. Jones
Seismology

Hon. Carol Liu
Alternate: Don Manning
State Assembly

Gary McGavin
Architecture Planning

Celestine Palmer
Insurance

Jeff Sedivec
Fire Protection

Daniel Shapiro
Structural Engineering

Keith Wheeler
Social Services

Dr. Dennis Mileti
Social Services

Dr. Arul Arulmoli
Soils Engineer

Tsunami Safety Ad Hoc Committee

Donald Parker, Chairman
Fire Chief, City of Vallejo

Commissioner Jones
Seismology

Commissioner Shapiro
Structural Engineer

Dr. Jose Borrero
Tsunami Research Center
University of Southern California

Dr. Lori Dengler
Redwood Coast Tsunami Wk. Gp.
Humboldt State University

Rich Eisner
Chief, Coastal Region
State Office of Emergency Services

Orville Magoon
President
Coastal Zone Foundation

Dr. Michael Reichle
Chief Seismologist
California Geologic Survey

Crystal Rockwood
Communications Director
Pillsbury Winthrop Shaw Pittman, LLP

Jeff Terry
Program Specialist
LA County Emergency Management

Linden Nishinaga
Senior Civil Engineer
City of Long Beach

Richard McCarthy
Executive Director
CSSC

Henry Reyes
Project Manager
CSSC

Robert Anderson
Geologist
CSSC

James Lee
Intern
CSSC

Veronica Ramirez
Intern
CSSC

Testimony Gratefully Received from

Lloyd Cluff
Director, Geosciences Department
PG&E

Mark Johnsson
Staff Geologist
Calif. Coastal Commission

George Meis
Chief, Office of Signs, Marking
& Permits, Caltrans

Doug Sandy
Emergency Planner
City of San Francisco OES

David Dystra
Senior Coastal Engineer
Moffat & Nichol

Martin Eskijian, P.E.
Senior Engineer
State Lands Commission

Linden Nishinaga, Committee Member
Senior Civil Engineer
City of Long Beach

Dr. Fred Raichlen
Engineering Professor
Caltech

Dr. Dick Seymour
Head, Ocean Research Group
Scripps Institute

Jeff Terry, Committee Member
Program Specialist
LA County Emergency Management

Dan Larkin
Program Coordinator
Humboldt County OES

Allen Winogradov
Program Coordinator
Del Norte County OES

California Seismic Safety Commission Staff

Richard J. McCarthy
Executive Director

Sue Celli
Robert Anderson
Fred Turner
James Lee

Karen Cogan
Henry Reyes
Henry Sepulveda
Veronica Ramirez

Appendix A

Support material used in the creation of this report is available at: http://www.seismic.ca.gov/Appendix_A_Tsunami_Report.htm