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## CALIFORNIA LEGISLATURE

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### Joint Legislative Committee on Emergency Management Assemblymember Freddie Rodriguez, Chair

## "California Earthquakes, Surviving the Mega-quake"

Tuesday, October 6, 2015, at 9:30 am  
Ronald Reagan State Office Building Auditorium, 300 S. Spring Street, Los Angeles, CA

"California Earthquakes, Surviving the Mega-quake" will review state preparedness for large magnitude earthquakes and look at the efforts of Los Angeles to mitigate the effects of such a disastrous event. After every catastrophic earthquake in California over the past eighty years, the Legislature and our state and local agencies have responded by passing new laws or regulations to implement policy changes to improve safety and response. Given the dire forecasts for the next earthquake disaster, this hearing seeks to learn what changes need to be made before that earthquake strikes, not after. The question is, "what can we do now?"

Regarding a large earthquake, experts have stated that "The earthquake is inevitable. The only question is when." There have been estimates that the death toll from a quake with a magnitude 7.5 or greater in the Los Angeles area could approach 2,000 people with injuries numbering 50,000 or more. Recently the United States Geological Survey adjusted its big-quake forecast in California by hiking its estimate on the chances of an 8.0 earthquake occurring in California in the next thirty years from 4.7% to 7%.

In 2014 the City of Los Angeles released a study, "Resilience by Design" that set forth a plan to address the city's earthquake vulnerabilities, including building retrofits and steps to secure water supply and communications infrastructure. Los Angeles has begun efforts to implement that plan.

The City and County of Los Angeles, the California Office of Emergency Services and numerous other local, state and federal agencies are actively planning and preparing for a coordinated response to disasters such as earthquakes. The Joint Legislative Committee on Emergency Management is holding this hearing to receive testimony from all interested parties to examine these efforts and to help facilitate the future of emergency response in California.

Effective planning will facilitate recovery efforts and save lives. The Committee wishes to investigate issues regarding: emergency communications, emergency transportation, immediate and continued availability of health care, disruption of utilities and return of service, transportation disruption, and problems associated with the coordination and provision of relief efforts and recovery.

## **BACKGROUND**

Scientists who study earthquakes and their frequency and strength have been predicting that California will be rocked by a strong earthquake in the next 30 years. They now estimate that the risk of a magnitude 8 or stronger earthquake striking California in the next three decades has jumped to 7 percent from 4.7 percent. This increase results because scientists are now taking into account the possibility that several faults can shake at once, releasing more seismic energy that will result in greater destruction. The report includes newly discovered fault zones and the possibility that a quake can jump from fault to fault.

Estimates that California will be rattled by a more moderate 6.7 magnitude or larger earthquake continues to be greater than a 99 percent chance in the next thirty years. A 6.7 earthquake is similar in size to the 1994 Northridge disaster that killed 57 people, injured more than 5,000 and caused property damage estimated to be at more than \$20 billion. According to the U.S. Geological Survey (USGS) the chance of a Northridge-size quake is slightly higher in Northern California than Southern California (95 percent versus 93 percent respectively).

The latest seismic calculations for a 6.7 earthquake or greater largely mirror previous findings issued by the USGS in 2008 when scientists determined that California faced an almost certain risk of experiencing another Northridge-size quake.

Thousands of quakes hit California every year between two of Earth's major tectonic plates, the Pacific and North American plates. Most earthquakes are too small to be felt. Of the more than 300 faults that crisscross the state, the southern segment of the San Andreas Fault, which runs from central California to the Salton Sea near the U.S.-Mexico border, remains a major threat because it hasn't ruptured in more than three centuries.

It should be noted that scientific reports with estimates for earthquakes are a forecast, not a prediction. Experts still cannot predict exactly where or when a quake will hit anywhere in the world. The USGS statistics, while only a forecast, should still be taken extremely seriously. Recent seismic activity has shown that California needs to be proactive and continue to prepare for survival and recovery.

### **Recent Events of Concern**

On September 6, 2015 an earthquake occurred 29 miles offshore from Illapel, Chile with a recorded magnitude of 8.3. The initial quake lasted three minutes and several aftershocks over magnitude 6 were recorded. The Chilean government reported 13 deaths, 6 missing and 34 people injured. Roughly 1 million people were evacuated from their homes because of the threat of tsunamis. A state of emergency was declared in the region around the coastal city of Coquimbo, which was struck by waves up to 15 feet. Experts credit Chile's strict building code requirements, a tsunami warning system and extensive planning and preparedness for minimizing deaths, injuries and infrastructure damage.

On August 24, 2014 at 3:20 a.m., a 6.0 magnitude earthquake struck the region around the City of Napa, California. The earthquake resulted in hundreds of injuries and at least one death, caused significant damage to buildings and infrastructure and was felt in many other areas of northern California.

## **Responding to Earthquakes**

In recent years, the USGS, several universities and private companies have been testing an early warning system designed to detect the first waves of an earthquake and send out an alert before the slower-moving damaging waves strike. The system is designed to provide from a few seconds up to a minute or more of notice to allow trains to slow down, utilities to shut off gas lines and people to duck for cover. The public alert system is still in a developmental pilot phase and will require more funding before it can effectively be rolled out statewide. The California Seismic Safety Commission has been tasked with development of this new technology.

In November of 2014 the Assembly Select Committee on Local Emergency Preparedness conducted a hearing on the Napa Earthquake to determine the “lessons learned” from that event. The Committee found that during the Napa earthquake state, local and private entities responded quickly to mitigate the effects of the earthquake. From the testimony obtained at this hearing, the Committee was able to make a finding that the years of preparation, coordination, planning and implementation paid off in the response to the earthquake. These findings are tempered by the fact that the Napa earthquake was only a moderate 6.0 quake. Even so, there was a death, more than 200 injuries and significant damages. In addition there were numerous problems in earthquake planning, preparation and response that must be addressed to improve California’s response to future earthquakes. The issues that arose during the Napa earthquake should be addressed during our continuing efforts to prepare for earthquakes.

## **Potential Earthquake Issues**

When California has experienced disastrous earthquakes in the past, it has responded by adopting more stringent laws and regulations on everything from building standards for schools, hospitals, transportation, infrastructure issues to preparation and response (see attachment A for statutory changes). As part of this response we have seen various state and local agencies being tasked to address earthquake safety and resilience.

As a result of past quake disasters our state and local agencies have undertaken a robust, proactive and cooperative approach to prepare for future events, to plan for recovery and frequently work together to conduct comprehensive earthquake drills and exercises. The OES has compiled a brief list of agencies and activities involved in earthquakes (see attachment B).

We know from past experience that after a catastrophic earthquake the first three days will be chaos, including fires, building collapses, utility outages, overwhelmed first responders, hospital triages, with everyone in survival mode. Afterwards, survivors may be living in a ruined city for up to a year before water, phone, gas, power and food supplies are fully restored. During that period some reconstruction will occur but, given the shortage of skilled labor, financing and a likely interruption of the supply chain, reconstruction could continue for up to 10 years. A decade after the disasters in New Orleans, New Jersey and Long Island; those communities were still under reconstruction.

California has already focused a lot of attention on plans to survive the actual shaking, on the immediate aftermath of the quake and the prospects for long term infrastructure rebuilding and economic recovery. The OES in cooperation with the federal government, state agencies, local governments, utilities and other private entities has worked on a comprehensive plan of response to a large scale earthquake in the Los Angeles. A report titled, “The Southern California Catastrophic Earthquake Response Plan” already considers and updates responses to many of the following issues. Given changing demographics, risk

assessments, technology developments and safety initiatives, it is vital to continually re-examine and re-assess our earthquake responses.

After a mega earthquake there will need to identify where and how to house individuals whose residences are deemed to be uninhabitable. No one knows how many buildings will be unlivable after a large quake but even a modest loss of structures might mean that hundreds of thousands of people could be displaced and homeless. Unless these individuals leave their communities, governments should identify required open spaces to park tents and FEMA trailers and plan for the distribution of goods and services to these displaced persons. While available hotel rooms, vacant apartments, empty classrooms and short-term rentals might be may be available for emergency housing they may not be enough to satisfy demand.

Consideration must continue to be given to future building standards. Some experts have suggested that apartment buildings or other living structures in at risk earthquake zones should not be more than four stories tall. Low-rise buildings are easier to escape from in the initial quake and resultant fires as well as easier to live in without power.

During that time, many senior citizens who have difficulty climbing stairs could become prisoners in their own apartments. Likewise, parents carrying small children and groceries may not be able to make it up long, multi-story stairwells. At risk populations such as the aged, blind, disabled, those with chronic illnesses must be taken into account during disaster risk planning. Mid-rise businesses such as hotels relying on elevators could become uninhabitable.

California communities should continue to review their existing buildings and infrastructure and consider how to harden buildings that are seismically at risk. Many local communities have looked at this issue and are taking steps to address the problem. How and who pays for seismic upgrades for existing structures has been a subject of discussion. Building designs integrating new seismic technology has progressed substantially in the last two decades and has been instrumental in improving survivability. The importance of strict seismic safety building standards was credited by experts in Chile for the low death and injury totals that the country. An effective and quick tsunami warning and evacuation system is also given credit.

Large earthquakes can easily generate forces that typical residential buildings are not designed to withstand. While many buildings may survive a large earthquake, the interaction of many repetitive elements and their short quake duration might make these buildings inhabitable or unsafe to use. In such cases these buildings may not collapse but still might be a total loss. This was the case after the 2014 Napa earthquake. Every opportunity must be taken to upgrade our existing buildings to reduce the possibility of a total collapse. State and local building standards should be continually reviewed and upgraded as new building techniques and technologies are developed.

During a large magnitude earthquake transportation may also be severely compromised. Freeways and roadways may collapse. The sheer volume of rubble and debris may render many streets unusable. Cars parked in deep subterranean parking lots could be trapped because of the no power for ventilation or garage gates. Gas stations may not be able to pump gas consistently or be resupplied and traffic and street lights may be down.

After the initial destructive shaking, we can expect a slow and partial power supply restoration to different parts of the area with continued intermittent brown outs or power loses. Some areas may be

without power or water for extended periods of time. Our cities and communities don't function well without electricity, natural gas and water. Without utility services, recovery will be delayed.

The availability of potable water after an earthquake is a great concern. People can live without power for long periods of time but only three days without water. There is a high probability that a large earthquake along the San Andreas Fault could cause the Los Angeles area to lose access to water. Much of the area's water comes from two aqueducts that cross earthquake faults. It is highly foreseeable that access to water will be interrupted for a significant length of time after a large magnitude earthquake.

Many newer homes that now use the newer tankless water heaters will not have access to the built-in water reserve that tank water heaters provide. A well strapped 50- to 60-gallon tank water heater can provide a family of four with about two weeks of water at the survival rate of 1 gallon per person per day. It is also unclear if water systems that rely on well pumps and sewer pumps can survive a power cut off or an intermittent power supply.

### **Los Angeles – Resilience by Design**

Los Angeles Mayor, Eric Garcetti assembled a Mayoral Seismic Safety Task Force whose duty was to create a report outlining the ways in which L.A. can prepare for the inevitable "Big One." In December of 2014 the report **Resilience by Design** was released with recommendations by the Task Force that focus on three major pillars: shoring up L.A.'s pre-1980 construction buildings ("non-ductile reinforced concrete" and "soft first story" structures); fortifying Los Angeles' water system; and bolstering telecommunications infrastructure.

The first sentence of that report is, "From a seismological standpoint, Northridge was not a big earthquake." Led by Dr. Lucy Jones of the U.S. Geological Survey (USGS), the report was the culmination of a year-long investigation into the greatest vulnerabilities of the city that would result from a major seismological event. The 126-page report lays out key recommendations for reducing those vulnerabilities and increasing safety with following in mind: Protecting the lives of residents, improving the capacity of the City to respond to earthquakes, preparing the City to recover quickly from earthquakes, and protecting the economy of the City and of Southern California.

The **Resilience by Design** report recommended taking actions focused on strengthening the city's most vulnerable building stock known to have poor performance during earthquakes, improving the aging water system, and enhancing the telecommunications system in order for the city to reduce losses and to adequately respond after a major seismic event.

The study, "**Resilience by Design**" can be found at: <http://www.lamayor.org/earthquake>

As a result of this study Los Angeles has taken proactive steps to prepare for and mitigate the effects of a disastrous earthquake. In May of this year the City of Los Angeles, became the first city in the United States to enact seismic safety standards for new cell phone towers.

### **Southern California Catastrophic Earthquake Response Plan**

The California Emergency Management Agency (Cal EMA), now the California Governor's Office of Emergency Services (Cal OES), released the "Southern California Catastrophic Earthquake Response Plan" (OPLAN) in 2010. This document recognizes the disastrous effects of a large earthquake in Southern California and sets forth a comprehensive plan to address preparation and recovery. The OES continues to refine the OPLAN and is constantly upgrading and improving preparations planned responses and coordination with others. The following excerpts are taken from that report:

Planning assumptions are based on the California Geological Survey and the United States Geological Survey's ShakeOut Scenario of 2008. The southern San Andreas Fault has generated earthquakes of magnitude 7.8 on average every 150 years—and on a portion of the fault that ruptures in the ShakeOut Scenario, the last earthquake happened more than 300 years ago. The most critical damage occurs to Interstate 10 in the Coachella Valley and in the San Geronio Pass, Interstate 15 in the Cajon Pass, California (CA)-14, CA-111, CA-62, Box Canyon Road, and Big Pines Highway. Other disrupted lifelines include fiber optic cables (90 crossings), petroleum and natural gas pipelines (39 crossings), railroads (21 crossings), aqueducts (32 crossings), and overhead electric power transmission lines (141 crossings).

#### **1.4 THREAT**

This OPLAN addresses the effects of a magnitude 7.8 earthquake on the southernmost segment of the San Andreas Fault, between the Salton Sea and Lake Hughes, as defined by the 2008 ShakeOut Scenario. The earthquake will impact eight (8) counties in Southern California: Imperial County, Kern County, Los Angeles County, Orange County, Riverside County, San Bernardino County, San Diego County and Ventura County. The effects of this earthquake include, but are not limited to, fault offsets, landslides, liquefaction, and fires (including conflagrations) following the earthquake.

#### **Reduce Hazards: Suppress Fire, Contain Hazardous Materials**

- 1,600 fires ignite after the disaster event; dozens of large fires merge into conflagrations destroying hundreds of blocks.
- Use of U.S. Forest Service may be limited by jurisdictional authority.
- Fires that follow this earthquake will double losses with over 3600 deaths.
- Alternate fire suppression water sources need to be identified to suppress fires burning over 4500 acres which equates to 133,000 single-family dwellings and \$65 billion dollars in property loss.
- Over 140,000 hazardous material incidents occur after disaster event: three chlorine gas releases and one ammonia release are expected.

#### **Conduct Safety Assessments**

- Over 300,000 buildings are significantly damaged (1 in 16) and require inspection.
- California has 5,926 in-state, trained building inspectors certified in the Safety Assessment Program: 25 exist in bordering states and 416 in the other states.

#### **Health and Human Services:**

##### **Provide Acute Care – Hospital/EMS**

- Hospital functionality will be decreased by an estimated 30%, as much as 75 % in specific OAs. An estimated 13,000 beds are lost.
- Demand will exceed capabilities; the system is currently taxed under normal conditions.
- Shortages will exist in hospital equipment, including beds and prescription medications affecting patient care.
- For the remaining hospitals to continue operation, they will immediately need water, fuel, pharmaceuticals and personnel.
- Approximately 2,600 public and private ambulances exist in California; about 27% are fire-based.

### **Provide Chronic Care – Medical Special Needs, Mental Health**

- Initially, 40% of Medical Special Needs (MSN) patients will require assistance immediately with an additional 40% requiring care within 72 hours and the remaining 20% of the population requiring care within the first week.
- Local jurisdictions will require significant amount of State and Federal resources to care for the large numbers of survivors with special medical needs.

### **Execute Patient Evacuation/Movement**

- Patient tracking systems among health care system components are currently not integrated.
- The ability to coordinate and control the flow of all patients requiring movement is limited.
- Many roads, highways, and bridges will be impassable in the first few days after the earthquake due to damage and debris on the roads, hampering patient movement.

### **Provide Care and Shelter, Including Animals**

- 2,600 current potential shelter structures will have to be inspected before they can be available.
- 255,000 displaced households, an estimated 542,000 people, will require emergency shelter.
- Although no estimate exists, a large percentage of the displaced population is expected to have pets.
- Mass care operations will also require:
  - Potable Water
  - Sanitation Disposal
  - Security
  - Mental Health
  - Functional Needs
- Over 8 million estimated cases of mental health (distress/disorders).
- Overflow veterinary facilities will have to be identified in other counties not impacted and possibly other states.
- Priority must be given to ESF 8.

### **Conduct Mass Fatality Operations**

- An estimated 1,800 deaths are anticipated in the region.
- Shortages in equipment and material to support and identify fatalities will exist.
- No State Coroner or Medical Examiner (ME) exists, thus the counties must rely on the mutual aid system.
- Within the impacted OAs, a surge capacity exists to store a total of 1400 remains: LA County can surge up to a capacity of 600 bodies; approximately 200 mortuaries exist with varying capacity; 4 mobile morgues exist with a capacity of 40-50 each.
- Disaster Mortuary Operational Response Teams (DMORTs) and DoD Mortuary Affairs Team can help with processing and identification; however there will be a shortage in capable mortuary and other personnel.

### **Support Mandatory and Self-Evacuations, including Logistical Needs**

- Evacuation may be limited due to non-passable roadways and vehicle-borne evacuees with vehicles containing limited gas.
- Conflagrations in downtown L.A. force the evacuation of 130,000 people within the first 72 hours.
- Attrition of the workforce is estimated to be nearly 50%, thus hampering evacuation operations.

The report provides a more in depth analysis of the anticipated 7.6 earthquake than is presented here. It provides responses and actions that will be taken in response to this threat. The information contained in this background report is included to provide the Committee with an idea of the devastation that will occur after a catastrophic earthquake. This report can be found on the OES website at:

It should be remembered that the United States Geological Survey has estimated the likelihood of 8.0 or larger earthquake occurring in California during the next 30 years is 7%. The forecast for a 7.6 earthquake or greater occurring is 99%.

### **Lessons Learned from the Assembly Select Committee of Local Emergency Preparedness Hearing on the Napa Earthquake**

The August 2014 Napa earthquake was a moderate sized earthquake yet caused significant damage in the community and created disruption in emergency care and services. The Committee noted these problems in a report on the hearing. For a copy of the hearing please contact the Joint Legislative Committee on Emergency Management.

The 2014 South Napa earthquake occurred in and around the city of Napa, California on August 24 at 3:20 a.m. local time, measuring at 6.0 on the magnitude scale. The tremor's epicenter was located south of Napa, approximately 3.7 miles (6.0 km) northwest of American Canyon near the West Napa Fault, beneath the Napa Valley Marina on Milton Road, just west of the Napa County Airport.

The Napa earthquake was the largest in the San Francisco Bay Area since the 1989 Loma Prieta earthquake which measured a 6.9. As a result of the Napa earthquake there was extensive damage and several fires reported in the southern Napa Valley area. There was also significant damage in the nearby city of Vallejo, in Solano County. The quake killed at least one person, injured over 200, and interrupted power to more than 69,000 Pacific Gas and Electric Company customers in the area. Early estimates by California officials indicated that the earthquake caused over \$400 million in damage, of which only \$87 million may be eligible for federal reimbursement. Later estimates stated that the overall damage could be closer to \$1 billion.

Issues identified in the Napa Earthquake Hearing to consider in future earthquake planning

1. The City and County of Napa experienced problems establishing their emergency operations center (EOC). An EOC is a central command and control facility responsible for carrying out the principles of emergency preparedness and emergency management, or disaster management functions at a strategic level in an emergency situation. Extensive damage to the planned EOC site resulted in a switch to an unplanned alternative site. This created a modest delay in getting the EOC established.
2. The computer equipment for the planned OEC was located at the administrative building and was not available for use at the alternative site. EOC staff stated that they wished they had backed up these computers on flash drives. In a computer driven world, planning on redundancy in emergency situations should include ready availability of information and programs that exist on computers. Each agency should assess their ability to access programs and information should their computer and communications equipment be made unavailable during an emergency.



3. Representatives from the City and County of Napa testified that FEMA had still not stepped in to provide assistance eight weeks after the earthquake. There was frustration expressed that the process of providing disaster relief is slow and was retarding the ability of the community to recover. County and City officials stated that if there was one recommendation to be made as a result from the earthquake, it would be that the state needs to accelerate this process to help the recovery efforts. While FEMA is a federal agency and California does not have the ability to directly change the FEMA assistance process, California should examine if there are ways to assist in the process.
4. It was estimated that only 3 to 5 percent of homeowners in the Napa area had earthquake insurance. Earthquake insurance is expensive and has high deductibles causing many home and building owners to refuse insurance coverage. Lack of insurance restricts and delays recovery of communities after an earthquake. California needs to look into making earthquake insurance more affordable and available.
5. Earthquakes, unlike hurricanes and other natural disasters however, can be tougher to assess for losses because damage is often beneath the facade of a road or a building. Consequently, earthquakes generally take longer to deem official disasters and qualify for assistance.
6. All fourteen of the Napa County buildings in the county sustained damage in the earthquake. Much of this was the result of water damage. Several of the County administration buildings suffered damage when water lines to roof top chillers were broken. Damage to County buildings caused the displacement of 400 or approximately one third of county employees. Several older commercial buildings in downtown Napa had extensive external damage even though many had been retrofitted for earthquake safety protection. Problems from brick or masonry fronts were evident and many homes had chimney damages. Businesses did not have access to shut off water lines that was causing flooding to their premises, water lines in government buildings, homes and businesses broke and caused damage that might have been prevented with automatic shut off devices. Historic Napa brick buildings were not safe even when retrofitted. California needs to continue to assess seismic safety building standards.
7. OES testified that they were not able to immediately establish a satisfactory communications link with the Counties of Solano, Sonoma and Napa. Even though OES has several redundancy communications methods they physically dispatched resources to local governments to tie in and get an optic on the situation. In spite of these issues OES was able to establish communications with the affected areas pretty rapidly.
8. OES stated that the state can better utilize data science and available geographic information system (GIS) mapping technology integration at all levels of government. It is currently available at some levels of government but it is not integrated.
9. The Napa City Manager testified that there were issues with switching from response to recovery phases. Part of this problem stemmed from a lack of personnel qualified to conduct inspections, assess damages and prepare appropriate reports. There was a definite need to identify local resources and personnel to assist Napa in recovery efforts such as structural engineers, building inspectors and accountants.
10. In looking at the damage to residences, Napa County first looked to protect the lives and safety of its residents and inspected structures; “red” and “yellow” flagging those that were dangerous

or unusable. Unfortunately the occupancy vacancy rate in the Napa area at the time of the earthquake was only 1.7 percent so there was no place to send people who were displaced. As a result, most people couldn't relocate in Napa. Wherever they could, Napa left people in their buildings.

11. One thing the City of Napa did not plan on was the sheer volume of debris left by the earthquake. They were faced with the decision of what do we do with the mass volume of debris the earthquake generated. Napa resolved this issue by setting up locations for debris deposits at city schools. The schools were out for summer break and worked with the city on the issue. Napa was also fortunate that no major roads or bridges were out which would have complicated debris removal.
12. Ambulance service in Napa County and City is provided by contract with American Medical Response or AMR. Dispatch for services is handled by the county which directs AMR to where services are needed. Local fire personnel also provide assistance and backup on services provided by AMR. After the earthquake, two of AMR's ambulance supervisors went down to the EOC at Fire Station Number 1 in Napa and were asked to become emergency medical response dispatchers. For the rest of the event, for every medical aid request that came through the 911 system, AMR employees employing a system that they developed on-the-spot, dispatched the appropriate resources. Normally, for every dispatch in Napa there is also fire agency support, either an advanced life support or basic life support level that will also responds to the request for transport. There were many cases that night where that was not possible, with AMR ambulances going to calls just by themselves, evaluating the situation and responding to it as best they could. In Napa, the modest increase in service requests caused the emergency response system to not break, but to bend. It is highly likely that a Katrina, style New Orleans failure in the emergency medical 911 system could occur in San Francisco or Los Angeles as a result of a catastrophic earthquake.
13. The Napa, Queen of the Valley Hospital (the Queen) stated that 234 patients visited the emergency room within 24 hours. Shortly after the quake the hospital's elevators automatically shut down as a safety feature. During this time there was an emergency room patient that needed to be put on a ventilator in the ICU which is on a different floor in the hospital. This necessitated carrying a portable ventilator unit downstairs from the ICU to the emergency room in order to stabilize the patient. The Queen stated that one of things they learned from the earthquake was that they must inventory critical equipment for an emergency and have this material at the proper elevation in the facility. In a disaster, maintenance of standard procedures and operating methods in a health care facility are often not possible. Health facilities should review vital infrastructure and placement of facility departments, equipment and necessary modalities of treatment and prepare for a worst case scenario.

The Select Committee found that existing emergency services response and the coordination with state, local and others worked well in Napa. It cautioned however that the response in Napa may not mean a positive result to an earthquake on a massive scale in the future. California needs to continue to plan, prepare, train and upgrade its emergency response capacities and recovery programs to be ready for the inevitable catastrophic earthquake.

# California Earthquake Hazards Mitigation Legislation

**Field Act (Education Code-§17281, et seq.):** In 1933, one month after the Long Beach Earthquake destroyed 70 schools, seriously damaged 120 others, and caused minor damaged to 300 more, California passed the Field Act to ensure seismic safety in new public schools. The Act establishes regulations for the design and construction of K-12 and community college buildings. The Division of the State Architect within DGS enforces the Field Act.

**Riley Act:** Following the 1933 Long Beach Earthquake, the state also passed the Riley Act, which requires local governments to have building departments that issue permits for new construction and alterations to existing structures and conduct inspections. Permit fees paid by building owners generally fund the work of local building departments. The Act also set minimum seismic safety requirements that have since been incorporated into all building codes.

**Garrison Act:** Requires school boards to assess building safety of pre-Field Act schools, ordered modernization of non-field act compliant structures.

**Strong Motion Instrument Act (Public Resources Code§§2700-2709.1):** The state passed the Strong Motion Instrumentation Act in 1972 in response to the extensive damage to buildings and bridges caused by the 1971 San Fernando Earthquake. The earthquake highlighted the need for more data on strong ground shaking during earthquakes and on the response of structures to the shaking. The Act established a statewide network of strong motion instruments to gather vital earthquake data for the engineering and scientific communities. Data obtained from the strong motion instruments is used to recommend changes to building codes, assist local governments in the development of their general plans, and help emergency response personnel in the event of a disaster.

**Seismic Safety General Plan Element (Government Code § 65302):** Requires city and county plans to include seismic safety elements.

**Alquist-Priolo Earthquake Fault Zoning Act (Public Resources Code § 2621-2630):** The state passed the Alquist-Priolo Earthquake Fault Zoning Act in 1972 to mitigate the hazard of surface faulting to structures built for human occupancy. The law was another response to the 1971 San Fernando Earthquake, which produced extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures. The Act's main purpose is to prevent the construction of buildings used for human occupancy on the surface trace of active faults. Before issuing building permits, cities and counties must require a geologic investigation to ensure that proposed buildings will not be constructed across active faults. Proposed building sites must be evaluated by a licensed geologist. If an active fault is found, a structure for human occupancy cannot be placed over the trace of the fault.

**Alfred E. Alquist Hospital Facilities Seismic Safety Act (Health and Safety Code§129675):** The loss of emergency functions and hospital collapses due to the 1971 San Fernando Earthquake prompted passage of the Hospital Seismic Safety Act of 1973. Regulates the design, construction and alteration of hospitals; set seismic safety standards for new hospitals; created an advisory Hospital Building Safety Board. Office of Statewide Health Planning & Development enforces this Act.

**Seismic Safety Commission Act (Business and Professions Code §1014):** The 1971 San Fernando Earthquake highlighted weaknesses in California's earthquake risk management policies. To address

these weaknesses, in 1975 the state legislature created the independent California Seismic Safety Commission (CSSC) to provide a consistent earthquake policy framework for the state. The mission of CSSC is “to provide decision makers and the general public with cost-effective recommendations to reduce earthquake losses and expedite recovery from damaging earthquakes.” The commission is also responsible for implementing the California Earthquake Hazards Reduction Act, which requires CSSC to “prepare and administer a program setting forth priorities, funding sources, amounts, schedules, and other resources needed to reduce statewide earthquake hazards.”

**Earthquake Hazard Reduction Program (Senate Bill 1279):** Directs California Seismic Safety Commission to assess policy and program implications of earthquake prediction and to develop seismic safety program and financing plan for the state.

**Alquist Hospital Facilities Seismic Safety Act of 1983 (Health and Safety Code §§130000-130070):** Requires design and construction standards for hospitals; requires that after Jan. 1, 2008 any general acute care hospital building determined to be at potential risk of collapse or poses a risk of significant loss of life be used only for nonacute care.

**California Earthquake Hazards Reduction Act of 1986 (Government Code §8870, et seq.):** After the 1985 Mexico City Earthquake, in 1986 California passed the Earthquake Hazards Reduction Act, which called for a coordinated state program to implement new and expanded activities to significantly reduce earthquake threat. The program is coordinated by California Seismic Safety Commission, which is required to specify priorities, funding sources and amounts, schedules, and other resources. Although historically funded by the state general fund, since the 2003-2004 fiscal year, the program was funded by fees imposed on property insurance companies.

**Un-reinforced Masonry Building Law (Government Code §§ 8875-8875.10):** In response to the 1983 Coalinga Earthquake, in 1986 the state legislature enacted the Un-reinforced Masonry Building Law, which requires local governments in high seismic regions of California to inventory un-reinforced masonry buildings, establish mitigation programs, and report progress to the CSSC. As of 2003, 251 local governments have established programs and 16,761 buildings have either been retrofitted or demolished. Cities and counties rely on a variety of funding sources, including building permit fees, to pay for these programs. Some local programs offer financial, planning, and zoning incentives to building owners for retrofit. The CSSC periodically reports on the progress made by local programs in a publication entitled Status of the Un-reinforced Masonry Building Law, most recently in 2003.

**Essential Services Building Seismic Safety Act (Health and Safety Code §16000):** In 1986 the state passed the Essential Services Building Seismic Safety Act to require enhanced regulatory oversight by local governments during the design and construction of new essential service facilities, such as fire and police stations and emergency communications and operations facilities. The Division of the State Architect within DGS enforces this Act. Pursuant to the Act, the Division of the State Architect within DGS adopted regulations that apply to the construction of all new essential services buildings (California Code of Regulations, Title 24, Part 1, §4-201 to §4-249). There are no statewide regulations for evaluating and retrofitting locally regulated essential services buildings that existed prior to 1986 except for unreinforced masonry buildings in some jurisdictions. Some local governments and state agencies have voluntarily retrofitted or replaced their vulnerable buildings.

**Katz Act (Education Code §§35295-35297):** Requires all private schools to develop disaster plans and an earthquake emergency procedure system.

**Bridge Seismic Retrofit Program (Senate Bill 2104):** Requires CalTrans to prepare an inventory of all state-owned bridges which require strengthening or replacement to meet seismic-safety standards, and prepare a plan and schedule for completion. Note: Since the 1971 San Fernando Earthquake, CalTrans has been authorized to seismically retrofit vulnerable state and local bridges. Phase 1 consisted of retrofitting 1,039 state-owned single- and multiple-column bridges at a cost of \$815 million. Phase 2 consisted of retrofitting the remaining 1,364 multiple-column state bridges at a cost of approximately \$2 billion. Approximately \$1.5 billion is being spent to replace major non-toll bridges and \$4.6 billion for major toll bridge retrofits and replacements. Replacement costs include significant non-seismic upgrades. Costs for retrofitting 1,212 locally owned bridges are expected to be approximately \$1 billion. Funds come from the State Transportation Improvement Fund, the State Highway Account, FEMA public assistance, sales tax increments, and gasoline taxes.

**Earthquake Safety and Public Buildings Rehabilitation Bond Act of 1990 (Prop 122 & Government Code §§ 8878.50-8878.52):** Proposition 122 was passed by voters in June 1990 after the 1989 Loma Prieta earthquake revealed vulnerabilities to state-owned and essential services buildings. The bond measure authorized the state to issue \$300 million in general obligation bonds for the seismic retrofit of state and local government buildings (\$250 million for state-owned buildings and \$50 million for partial financing of local government essential services facilities). The Seismic and Special Programs Section of DGS' Real Estate Services Division administers Proposition 122 grant programs.

**Seismic Hazards Mapping Act (Public Resources Code §§ 2690-2699.6):** The Seismic Hazards Mapping Act, passed in 1990, directs the Department of Conservation to identify and map areas prone to liquefaction, earthquake-induced landslides, and amplified ground shaking. The purpose of the Act is to reduce the threat to public safety and to minimize the loss of life and property by identifying and mitigating these seismic hazards. The Act requires geotechnical investigations to identify hazards and formulate mitigation measures before permitting most developments within mapped Zones of Required Investigation.

**Health & Safety Code § 1226.5:** Establishes seismic safety standards for ambulatory surgical centers; requires fixed medical equipment (floor roof or wall mounted) to be installed using services of licensed architect or structural engineer; and requires inspection every five years.

**Health and Safety Code §§ 19210-19214:** Requires new and replacement water heaters to be braced and anchored.

**Executive Order D-86-90:** Requires CalTrans to prepare plan to retrofit transportation structures; requests UC and requires CSU to give priority consideration to seismic safety in allocation of funds for construction projects.

**California Earthquake Authority (Insurance Code §§ 10089.5-10089.54):** Creates the California Earthquake Authority and authorized CEA to issues policies of basic earthquake insurance.

**Education Code § 17317:** Requires Department of General Services to conduct inventory of public school buildings that are concrete tilt-up or have non-wood frame walls that do not meet requirements of 1976 UBC by Dec. 31, 2001.

**Government Code § 8587.7:** Program Requires Office of Emergency Services, in cooperation with State Department of Education, Department of General Services and the Seismic Safety Commission to

develop an educational pamphlet for use by K-14 personnel to identify and mitigate risks posed by nonstructural earthquake hazards.

**Health and Safety Code §§19180-83 & §§19200-05:** Authorizes local governments to adopt ordinances requiring installation of earthquake sensitive gas shutoff devices in buildings due to motion caused by an earthquake; allows Division of the State Architect to establish a certification procedure for installation.

**Streets & Highways Code §188.4:** Program Authorizes retrofit of state-owned toll bridges using seismic toll surcharge.

**Highway Safety, Traffic Reduction, Air Quality, and Port Security Bond Act of 2006 (Proposition 1B, Government Code §8879.23(i)):** 2006 Essential facility seismic safety Program Provides \$125 million funding for seismic retrofit work on local bridges, ramps, and overpasses; establishes Local Bridge Seismic Retrofit Account.

**California Emergency Services Act (Government Code §8550):** The California Emergency Services Act provides the legal authority for emergency management and the foundation for coordination of state and local emergency response, recovery, preparedness, and mitigation activities throughout California.

**Disaster Recovery Reconstruction Act, Government Code §8877.1:** The Legislature finds and declares that the impact of the Mexico City earthquake disaster of September 19, 1985, has rendered more cogent and compelling the findings of the Legislature set forth in Section 8870, particularly subdivision (c) thereof, and heightened the need for authority for local agencies to engage in effective pre-event and post-event activity to accomplish those goals set forth in paragraph (4) of subdivision (b) of Section 8872. It is the intent of this chapter to provide that authority. 8877.3. It is the purpose of this chapter to authorize, guide, and otherwise enable cities, counties, and other entities to prepare in advance of a disaster, such as a devastating earthquake, for the expeditious and orderly recovery and reconstruction of the community or region. Each city, county, or other local subdivision of the state, may prepare, prior to a disaster, plans and ordinances facilitating the expeditious and orderly recovery and reconstruction of the area under its jurisdiction, should a disaster occur. These plans and ordinances may include any of the following: An evaluation of the vulnerability of specific areas under its jurisdiction to damage from a potential disaster, together with streamlined procedures for the appropriate modification of existing general plans or zoning ordinances affecting those areas after a disaster. A contingency plan of action and organization for short-term and long-term recovery and reconstruction to be instituted after a disaster.

**Economic Disaster Act of 1984, Government Code §8695:** The Legislature finds and declares that the disaster response of state agencies does not adequately focus on the economic impact of a natural disaster on the business community. 8696. It is the purpose of this chapter to institutionalize the planning and response of state agencies to disasters in order to reduce economic hardship stemming from these disasters to business. Upon the completion of the emergency phase and the immediate recovery phase of a disaster, appropriate state agencies shall take actions to provide continuity of effort conducive to long-range economic recovery. The Director of the Office of Emergency Services shall invoke the assignments made pursuant to Section 8595, specifying the emergency functions of each agency or department. The Director of the Office of Emergency Services, in executing the purposes of this chapter, shall establish appropriate task forces or emergency teams to include concerned elements of federal, state, and local governments and the private sector.

**Natural Disaster Assistance Act, Government Code §8680:** Provides state financial assistance for recovery efforts to counties, cities and/or special districts after a state disaster has been proclaimed. The applicant must incur a minimum aggregate total damage cost of \$2,500 state share for each declared disaster for costs to be eligible under CDAA. A local agency must submit a Project Application (OES 126) to the California Emergency Management Agency (Cal EMA) within 60 days after the date of a local proclamation. When filing an application for assistance, an applicant may attach a List of Projects (OES 95). Applicants are also required to have on file with Cal EMA, a resolution designating an authorized representative (OES 130) for each disaster. Cal EMA coordinates the state's response to major emergencies in support of local government. The primary responsibility for emergency management lies with local government. Local jurisdictions first use their own resources, and as they are exhausted, obtain more from neighboring cities and special districts, the county in which they are located, and other counties throughout the state through the Statewide Mutual Aid System. Cal EMA serves as the lead agency for mobilizing the State's resources; it also maintains oversight of the State's Mutual Aid System. During an emergency, Cal EMA coordinates the state's response efforts. After a natural or man-made event causes extensive damage and a state disaster has been declared, Cal EMA has the regulatory responsibility to act as the grantor for the California Disaster Assistance Act (CDAA). The CDAA program may be implemented as a "stand alone" funding source following an Cal EMA Agency Secretary's Concurrence for a local emergency, or a Governor's Proclamation when there is no federal declaration.

**Natural Hazards Disclosure Act, Civil Code §1102:** This article applies to the transfer by sale, exchange, installment land sale contract, lease with an option to purchase, any other option to purchase, or ground lease coupled with improvements, of any real property described in subdivision or residential stock cooperative, improved with or consisting of not less than one nor more than four dwelling units. NATURAL HAZARD DISCLOSURE STATEMENT-The transferor and his or her agent(s) or a third-party consultant disclose the following information with the knowledge that even though this is not a warranty, prospective transferees may rely on this information in deciding whether and on what terms to purchase the subject property. The following are representations made by the transferor and his or her agent(s) based on their knowledge and maps drawn by the state and federal governments. This information is a disclosure and is not intended to be part of any contract between the transferee and transferor. The disclosures must indicate if the real property lies within any of the following hazardous areas: A SPECIAL FLOOD HAZARD AREA (Any type Zone "A" or "V) designated by FEMA; AN AREA OF POTENTIAL FLOODING shown on a dam failure inundation map; A VERY HIGH FIRE HAZARD SEVERITY ZONE; A WILDLAND AREA THAT MAY CONTAIN SUBSTANTIAL FOREST FIRE RISKS AND HAZARDS; AN EARTHQUAKE FAULT ZONE; and/or A SEISMIC HAZARD ZONE.

**Planning and Zoning Law, Government Code 65000:** Establishes the protocols and authority for land-use, planning and zoning laws for local jurisdictions throughout the state. The Legislature finds and declares that California's land is an exhaustible resource, not just a commodity, and is essential to the economy, environment and general well-being of the people of California. It is the policy of the state and the intent of the Legislature to protect California's land resource, to insure its preservation and use in ways which are economically and socially desirable in an attempt to improve the quality of life in California. The Legislature also finds that decisions involving the future growth of the state, most of which are made and will continue to be made at the local level, should be guided by an effective planning process, including the local general plan, and should proceed within the framework of officially approved statewide goals and policies directed to land use, population growth and distribution, development, open space, resource preservation and utilization, air and water quality, and other related physical, social and economic development factors. 65030.2. Costs and benefits of growth. It is further

the policy of the state and the intent of the Legislature that land use decisions be made with full knowledge of their economic and fiscal implications, giving consideration to short-term costs and benefits, and their relationship to long-term environmental impact as well as long-term costs and benefits. The Legislature further finds and declares that recommendation, continuous evaluation and execution of statewide environmental goals, policies and plans are included within the scope of the executive functions of the Governor and responsibility for assuring orderly administration of this process within state government should be assigned to a governmental unit reporting directly to the Governor.

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## **California Governor's Office of Emergency Services And Partner Agencies**

### **About Cal OES and Partner Agencies**

Under the authority of the California Emergency Services Act (Government Code Section 8550 et seq.), the Governor's Office of Emergency Services (Cal OES) coordinates all State emergency planning and preparedness, disaster response and recovery, disaster mitigation, and homeland security activities. The agency mission is to protect lives and property, build capabilities, and support our communities for a resilient California. The mission is achieved through effective collaboration in preparing for, protecting against, responding to, recovering from, and mitigating the impacts of all hazards and threats.

The Cal OES Earthquake and Tsunami Program consist of six core staff members who are dedicated to serving the public through partnerships with federal, state and local agencies, universities, networks and associations, voluntary organizations and the private sector. The staff is comprised of an earthquake program officer and coordinator, tsunami program officer and coordinator, program manager and an associate program assistant. This core staff leverages the agency's charge to manage an earthquake and tsunami preparedness and response program by effectively cooperating with its network of partner agencies.

The Cal OES Earthquake and Tsunami Program is an active participant on boards and committees as well as in professional associations involved with disaster preparedness. Program staff participates in Board of Directors meetings for the Western States Seismic Policy Council (representing the Cal OES Director), the Cascadia Region Earthquake Workgroup, the External Advisory Board of Southern California Earthquake Center, and the External Advisory Board of the Federal Alliance for Safe Homes.

In addition to board participation, Program staff has held leadership positions in: the California Tsunami Steering Committee (Chair), the Coordinating Committee of the National Tsunami Hazard Mitigation Program, the California Integrated Seismic Network Steering Committee, and the California Post-Earthquake Clearinghouse Management Committee.

### **Earthquake, Tsunami and Volcano Hazards**

California sits on the juncture of two major tectonic plates, the North America Plate and the Pacific Plate. The San Andreas fault generally parallels the coast in a southeasterly direction, coming ashore near Eureka, passing west of San Francisco and east of Los Angeles into Mexico. The associated seismic activity contains the potential for more than seventy four percent of the country's overall expected annualized losses (FEMA 3666, 2008).

In the past two centuries, earthquakes have claimed the lives of more than 3,000 Californians. Currently, approximately 30 million residents are exposed to significant risk for damaging 2014 earthquakes. In addition, the state attracts 200 million visitors every year, largely to areas at risk for catastrophic earthquake.

Of the 58 county operational areas, 20 have exposure to the potential for tsunami damage. This includes 99 coastal cities, three metropolitan areas with major harbor facilities and approximately 376,000 people living in mapped tsunami inundation zones. The population does not include the several million visitors who are attracted to the beach every year.

The state's population, infrastructure and economy are also vulnerable to the threats posed by volcanic activity. The United States Geological Survey (USGS) Volcano Observatory suggests there is a high to very high threat potential from seven volcanic fields, centers, chains, craters and calderas. Three more pose a moderate threat potential.

### **Earthquake Activity in 2014**

As of this writing the USGS reports that 72 earthquakes of Magnitude 3.5 or greater have occurred in the state since January 1, 2014. Twenty-six of those were of M4.0 or greater. Of those, one was in the M5.0 range and two were in the M6.0 range.

The Magnitude 5.1 La Habra Earthquake occurred on March 28, 2014 and resulted in damage and emergency responses in Orange and Los Angeles Counties. Local Emergencies were proclaimed, but the losses did not result in a state or federal declaration.

A M6.8 earthquake occurred in the ocean 78km WNW of Ferndale, California on March 10, 2014 (Gorda Plate / Triple Junction area). While the temblor was near enough to the coast to be felt by local residents, no significant damage was reported.

Most recently and most significantly, the M6.0 Napa Earthquake on August 24, 2014 resulted in one death and caused more than \$87 million in public losses. Some reports estimate the total public and private losses to be closer to \$1 billion. Local Emergency Proclamations and requests for state assistance were received from Napa and Solano Counties. Governor Brown proclaimed a State of Emergency for the Napa Earthquake on August 24, 2014. President Obama declared the Napa Earthquake to be a Major Disaster on September 11, 2014.

Since 1971 there have been 12 other notable earthquakes that have generated direct losses, deaths and injuries. These include the M6.6 San Fernando earthquake on February 9, 1971, M6.5 Imperial Valley Earthquake on October 15, 1979, M6.5 Coalinga Earthquake on May 2, 1983, M6.0 Whittier Narrows Earthquake on October 1, 1987, M6.9 Loma Prieta Earthquake on October 17 1989, M7.0 Cape Mendocino Earthquake on April 25, 1992, M7.3 Landers/Big Bear Earthquake on June 28, 1992, M6.7 Northridge Earthquake on January 17, 1994, M7.1 Hector Mine Earthquake on October 16, 1999, M7.1 San Simeon Earthquake on December 22, 2003, M6.5 Eureka/Humboldt Earthquake on January 9, 2010, and M7.2 El Mayor Cucupah Earthquake on April 4, 2010.

## Exhibit 1: Recent Earthquakes with Direct Losses, Deaths and Injuries

Earthquake	Date	Magnitude	Direct Losses <sup>a</sup>	Deaths <sup>d</sup>	Injuries <sup>d</sup>
San Fernando	February 9, 1971	6.6	\$2,200 <sup>b</sup>	58	2000
Imperial Valley	October 15, 1979	6.5	\$70 <sup>b</sup>	0	91
Coalinga	May 2, 1983	6.4	\$18 <sup>b</sup>	1	47
Whittier Narrows	October 1, 1987	6.0	\$522 <sup>c</sup>	9	200+
Loma Prieta	October 17 1989	6.9	\$10,000 <sup>d</sup>	63	3757
Cape Mendocino	April 25, 1992	7.0	\$80 <sup>c</sup>	0	356
Landers/Big Bear	June 28, 1992	7.3	\$120 <sup>c</sup>	1	402
Northridge	January 17, 1994	6.7	\$46,000 <sup>b</sup>	57	11,846
Hector Mine	October 16, 1999	7.1	minor	0	11
San Simeon	December 22, 2003	6.5	\$263 <sup>e</sup>	2	46
Eureka/Humboldt	January 9, 2010	6.5	\$43	0	43
El Meyor Cucapah	April 4, 2010	7.2	\$91	0	91

<sup>a</sup>Estimate in millions of dollars

<sup>b</sup>FEMA, 1997; U.S. Office of Technology Assessment

<sup>c</sup>National Research Council, 1994

<sup>d</sup>Cal OES

<sup>e</sup>CSSC 2004-02, 2004

### California Earthquake Prediction Evaluation Council (CEPEC)

California Government Code Section 8657 establishes the California Earthquake Prediction Evaluation Council (CEPEC) to advise the Governor on the existence of earthquake or volcanic prediction having scientific validity. CEPEC was convened twice in 2014 at the request of either the State Geologist or the Cal OES Director.

On March 19, 2014, CEPEC was convened to discuss concerns about an apparent increase in earthquake activity throughout the State. Cal OES Director Mark S. Ghilarducci requested that the CEPEC assess the latest seismic activity and its potential impact to the State. Director Ghilarducci said that Governor Brown asked about the number of minor to moderate earthquakes that have occurred over the state in the past week.

Recent seismic activity of note through March 19, 2014 included:

- 3/10: M6.8 77km WNW of Ferndale in the Gorda Plate / Triple Junction area
- 3/12: M4.4 57km NE Kernville, CA
- 3/15: M3.9 near Castaic Lake Dam
- 3/16: M3.5 28km ENE of Pine Valley
- 3/17: M4.4 near Westwood, CA

The CEPEC Members concluded that that neither the M6.8 event off-shore of Ferndale on Monday, March 10, 2014, nor the M4.4 event near Westwood on Monday, March 17, 2014, was outside normal earthquake parameters.

On August 24, 2014, CEPEC again met by teleconference to discuss the circumstances of the M6.0 South Napa Earthquake and assess the implications for future damaging earthquakes that may occur in the vicinity.

A previous M4.9 event in the same area on September 3, 2000 resulted in no fatalities, 60 injuries, and minimal damage. On March 31, 1898 a M6.4 earthquake occurred on the nearby Rodgers Creek fault several miles to the west. The 1898 quake caused considerable damage to the Navy facilities at Mare Island. The San Francisco City Hall dome was also damaged.

CEPEC concluded that numerous aftershocks are typical in the days and weeks following an earthquake of this magnitude. While it is unlikely that any of these aftershocks will be larger than this morning's M6.1, there have been several examples in our past where a M6.0 was a foreshock to a larger event.

CEPEC stated that these events remind all Californians to be vigilant in their preparedness for earthquakes. People should be prepared for future aftershocks, which may cause additional damage to existing, damaged buildings. Residents should be prepared to not reenter structures until those structures have been inspected for structural soundness, natural gas leaks and water leaks. Now is a good time for residents to update their earthquake survival kits.

### **California Seismic Safety Commission**

California Government Code Section 8690.45 provides for an Earthquake Emergency Investigations Account for the Seismic Safety Commission to enable them to investigate damaging earthquakes and fund investigation expenses. The commission also manages California's Earthquake Hazards Reduction Program and is charged to review seismic activities funded by the State as well as earthquake-related legislation.

After the Napa Earthquake the Seismic Safety Commission conducted public hearings to assess seismic safety issues and investigate earthquake damage and reconstruction efforts.

### **California Earthquake Clearinghouse**

The California Earthquake Clearinghouse is a place to coordinate earthquake field investigations and share observations and knowledge among emergency responders and the engineering and scientific communities.

In response to the 2014 Napa Earthquake, the California Earthquake Clearinghouse provided a centralized coordination center where engineers, geologists, seismologists, sociologists, economists, and other professionals could coordinate the gathering of information, maximizing the use of its resources and capabilities. Responding engineers, inspectors and subject matter experts provided field observations that added valuable insights for use by officials managing response and recovery operations.

As part of the After-Action / Corrective Action analysis, the Clearinghouse identified the need to better coordinate NEHRP funding through state agencies so that operational priorities can be

centralized through each state. During the Napa event, funding issued directly to consortia members was used to meet consortia priorities, but their priorities were not always aligned closely with state response and recovery objectives.

### **2014 Earthquake, Tsunami and Volcano Preparedness Activities**

In 2014, Cal OES coordinated earthquake, tsunami and volcano preparedness and response efforts with its partner agencies. Cal OES worked closely with the California Geological Survey (CGS), U.S. Geological Survey (USGS), California Seismic Safety Commission, California Earthquake Authority (CEA), Southern California Earthquake Center (SCEC) and Tsunami Research Center at USC, Caltech, University of California at Berkeley, American Red Cross; Earthquake Engineering Research Institute (EERI), Structural Engineers Association of California (SEAOC), local government, private industry, and non-profit entities, and California's Earthquake Country Alliance (ECA).

The Southern California Earthquake Center (SCEC) provides earthquake research and education as part of the outreach partnership. SCEC is a partner in UCERF, the California Earthquake Clearinghouse, and serves as the administrative "home" of Earthquake Country Alliance.

Other divisions of Cal OES involved in earthquake and tsunami mitigation and education include Mitigation Planning, Mitigation Grants, and Office of Communications.

### **2014 Great California ShakeOut**

The Great ShakeOut earthquake drills that began in Southern California in 2008 have rapidly grown to be the world's largest preparedness activity. In 2014, a record ten million people and organizations participated in California alone.

Cal OES supported the Southern California Earthquake Center (SCEC) at the University of Southern California and the California Earthquake Alliance (CEA) to promote ShakeOut activities to improve ways that people can protect themselves during earthquake events. The recent South Napa Earthquake, the 20th anniversary of the '94 Northridge earthquake, and the 25th anniversary of the 1989 Loma Prieta earthquake are critical reminders that California is Earthquake Country.

Notable ShakeOut venues in 2014 included the Biola University and City of La Mirada Earthquake Drill (Southern California), the Loma Prieta 25th Anniversary Symposium and the 2014 Buildings-At-Risk (BAR) Summit.

### **Biola University / City of La Mirada Earthquake Drill**

The drill was held as part of the ShakeOut events on October 16, 2014 that included a shake trailer simulations, interviews, press conference, and full-scale drill exercise with aftershocks.

## **Loma Prieta 25th Anniversary Symposium**

The Loma Prieta 25th Anniversary Symposium: Still on Shaky Ground event was held on October 16 to commemorate the 25th anniversary of the 1989 Loma Prieta earthquake and support future resilience action. CalOES personnel served on the planning team as well as presenting and facilitating sessions. The symposium offered Bay Area residents and regional leaders an opportunity to inspire regional action for safer, more resilient communities. During the event, Bay Area leaders, community advocates, and elected officials launched a three-year public policy program designed to spark quick recovery from future disasters and enact place-based action for a safer future in the places we call home.

## **2014 Buildings-At-Risk Summit**

Cal OES supported the 2014 Buildings-At-Risk (BAR) Summit: Strengthening Our Cities, presented by the Structural Engineers Association of Southern California (SEAOSC). The event convened over 300 engineers and other community leaders at The Center at Cathedral Plaza in downtown Los Angeles to talk about how to mitigate losses from a seismic event in Southern California, including potential liability issues and the official process for addressing its older, pre-1980 buildings.

## **Other ShakeOut Activities**

As part of Cal OES support, staff coordinated with several local governments to promote and participate in ShakeOut events in both Southern and Northern California. Staff also developed copy and voiced a ShakeOut PSA sponsored by the Los Angeles County Professional Employees and coordinated with UC Berkeley to create an Earthquake Early Warning “ShakeAlert” model for use in a ShakeOut drill at the Loma Prieta 25th Anniversary Symposium. ShakeOut is further supported by the Federal Emergency Management Agency (FEMA), National Science Foundation (NSF), United States Geological Survey (USGS), and other sponsors.

## **Earthquake Country Alliance**

This year Cal OES continued its support for the Earthquake Country Alliance by participating on several committees to promote earthquake preparedness. Activities included arranging speakers for the Los Angeles County long-Term Care Disaster Preparedness Summit, California Science Center media event regarding Volcano hazards in connection with their Pompeii exhibit, and an LA City business hazard mitigation and resiliency workshop.

The Earthquake Country Alliance is a public-private partnership of people, organizations, and regional alliances that work together to improve preparedness, mitigation and resiliency. Strategic Partner Organizations include California Governor’s Office of Emergency Services, United States Geological Survey, California Earthquake Authority, Southern California Earthquake Center, California Geological Survey, Federal Emergency Management Agency, American Red Cross, State Farm Insurance Company, and many others.

## **California Earthquake Authority**

The California Earthquake Authority (CEA) is a publicly managed, largely privately funded organization that provides catastrophic residential earthquake insurance and encourages Californians to reduce their risk of earthquake loss.

The CEA provides significant in-kind support for ShakeOut and Earthquake Country Alliance, including hundreds of thousands of dollars of earned media donated to ShakeOut. This has provided Cal OES with the ability to leverage federal funds through co-funding of significant projects.

Through their partnership with ShakeOut and the Earthquake Country Alliance, the CEA has facilitated the publication of the Staying Safe booklets for public distribution. The CEA also partners with Cal OES to dispense household mitigation grants. The CEA continues to work closely with American Red Cross on the “Joined Forces” program. The CEA and Red Cross worked together to promote the annual Great California ShakeOut in October. The CEA also continued its support of federal legislation to lower rates and make earthquake insurance more affordable and accessible.

## **California Residential Mitigation Program**

In 2014, Cal OES continued its coordination with California Earthquake Authority to implement an incentive program to help homeowners seismically retrofit their homes. The resources for this program, called the California Residential Mitigation Program (CRMP), come from the CEA Earthquake Loss Mitigation Fund. By statute, 5% of CEA’s insurance premiums are used to support mitigation.

The program, called the Bolt + Brace Program, focuses on helping the retrofit of wood-frame family dwellings where those two specific elements are inadequate. The program has been piloted in two California Communities, the Los Angeles neighborhood of Eagle Rock and the Rockridge neighborhood of Oakland.

A typical retrofit can cost between \$2,000 and \$10,000. Earthquake Brace + Bolt will pre-qualify homeowners whose homes meet certain criteria and then select the recipients of the rebate (up to \$3,000) using a database which will randomly select participants. The full program is projected to roll out in fall 2014.

## **NEHRP State Assistance Fund Administration**

The loss of NEHRP State Assistance funding continues to inhibit the State’s ability to be the leader in earthquake preparedness. Prior to Federal FY2012, Cal OES received and administered federal funding through the National Earthquake Hazards Reduction Program (NEHRP) to support earthquake preparedness in the state. However, beginning with FFY 2012 which dispersed funding in the 2nd quarter of 2013, FEMA no longer allocated NEHRP State Assistance Program funding to the states, but instead, to FEMA's Earthquake Consortia and other cooperative agreement holders. This change in policy impacts California most, since our risk is

(and funding was) highest among the NEHRP states. Since then, Cal OES has engaged the NEMA Mitigation Committee in support of State NEHRP priorities and management to restore funding administration to high-risk states in order to provide effective, coordinated earthquake preparedness programs. To further the cause, Cal OES has promoted stronger emergency management representation on NEHRP's Advisory Group, which is currently dominated by scientists/engineers. Their priorities are many times different than those of the emergency management community, which affects funding allocation decisions. Cal OES has recommended that FEMA consider involving other parts of their organization - beyond the Mitigation Directorate - in NEHRP in order to balance perspectives when it comes to setting NEHRP priorities.

On May 20-23, 2014, Cal OES staff represented California at the annual meeting of State Earthquake Program Managers (EPMs). Loss of state earthquake program functionality (due to loss of state NEHRP funding discretion) was discussed. Input from Alabama, Alaska and the NEMA executive board resulted in State EPMs organizing as a group for year-round coordination, along with the development of a White Paper on NEHRP funding and related issues.

In June and July, Cal OES staff worked with CUSEC staff and other National Earthquake Program Managers (NEPM) to create a survey of NEHRP state earthquake programs as support for developing a white paper regarding NEHRP and funding impacts on state earthquake programs. Staff also participated in calls with FEMA and earthquake program managers from all 33 NEHRP states regarding submission of project recommendations for NEHRP 14 and 15.

### **California Integrated Seismic Network (CISN)**

Cal OES supports the activities of the California Integrated Seismic Network (CISN) Steering Committee and the California Earthquake Early Warning System (CEEWS) Steering Committee in order to provide real-time earthquake monitoring and develop the capability to provide advance notification of seismic events.

Prior to 2000, with funding provided by FEMA, Cal OES, and USGS, three seismic monitoring systems operated by CGS, CalTech, UC Berkeley and USGS were integrated into a single seismic system. Under this arrangement, CGS provides scientific products and services about the state's geology, seismology and mineral resources and administers the California Strong Motion Instrumentation Program. UC Berkeley conducts research on earthquake processes and earth structures and coordinates the Northern California Seismic Network to provide timely and accurate earthquake information. Cal Tech operates the Seismological Laboratory and coordinates the Southern California Seismic Network and serves as a focal point for earthquake information in Southern California. Other partners include Humboldt State University, which focuses its study on the Cascadia Subduction Zone and serves as a partner of the Redwood Coast Tsunami Work Group, promoting Earthquake and Tsunami education efforts. Cal OES manages the funding contracts with three participating CISN institutions, CGS, UC Berkeley and CalTech. Since 2002, Cal OES has provided funding for the development and



maintenance of CISN at approximately \$2-3 million per year. General Fund cuts in fiscal year 2011/12 reduced support for CISN to \$1.7 million.

In 2014 Cal OES supported the efforts of the primary CISN partners in hosting the annual CISN Steering Committee meeting. This year's agenda focused on the evolving California Earthquake Early Warning System. The CISN advisory committee will review the CISN Strategic Plan and recommend revisions for the next planning period.

### **California Earthquake Early Warning System (CEEWS) Initiative**

In 2014, the Cal OES Earthquake and Tsunami Program continued its collaboration with the California State Geologist, the Directors of the Seismological Laboratories at UC Berkeley and Caltech, the California and U.S. Geological Surveys and the California Seismic Safety Commission to promote the development of an Earthquake Early Warning System in California.

Timely warnings of an earthquake can provide seconds to minutes before the arrival of damaging shaking. Even a few seconds can allow time to take protective action such as taking cover in safe locations, stopping elevators and opening doors at the nearest floor, or automatically stopping critical processes to mitigate damages or to enhance public safety.

Several countries, including Japan and Mexico, have existing earthquake early-warning systems. In Japan, information is transmitted to the public through a variety of mechanisms, including television and radio broadcasts, computer pop-ups featuring real-time maps showing the location of the epicenter and radiating seismic waves and text-style messages accompanied by an audible alert sent to cell phone users.

On September 24, 2013, Senate Bill 135, sponsored by Senator Alex Padilla, was signed into law by Governor Brown and codified as Government Code Section 8587.8. Under the law, Cal OES is tasked to develop a comprehensive statewide earthquake early warning system in California through a public-private partnership and identify funding sources, other than the State General Fund, by January 1, 2016.

The goal for this initiative is to rapidly detect the initiation of an earthquake, estimate the level of ground shaking to be expected, and issue a warning before significant ground shaking arrives.

Five objectives are established to meet the goal:

1. Develop an earthquake early warning model that represents a public-private partnership, and a cost effective and reliable system.
2. Formalize an earthquake early warning organization structure that incorporates existing roles and responsibilities, such as the CISN.
3. Establish performance standards and participation criteria for the application and operation of earthquake early warning components.
4. Develop guidelines for the public education about the system.
5. Develop funding options including a distributed funding model.

California has the foundation for an early warning system through the California Integrated Seismic Network (CISN) and the USGS “ShakeAlert” demonstration model. CISN allows for earthquake notification, location, magnitude and intensity of ground shaking in the form of a “Shake Map”. Using real-time information gathered by a network composed of nearly 1,000 seismic stations in Southern and Northern California, CISN provides real-time information to develop maps and other products to assist emergency managers deploy resources to help protect lives and property in the areas hardest hit and rapidly determine the magnitude of the damage in order to qualify for federal assistance. CISN is a partnership among Cal OES, the California Geological Survey, the United States Geological Survey, the Caltech Seismological Laboratory and Berkeley Seismological Laboratory, with support from several contributing agencies and organizations.

The state is collaborating with a number of institutions, along with public agencies and the private sector, to assess current capabilities and resources to implement a system specific to California’s unique needs. A series of committees are established to develop the plan. They include:

1. A Steering Committee comprised of public and private stakeholders and subject matter experts to review and provide advice on the progress of the other project committees as they work toward meeting the objectives. The steering committee is comprised of the chairs of the five committees and chaired by an executive level member of Cal OES.
2. A Stakeholder Liaison Group to inform and receive input on the development of the CEEWS external stakeholders and potential users of an earthquake early warning system during CEEWS development.
3. A Model Committee will develop a model that represents a public/private partnership that will operate in a cost effective and reliable manner. The Standards Committee and Model Committee are tasked with developing the system description for earthquake early warning in California.
4. A Standards Committee will ensure that the system operates in a timely, reliable and efficient manner.
5. A Management Committee will formalize an organizational structure that incorporates existing roles and responsibilities for seismic monitoring in California.
6. A Funding Options Committee will identify costs and options for system funding that do not identify the state General Fund as one of those sources.
7. An Education and Training Committee will identify the components of a comprehensive training and education program that addresses the needs of all potential users of an earthquake early warning system.

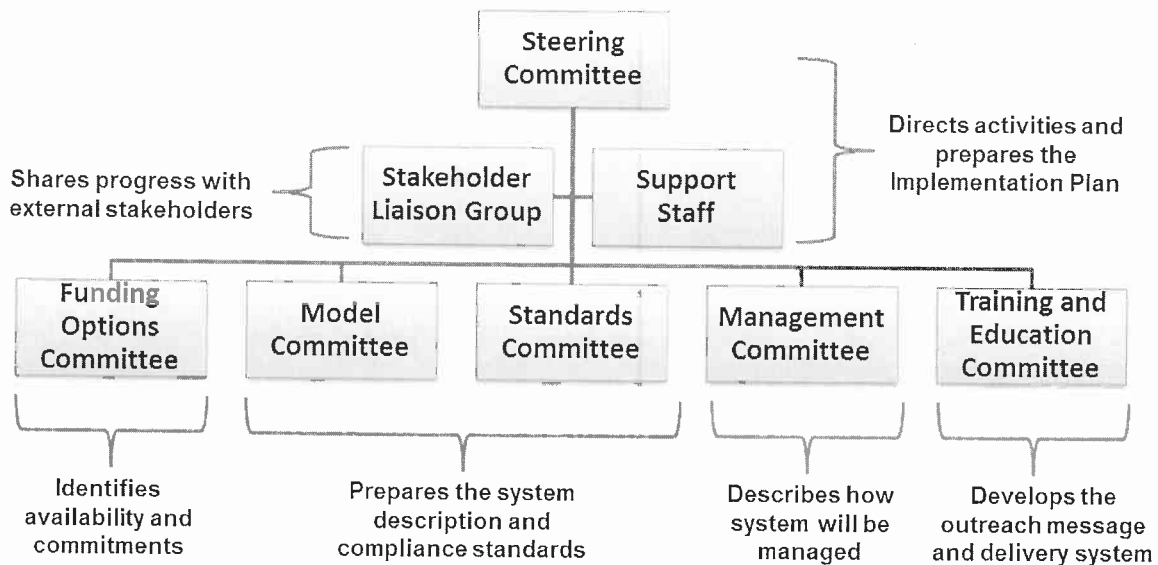
The Model Committee and Standards Committee are currently developing the system description which will outline the features and functions and performance requirements. The Management committee will contribute to the system description by defining how it will be managed and maintained. The Education and Training Committee will provide the outreach requirements.

In order to send earthquake early warning before shaking waves arrive will depend on five elements:

1. A network of sensors, which are densely and uniformly spaced, and situated in proximity to earthquake faults.
2. Quick, robust telecommunications from sensors with sustainable 24 hour coverage.
3. Computer algorithms for fast evaluation of seismic activity including location, magnitude, and potential for continued propagation.
4. Quick reliable mass notifications.
5. End user education.

A cost estimate for the system will need to consider construction costs for new installations, new or upgraded seismic stations and GPS stations, significant field telemetry upgrades, annual operation and maintenance, staffing costs for implementation and testing, operation and user outreach and continued research and development.

**Exhibit 2: CEEWS Steering Committee Organization**



A Project Charter has been developed to serve as a blueprint for developing an implementation plan for a California Earthquake Early Warning System. The charter identifies the project goals and objectives, outlines committee roles and responsibilities and establishes product timelines. The charter was published on February 21, 2014.

The Steering Committee agreed that a findings and recommendations report would be the appropriate format for summarizing the overall Steering Committee work. The recommendation for development of a technical implementation plan, including assignment to the appropriate agencies, could be included in the Steering Committee report. A draft Findings and

Recommendations Report will be prepared for presentation to the Steering Committee at the January 2015 meetings.

The CEEWS Implementation Plan will describe how the system will be developed, a time frame for implementation, an organization and management structure that clearly defines roles and responsibilities of public and private sector entities, conforms to performance standards that assure timeliness and accuracy of alerts, identifies and addresses user needs for training and education to effectively utilize alerts and provides a feasible and broadly consensual model for funding and maintaining the system. The draft Implementation plan is scheduled for presentation to the CEEWS Steering Committee in September 2015. In January 2016, the Steering Committee will convene to consider approving the final implementation plan.

Once the implementation plan is approved, each agency with a role in implementing the California Earthquake Early Warning System will develop its own work plans for developing and operating the system.

### **3rd International Earthquake Early Warning Conference**

On September 3-5, 2014, Cal OES and partner agencies participated in the 3rd International Earthquake Early Warning Conference, organized and sponsored by UC Berkeley, USGS, CalTech, Moore Foundation and the University of Washington. Cal OES staff moderated a panel on the Public Use of Earthquake Early Warning.

The three-day meeting brought together scientists, policy makers, engineers, social scientists, and business representatives from public and private sector institutions to examine the state of the art in earthquake early warning today and to innovate new ways to push the technology forward.

### **Tsunami Preparedness**

In 2014, the Cal OES Earthquake and Tsunami Program staff continued their coordination with CGS to support communities developing plans and programs to protect the public in the event of a future damaging tsunami. Cal OES and CGS staff has actively coordinated with government agencies and non-governmental organizations to promote an understanding of the tsunami risk in California. This program is made available through funding authorized by Public Law 109-424, 33 U.S.C. 3201 seq.: The Tsunami Warning and Education Act, 2006 (TWEA) and administered through the National Tsunami Hazard Mitigation Program (NTHMP). On March 27, 2014 a new bill, the Tsunami Warning and Education Reauthorization Act of 2014 was introduced in Congress. It reauthorizes the above Tsunami Warning and Education Act with specified appropriations for FY2015-FY2019 and expands the tsunami forecasting and warning program operated by the National Oceanic and Atmospheric Administration (NOAA), through the National Weather Service (NWS). This bill is currently pending in Congress.

The tsunami planning scenario is provided by the USGS Science Application For Risk Reduction (SAFRR) Program. The SAFRR Tsunami Scenario is based upon an earthquake offshore from the Alaskan peninsula and that extends to the California coast. This scenario integrates physical

science, social science and emergency management in creating detailed analysis to support officials and the public in reducing the risk of future tsunamis that will impact California.

According to the scenario approximately 750,000 people will need to be evacuated, with 90,000 of those being tourists and visitors. One-third of the boats in California's marinas could be damaged or completely sunk, resulting in \$700 million in losses.

### **Tsunami Steering Committee**

In 2014, Cal OES chaired and facilitated the Tsunami Steering Committee meeting held at San Francisco Airport. Steering Committee members include Cal OES, CGS, NOAA and 20 coastal county jurisdictional representatives. The Steering Committee reviewed a proposed maritime evacuation fathom policy and all California Tsunami Program priorities conducted within the state.

### **Tsunami Inundation Modeling**

State tsunami modelers have completed all of the required modeling to validate 2nd generation tsunami inundation maps. Modeling and mapping tsunami inundation from a new large Aleutian Islands source developed by the USGS has been compared to the state inundation line. High resolution modeling (10m) in Orange and San Diego counties has been used to verify the inundation maps.

### **TsunamiReady Program**

In 2014, the Cal OES Earthquake and Tsunami Program coordinated the delivery of Tsunami Signage as part of the TsunamiReady Program. Staff worked with the City of Alameda and Naval Base San Diego (NBSD) to develop their tsunami warning sign implementation plans. Several jurisdictions, including Mendocino County have placed a sign orders to implement their existing sign plan.

### **Tsunami Preparedness Month**

In 2014, California continued to observe Tsunami Preparedness Week during the fourth week of March. The week is supported nationally by NOAA and is an opportunity for focused outreach and education at the community level. Cal OES facilitated assistance of a number of local activities, including:

- Proclamations by County Boards of Supervisors
- High-profile workshop presentations and the San Francisco Exploratorium, Long Beach Aquarium, Burton W. Chase Park Community Center in Los Angeles, and a media event at La Jolla Shores in San Diego.
- "Tsunami Walk" evacuation drills in Del Norte, Marin, San Francisco, Los Angeles, Orange, and San Diego Counties
- Governmental emergency management exercises in San Francisco, Marin, San Mateo, Orange, and Los Angeles Counties
- Participation in Tsunami Warning Communications Test (Del Norte, and Humboldt Counties)
- Participation in Required Monthly Test (Monterey, Oxnard, and San Diego NWS Weather Forecast Office areas of responsibility)

- Participation in PACIFEX14 (Marin, San Francisco, and San Mateo Counties)
- Discussion of development of Tsunami Preparedness Week Website (TsunamiZone.org)

During Tsunami week, the program has conducted a “Live Code” Tsunami Warning Communications Test which tests the operation and performance of the last critical link in the tsunami warning communications system—the Emergency Alert System that provides tsunami warnings to the public. This test uses the actual tsunami event codes that are used when a tsunami warning is issued by NOAA, a test few other states conduct due to the perceived risk that residents and visitors may mistake the test for an actual tsunami emergency. California has chosen to conduct this test to ensure that these EAS codes will function properly in an actual tsunami emergency.

### **Tsunami Modeling and Mapping for the Maritime Community**

In 2014, the state continued its coordination with coastal jurisdictions to: 1) analyze risks to the maritime community 2) provide planning data and assistance for multiple scenarios to the emergency management community, and 3) work to produce probabilistic tsunami hazard analysis maps for the coast of California.

Cal OES and CGS staff assisted Base San Diego (NBSD) with incorporating evacuation Playbook, maritime Playbook, and FASTER decision support tools into NBSD operations plan. Staff participated in a Tabletop exercise with naval personnel involving a tsunami scenario. Cal OES and CGS participated with the USGS and the City of Alameda to look at GIS modeling of vulnerability for Playbook phases, pedestrian and vehicular evacuation, and vertical evacuation analysis for Response planning purposes. State will facilitate coordination of project scope and eventual results with city.

Cal OES supported several coastal counties by reviewing and providing recommendations for editing tsunami evacuation annexes to their county emergency plans, including San Francisco and Marine counties. Staff worked with San Mateo County to explain the models used to derive the maximum tsunami run-up projections for the Princeton Harbor area. Staff also coordinated with Los Angeles County to provide tsunami evacuation lines for inclusion in the newly adopted Tsunami Annex to the Los Angeles County Response Plan.

### Exhibit 3: Tsunami Playbooks Provide Decision Makers with Evacuation Alternatives



#### Concerns about Tsunami Warnings via Wireless Emergency Alerts (WEA)

NOAA's National Weather Service (NWS) is now able to activate Wireless Emergency Alert (WEA) capable cell phones for the most critical Tsunami Warnings. This will not include Tsunami Information Statements, Advisories, and Watches. This policy has caused concern in the emergency management community who believe the alerts will diminish public safety by taking away local decision authorities to order and manage mass evacuations.

Local emergency managers are recommending that NOAA provide local officials with the authority to issue WEA messages so there can be coordinated protective actions taken by the jurisdiction.

Ventura County submitted a letter to Cal OES requesting assistance in resolving the WEA message issue. Since then, Ventura County and National Weather Service officials have met to discuss the concerns.

#### NTHMP Annual Meeting

Cal OES participated in NTHMP annual meetings held January 27-31, 2014 in Menlo Park. The meeting discussed common issues of coordination among member state and territory partners, including:

- Tsunami Program Update
- NOAA Response to National Academy of Sciences Report
- TsunamiReady Update
- Evacuation Response
- Vertical Evacuation Update
- Marine Guidance Project Update

- NTHMP Member Accomplishments

Cal OES participated in the NTHMP Mitigation & Education (MES) and Mapping & Modeling (MMS) Subcommittee Meetings held August 18-22, 2014, in Seattle, Washington. Staff served on the MES and facilitated workshops at the meeting. Staff discussed:

- How California is using the results of USC modeling work for maritime planning.
- Plans to create in-harbor hazard maps and guidance on how to use them during event.
- How modeling results were translated to maps for Tsunami Response Playbooks and dangerous current duration.
- Offshore safety zones evacuation considerations, including 'Safe offshore depth': 30 fathoms (180ft).

### **AGU Fall Meeting**

Cal OES and CGS staffers are preparing to co-sponsor and attend the American Geophysical Union (AGU) meeting on December 15-19, 2014 in San Francisco. Staff coordinated with fellow NTHMP chairs, National Tsunami Warning Center (NTWC) Director, NOAA Alaska Director, and CGS on scheduling panel presentations. Tsunami planners, modelers, and other professionals will present topics including:

- "Evaluation and Application of Probabilistic Tsunami Hazard Analysis in California"
- "The FASTER Approach: A New Tool for Calculating Real-Time Tsunami Flood Hazards"
- "Assessment of Near Shore Hazard due to Tsunami-Induced Currents"
- "The SAFRR Tsunami Scenario: from publication to implementation"

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