NORTHRIIDGE EARTHQUAKE
Los Angeles, California
January 17, 1994

FIRE INVESTIGATIONS
NATIONAL FIRE PROTECTION ASSOCIATION

1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101 USA
Telephone: 1-617-984-7263 E-mail: investigations@nfpa.org
SUMMARY INVESTIGATION REPORT

Northridge Earthquake, California
January 17, 1994

Prepared by
Stephen N Foley
Senior Fire Service Specialist
National Fire Protection Association

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On January 17, 1994, a magnitude 6.8 earthquake occurred at 4:31 a.m. in Los Angeles. The ten plus seconds of ground shaking resulted in up to $20$ billion in damage. There were 57 fatalities, 19 that were attributed to heart attacks, and 9,158 people seriously injured. Comparing this to the Loma Prieta earthquake, there were 63 fatalities and more than 3,750 injuries. The earthquake’s epicenter was about one mile south-southwest of Northridge at a depth of about 12 miles according to the California Technological Seismological Laboratory.

The magnitude was not the key seismologic issue, but the unprecedented accelerations in horizontal and particularly vertical direction. Vertical accelerations greater than 2g (2 time’s gravity) were recorded and some engineers feel this may have caused the failure of parking and other structures. A similar report done by the NFPA for the Federal Emergency Management Agency (FEMA) after Loma Prieta (1989) shows that the magnitude was 7.1, but the vertical acceleration was not comparable to what occurred in Northridge.
INTRODUCTION

The National Fire Protection Association (NFPA) with the cooperation of the Los Angeles City, Los Angeles County, and Santa Monica Fire Departments, California State Fire Marshal’s Office, California Department of Forestry and Fire Protection and the Office of Emergency Services responded to this disaster as part of its on-going program to investigate technically significant incidents. It is not NFPA’s intention that this report pass judgment on, or fix liability for, the loss of life or property resulting from this incident. NFPA documented and analyzed this incident intending to determine the significant factors that resulted in the loss of life and property.

This report documents the impact of the earthquake, the response, and the other efforts that were undertaken in southern California. California is identified as the most seismically active area of the contiguous United States. Large earthquakes over the past two centuries have struck across the state. These include the Long Beach earthquake (1933), San Fernando (1971), Coalinga (1983), Whittier (1987), and Loma Prieta (1989). It is safe to say that the mitigation efforts after each of these previous incidents proved their effectiveness the morning of January 17, 1994.
Several decades without major earthquakes may have lulled Californians into a false sense of security. The recent increase in earthquakes in southern and northern California (Whittier-1987, Loma Prieta-1989, Upland-1990, Sierra Madre-1991, Humboldt-1992, Landers-1992) has produced great human and financial costs to both the state and federal government. It is a safe assumption that had the Northridge earthquake occurred five hours later, hundreds would have likely been trapped in collapsed department stores, office buildings, freeway collapse, and parking structures. The magnitude of the emergency response would have been significantly greater.
The damage to buildings was severe and spread over a significant area. Most of the damage to structures in the Northridge earthquake was caused by strong ground shaking: the distribution of damaged buildings was affected by spatial variations in the intensity of the shaking. At the Olive View Hospital ground motions were recorded in the parking lot. There was a peak acceleration of .89g and a peak velocity of 129cm/sec. There were also numerous landslides, rock slides, slope failures, liquefaction, lateral spreading, and differential ground settlement.

County and city building inspectors estimate that approximately 80 percent of the structures that were declared unusable after the earthquake were residential. In the City of Los Angeles alone, there were 34,500 damaged dwelling units, of which 32,500 were townhouses or condominiums; 2,000 single-family houses. Utilizing a tag system, red— for unsafe no entry permitted, yellow— limited entry— authorized personnel only, and green— for safe; inspectors tagged 2800 buildings red, and 11,000 yellow.

The apartment buildings that were especially hard hit were low-rise, multi-story, wood-frame structures typically two and three stories. These structures had a seismically weak (soft) first story. Many of these buildings were 30 to 40 years old, but some had been constructed in the last ten years. In many of these structures, the first floor was either a parking garage or was fully enclosed without adequate shear walls. An example of this is the Northridge Meadows Apartment Complex located at 9565 Reseda Boulevard. This 120-unit apartment complex collapsed crushing the first floor to within a two to three foot crawl space. Single-family houses that sustained the greatest damage were those not bolted to the foundation or with unbraced cripple walls above the foundation.

Experience in other U.S. earthquakes have shown that mobile homes suffer extensive damage. This was the case as well in Northridge. In Santa Clarita, 50 percent of the community’s mobile homes (approximately 1,500) were shaken off their pedestal foundations. In the process of falling off their foundations, the mobile homes severed gas lines and started fires. Approximately 100-150 mobile homes burned as a result. In total, damage occurred in 95 mobile home park communities.

Photo 1: The 2,800 buildings that couldn’t be entered were marked with red warning signs.

Photo 2: One of the 95 mobile home communities that were damaged or destroyed.
Commercial structures in some areas suffered extensive damage. Even some of the more modern buildings that were built to newer codes incurred substantial non-structural damage; older buildings were severely damaged and some even collapsed. There was damage to shopping centers which ranged from a nearly total collapse of a department store to large inventory losses. These large inventory losses were attributed to warehouse failure of shelving, displays, and sprinkler systems.

One of the major problems associated with damage in this type of structure was the release of asbestos. Asbestos clean up was time-consuming and kept some businesses from re-opening for two to four weeks. Industries in the most heavily damaged area were predominately light manufacturing and service-oriented enterprises such as high-technology, defense and aerospace firms, and the component manufacturers that support them.

Many facilities, including fire stations, suffered extensive damage to non-structural components which even forced vacating some of the facilities. Facilities that had been retrofitted to withstand earthquake forces experienced less damage. Vertical or horizontal holding tanks storing a variety of fluids were among those most frequently damaged at industrial sites in the San Fernando Valley.

Most damage to schools was non-structural, although some were damaged and deemed unsafe for occupancy. Three hundred of the approximately 800 sites in the Los Angeles Unified School District sustained damages and 22 structures were closed. Almost a quarter of a million students were out of school two weeks or longer. Portable classrooms also suffered extensive damage as a result of not being properly anchored to their foundations.

It is fair to say that if students had been present in schools at the time of the earthquake there would have been extensive injuries and perhaps deaths. These would have occurred from the failure of non-structural hazards including falling light fixtures, ceiling collapses, toppled cabinets and bookcases, hazardous material spills in chemical labs, and released asbestos.

Evacuation would have been compromised due to power outages, doors jammed, and corridors impassable due to fallen debris.

California State University, Northridge (CSUN) Campus had dramatic damage. Three buildings were damaged beyond repair out of the sixty major buildings on campus. Fifteen to twenty buildings required structural repair and upgrading to applicable codes. The Oviatt Library was architecturally and structurally damaged and is closed indefinitely pending repairs. The library is steel-framed with X-braced bays. Vertical forces which acted on the steel base plates created overturning movements in the braced bays. These were sufficient to completely fracture the 4-in. thick plates. These fractures appeared to start at the fillet welds that attached the columns to the base plates. An article appeared in the LA Times five weeks after the initial quake. This article outlined specific structural failures in steel buildings that had not been previously discovered. Because the steel skeleton is covered with fireproofing and architectural finish, and because none of the affected buildings collapsed or leaned appreciably, the damage was not apparent.

In addition, many buildings on the CSUN campus suffered extensive non-structural damage that necessitated the use of numerous new modular classrooms. A four-story science building suffered extensive damage due to a hazardous materials spill and a large fire. The damage delayed the start of the spring semester by three weeks.

Similar to CSUN, buildings on the University of California at Los Angeles (UCLA) campus were damaged and the Santa Monica College Science building was the site of a hazardous materials response due to the number of cadavers that were disturbed during the earthquake.

Of the 750 licensed health care facilities in the area, 90 percent had widespread non-structural damage. The most severe damage to health care facilities was in Santa Monica. St. John's Hospital suffered significant damage. Twenty facilities were red or yellow tagged because of significant structural or non-structural damage, eight were major hospital buildings. Penthouse
structures and roof mounted equipment such as piping, duct systems, and HVAC appliances suffered severe damage. Similarly, labs and other high-tech medical equipment were especially vulnerable to non-structural damage. Those listed as well as others severely damaged compromised the abilities to offer quality patient care. The logistics of patient care became critical during this period and many had to be quickly evacuated and/or transported to other medical centers.

Photo 3: Damage to the exterior walls of St. John’s Hospital in Santa Monica.
The collapse of, or extensive damage to, freeway structures and bridges caused massive traffic disruptions. Most of the 600-mile Los Angeles Freeway system survived the earthquake with minimal or repairable damage. One death and several injuries are attributable to the elevated freeway collapses. More people would have been injured had the earthquake occurred during peak commuting hours.

Electric service was lost throughout much of Los Angeles area after the earthquake. Approximately 2 million customers were without power on the morning of January 17. Damage to electric power equipment was concentrated in porcelain components in voltage classifications of 230 kV and 500 kV. At the Pardee Substation all eight of the older 230 kV live tank circuit breakers suffered damage. Additionally, ten two-legged tubular steel 220 kV transmission towers were leaning. The leg on one nearly fractured above the base plate. This was later attributed to the weld being not sufficient at the tubular section (5 ft sq 3/4 in. plate thickness). This is the first time that an earthquake caused the collapse of lattice-type transmission towers. A 66 kV tower collapsed because of differential movement and all six conductors snapped bringing down an additional four nearby towers. In addition to Los Angeles customers, 600,000 in nearby cities and 150,000 tied into the power grid lost power. However, by dusk 900,000 customers had power restored, with virtually all restored by January 26.

A considerable portion of the water supply to the L.A. Basin comes from Northern California and the Colorado River. A water tank in Valencia experienced roof damage, and buckling at its base. The tank lost 800,000 gallons after its piping ruptured. Four major pipelines that serve both the San Fernando and Santa Clarita Valleys were disrupted. These steel pipelines ranged in size from 54” to 120,” and breaks were repaired in two to ten days. Water service was not restored to many areas until late January or early February. There were over 1200 leaks in the San Fernando Valley, and 300 in the Santa Clarita Valley. Most pipes were broken by ground deformation.

The water treatment plants suffered minor damages and were repaired quickly. The Jensen Filtration Plant fared much better than in the 1971 San Fernando earthquake. However, the plant had to be taken out of service for a period because the influent conduit, an 85” diameter pipe ruptured.
The upper and lower San Fernando earthen dams which liquefied and nearly failed in 1971, and were replaced by the Los Angeles Dam experienced minor superficial cracking. Horizontal peak ground accelerations reached 0.42g on the abutment of the Los Angeles Dam. There were 2g measurements at the abutments of the Pacoima Dam. These caused extensive rock slides, opened a 2" wide gap between the dam and its thrust block on the southern abutment, and cracked the southern most block of the dam in several places. The Pacoima Dam is operated for flood control and the water level is seldom high.

The most significant failure in the gas transmission system was in a 22-inch steel pipe along Balboa Boulevard in Granada Hills which broke in two places. Approximately 1400 other breaks and leaks occurred in the gas piping system; 490 in distribution lines, 40 in transmission lines, and 850 in service connection lines. About 130,000 of the 150,000 natural gas outages were caused by customers turning off service unnecessarily. Restoration of customer service was very time consuming.

Photo 5: The natural gas pipe shown in this photograph broke in two places.

Post-earthquake telephone congestion and overload set in almost immediately. For example, telephone call attempts increased at one central station from 2,000/hour to 250,000/hour. Part of the problem was disruption of service caused by damage to buildings, transmission lines, or equipment malfunctions. Also a combination of water problems which caused flooding as well as electrical power outages contributed to communication system failures.
The activation and utilization of Comprehensive Emergency Management Plans (CEMP) by the Local Emergency Planning Committees (LEPC), provided for the successful response, mitigation, recovery, and reconstruction to the Northridge earthquake. The local governments and their agencies responded to the challenges presented to them.

The utilization of mutual aid was an important element in providing the resources to manage this incident. The California Mutual Aid System is founded on a concept of self-help and neighbor-assisting-neighbor. During the earthquake, several federal, state, and local government agencies provided resources in fire, law enforcement, medical, and public information.

Within the first hour of the earthquake, the State Operations Center (SOC) in Sacramento was activated. This agency’s responsibilities included coordinating emergency response, activating the mutual-aid system, maintaining situation status reports for the Governor, and coordinating the dissemination of public information. The Regional Emergency Operations Center was also activated within the first hour. The REOC is located at the Los Alamitos Armed Forces Reserve Base, which is approximately 50 miles southeast from the epicenter. The REOC remained operational on a 24-hour basis, and worked closely in supporting the local emergency planning committees. There were 600 individuals during the peak of operations assigned to this operation. This was the longest activation of the REOC.

Over 2,500 members of the National Guard provided support to assist in protecting public safety, distributing food and water, deploying tents and shelters to protect victims from the rains, and provided additional security to certain areas under the curfew. The Guard flew missions to assist with aerial reconnaissance and some medical and health missions.

Due to the extensive damage to the state and interstate highway infrastructure California Highway Patrol were used in coordination with California Department of Transportation to assist with traffic management. This also included scheduling additional passenger trains to relieve traffic congestion. The law enforcement community suffered a fatality when Los Angeles City Police Officer Clarence Dean was killed rushing to work in the pre-dawn hours. Officer Dean was a motor patrol officer and his motorcycle plunged nearly 25 feet off of the severed Antelope Valley Freeway (14) overpass.

The California Department of Forestry (CDF) provided staff in support of the overall operation. Approximately 600 CDF personnel were assigned to support OES in the application of the state’s newly established Standardized Emergency Management System, which is based on the principles of the Incident Command System (ICS). CDF personnel are trained on this system and assisted in implementing it along with OES personnel. CDF personnel staffed the following functions: planning and intelligence, logistics, operations, and administration/finance.

The Emergency Managers Mutual Aid (EMMA) Program is a cooperative effort with OES and city and county emergency managers. During EMMA’s operational period (1/17-3/14), 107 emergency managers provided support to local jurisdictions and OES. This mutual aid system was patterned after the Fire and Law Enforcement Master Mutual Aid Agreement. Managers gained valuable experience in coping with an earthquake, affected jurisdictions received needed assistance, and OES was able to facilitate more organized and coordinated response and recovery operations.

A specific example of this was the activation of the Water Tender Strike Teams. Due to the loss of water supply for fire fighting, OES put together six strike teams. These Tender Strike Teams, as described in the ICS system as 5 units of similar type, were comprised of fire mutual aid departments, private contractors, and the military. These strike teams were deployed at LA City fire stations and were automatically dispatched with law enforcement escorts, along with companies to incidents...
where the water supply was compromised. This concept worked extremely well and provided suppression forces with additional water supply for operations.

Photo 6: Due to the loss of water supply for fire fighting, the Office of Emergency Services put together six Water Tender Strike Teams like the Orange County team shown in this photograph.

Another example of OES resource management was the above-ground water main system. This 6-in. steel pipe is stored in regions throughout California and available for deployment throughout the state. Chief Don Anthony, Chief of Operations, Los Angeles City Fire Department (See LA City Command Organizational Chart) requested this resource through OES early into the incident and it was made available, though not used. Los Angeles City Fire Department reserve pumpers were deployed at key intersections and water mains to pump water from undamaged mains through the system. This enabled the fire department to maintain parts of the system for fire fighting capabilities. This plan also worked well due to the interaction with the fire prevention bureau and water and power personnel who identified key mains, and pumping locations to manage this portion of the operation.

After the Loma Prieta earthquake (1989) the state established eight urban search and rescue task forces. The necessary funds to do this were matched by the Federal Emergency Management Agency (FEMA) and is also in use in other regions of the country. There are currently 25 teams across the country that are able to respond to these types of emergencies. During the earthquake the eight teams from the state were activated and responded. Two additional teams from Phoenix, Arizona and Puget Sound were activated and deployed to March Air Force Base. These teams were not utilized during the operation. Additionally the teams from Montgomery County, Maryland, Fairfax County, Virginia Fire & Rescue, and Metro-Dade, Florida were activated but were unable to deploy due to the severe winter weather conditions on the east coast. Members of these teams participated in the development of NFPA 1470, Standard on Search and Rescue Training for Structural Collapse Incidents, 1994 edition. This standard was utilized by team members during the course of operations. Teams were utilized both in emergency search and rescue operations, but also assisted in the recovery phase of the incident. Team members assisted in the recovery of personal belongings, both in Santa Monica and in Los Angeles. This additional customer service proved to be an excellent public relations tool, and formed additional respect from the affected victims and the fire service.
The earthquake damaged more than 15,000 structures, leaving thousands of people homeless in the Simi, San Fernando, and Santa Clarita valleys and in the western sections of Los Angeles and Santa Monica. The uncertainty of the stability of damaged structures required inspections of more than 110,000 structures before their safety could be determined. This is another area where mutual aid was utilized. Teams of building inspectors from across the state were used to inspect structures. Inspectors from the California State Fire Marshal’s Office inspected state owned structures.

The 8,500 Salvation Army volunteers, and the 14,000 American Red Cross volunteers responded to set up shelters within hours after the quake. Eventually they set up and staffed over 45 shelters to assist those who were displaced. A number of residents, fearful of the structural integrity of their residences, set up tents and shelters on their property or in parks. Specific park locations were identified by local jurisdictions. A Housing Task Force comprised of local, state, federal, military, Red Cross, and Salvation Army officials directed the sheltering operation. This task force was the first attempt in California to create a coordinated response to the housing needs of disaster victims. Military support provided the personnel to set up tents and other support services. There were approximately 12,000 persons either camping in parks or in shelters. The last of the temporary shelters was closed February 21, 1994, five weeks after the quake.

Photo 7: Approximately 14,000 American Red Cross volunteers organized shelters within hours of the earthquake.

There were 160 plus feeding locations in Ventura and Los Angeles counties. At the end of the third week after the earthquake, 1.3 million meals had been served. These were in addition to the thousands of meals served to emergency responders and other support personnel.

As stated earlier in this report, there was significant damage to both the water distribution and purification systems. This necessitated the provision of canned, bottled, and bulk water supplies for domestic use and consumption. Numerous private companies, including Coca-Cola, Wal-Mart, Sparkletts, Arrowhead, and the Anheuser-Busch and Miller breweries provided more than 4 million gallons of containerized water. The U.S. Army Corps of Engineers with assistance from the California Conservation Corp were delivering over 1 million gallons of water per day at 31 different sites. This system was established within days by the Corps, and serviced sites that had no access to the containerized water.
Three days after the earthquake, the first of 11 Disaster Application Centers (DAC) were opened. Eventually 21 fixed DACs were opened and several mobile DACs conducted over 100 visits to assist individuals and others in remote locations. These mobile offices also visited and assisted emergency response personnel who had been affected by the quake. As of March 31, 1994, over 497,000 applications for assistance had been received. As a comparison, in the first ten days after the earthquake the number of disaster assistance applications surpassed those that were received in the first six months following Hurricane Andrew.

The Housing Task Force, established by the Governor’s Office of Emergency Services, coordinated the response for housing applications with the U.S. Department of Housing and Urban Development, the California Department of Housing and Community Development, and local agencies. Approximately 19,000 HUD Section 8 housing certificates were provided by FEMA to facilitate relocation of the homeless. More than 497,00 have registered with FEMA for disaster assistance. Of that number 350,000 have requested housing assistance. In a number of communities the quake exacerbated the tight housing market reducing the number of available affordable housing units.

The Governor authorized HUD to waive all permitting fees for the reinstallation of mobile homes and accessory structures. FEMA, under the Minimum Housing Repair Program, authorized the repair and placement of mobile homes on seismically braced support systems. This program was used to expedite re-occupancy of existing mobile homes and decrease the vulnerability of these units in future earthquakes. The Governor also ordered the extension of tax deadlines to assist those affected by the quake.

FEMA has committed to providing 90 percent of the cost of repair of damaged public structures, with the state providing the 10 percent not covered by FEMA. OES is administering this program in-state for FEMA. Immediately after the quake, FEMA provided a $200 million advance to counties, cities and school districts to expedite repair work. OES and FEMA entered into a Memorandum of Understanding (MOU) for expe-
diting the Public Assistance Program. This memo-
randum provides funding for engineering work, repair,
and mitigation. Local governments were encouraged
to develop and implement specific repair ordinances
which require mitigation measures to accompany spe-
cific repairs. Specific Staff from the OES Disaster As-
sistance Branch (DAB) were augmented with an addi-
tional 160 temporary employees to assist with the
permitting process.

OES also activated their Hazard Mitigation Branch
within the first hours of the earthquake. Meetings were
held with the California Seismic Safety Commission
and the California Department of Conservation, Divi-
sion of Mines and Geology. The meetings objectives
were to develop strategies and priorities for projects
to be funded through a mitigation grant. The initial
grants would prioritize projects that would have the
largest impact on the affected population. They also
sponsored workshops for contractors specifically deal-
ing with earthquake mitigation and repair.
CONCLUSIONS

At this point in time emergency relief efforts have been concluded, but the recovery effort is continuing. This post-emergency environment can best be described as one of continuing needs and opportunities. At all levels of government, the commitment continues to provide those who need assistance to provide them with essential services. It will be extremely important to maintain that level of commitment for the long-term duration of the recovery process.

Much was learned from past earthquake disasters. There is an opportunity to apply those lessons in this disaster. As outlined earlier in this report, if this disaster had occurred later in the day, or in a different region of the country, the life loss and devastation could have been significantly greater.

The utilization of an incident management system proved its worth during this incident. The Southern California area, having experienced large wildland fires, floods, civil disturbances, and other disasters has effectively used incident management as a tool. This system has also been used to successfully manage other large-scale operations such as the Summer Olympics. The key components are the same in dealing with interagency roles and responsibilities, resource allocation, organizational structure, and effective span of control.

Other areas of the country and the world would learn a great deal from this area of the country in implementing an effective incident management system. The people at all levels are trained in the system and use it. The coordination and mutual aid support between both public and private organizations was the key to a well managed incident.

During the summer of 1994, the White House released a report assessing the federal response to the January 17 earthquake. The report stated that the government had allocated $11.9 billion for earthquake aid, the largest amount of assistance ever provided for a single disaster. Of the $225 million requested, $200 million would go to Los Angeles and $25 million to Santa Monica. Other disaster assistance coffers would be reduced by a like amount. Los Angeles City Mayor Richard Riordan said the money would be used to put up approximately 15,000 housing units in Los Angeles that otherwise could not get financing.

Santa Monica Mayor Judy Abdo said her city lost 5 percent of its housing stock in the earthquake and most of the damaged units were for low-income families. She said the money would be used to repair “ghost buildings”, very large buildings which were heavily damaged.”