Landers and Big Bear Earthquakes of June 28 & 29, 1992

Double Event Shakes Southern California

Southern California was jolted by a double earthquake on Sunday, June 28, 1992. It began at 4:58 am with a magnitude 7.4 earthquake centered in the Landers area north of Joshua Tree (34.217°N, 116.433°W). This was the largest earthquake to occur in California since 1952. Three hours later, at 8:04 am, a magnitude 6.5 earthquake occurred on a separate fault near Big Bear Lake (34.167°N, 116.817°W). The second epicenter was less than 45 km from the first. Numerous aftershocks followed, several in the M4.4 to M5.3 range.

On July 1, 1992, Governor Wilson requested that the President declare the Counties of San Bernardino and Riverside major disaster areas. President Bush signed the declaration on July 2, allowing individuals and public agencies to apply for federal disaster assistance.

As of July 3, 1992, the California Office of Emergency Services reported 1 death, 25 serious injuries, and 372 other injuries as a result of the series of earthquakes. In San Bernardino County 77 homes were destroyed and 4,369 were damaged, with losses estimated at $47.5 million. Twenty-seven businesses suffered major damage or destruction, and an additional 139 suffered lesser amounts of damage, resulting in losses estimated at $17 million. Public sector damage, including water and sewer damage and damage to public buildings was estimated at $26.6 million. Damage estimates for Riverside County, where 24 residences and 7 businesses were damaged, were slightly less than $1 million.

What these damage figures fail to show is the good performance of buildings designed and built to the requirements of modern codes. Damage to unreinforced masonry buildings and unanchored modular and mobile homes was as expected. The lack of widespread damage to post-1960’s structures is especially encouraging given the magnitude and duration of the event.

EERI did not appoint a special Reconnaissance Team to investigate these events. Many EERI members inspected the earthquake area and submitted preliminary reports to EERI that have been incorporated into the summary report that follows.

The publication and distribution of this report was funded by NSF Grant #CES-8822367.

Landers Strong Motion Data Provides Records From Largest Magnitude Yet Recorded in US

The California Strong Motion Instrumentation Program (CSMIP) of the Division of Mines and Geology has recovered over 250 records from the Landers and Big Bear earthquakes, collected at over 150 stations. The Landers earthquake is now the largest event with an extensive set of strong motion recordings. The map in Figure A-1 shows the locations of the two epicenters and of selected CSMIP stations. Some highlights of these records include:

- **Long Duration.** The most unusual aspect of the records from the Landers earthquake, compared to most records obtained in California, is their long duration. The record from the Joshua Tree station for the Landers event (0.29 g peak acceleration, about 30 sec duration) can be compared to that recorded in the M6.1 earthquake of April 22, 1992 (0.3 g peak acceleration, about 5 sec duration). The epicentral distance for the two events is comparable (20 and 14 km, respectively). While durations are long for this event, peak accelerations are not particularly high for an event of this magnitude.

- **Amplitudes in Direction of Rupture.** Stations to the north and east have relatively high peak acceleration values, which may be due to the propagation of the rupture northward from the epicenter near Landers.

- **Big Bear Lake - Civic Center Grounds.** A peak acceleration of 0.55 g during the Big Bear event

continued on page 2
Earthquake, centered about 69 km distant.

U.S. Geological Survey National Strong-Motion Program (NSMP) instrumentation at more than 175 stations was triggered by the two earthquakes, including those at three well-instrumented structures in the San Bernardino area. Peak accelerations were recorded at Indio, 0.29 g, during the Landers earthquake, and at Forest Falls, 0.30 g, during the Big Bear earthquake.

An accelerometer in the Lucerne Valley area adjacent to the Camp Rock-Emerson Fault near the north end of the rupture recorded the Landers earthquake. Preliminary peak acceleration readings from the accelerogram, maintained by the Southern California Edison Company, were in the range of 0.8 g to 1.2 g. The duration of strong motion was in excess of 20 seconds.

(Information included in this report provided by CDMG CSMIP, USGS NSMP, and an EQE International investigation team. EQE investigators include Ray Kincaid, Mark Pieper, Jack Wiggins, Ron Eguchi, Tom Roche, Charles Scawthorn, Doug Honegger, Hope Seligson, Craig Van Anne, Carl Nemel, and Mike Salmon.)
Landers & Big Bear Earthquake Characteristics

(This report was submitted by Paul Somerville, Woodward-Clyde Consultants, with the following note: "This article summarizes the available information about these two events collected at the time of this writing. This information was gathered from a large number of sources, in addition to the authors, including press releases and personal interviews with geologists, seismologists, and engineers from the U.S. Geological Survey, California Division of Mines and Geology, California Institute of Technology, and other organizations. Current ongoing investigations by many of these individuals will undoubtedly produce refined and more specific data and information regarding the Landers and Big Bear earthquakes than presented here.")

Geologic Setting

The Landers earthquake occurred along a series of north- to northwest-trending faults located in the western portion of California's Mojave Desert Physiographic Province. Primary ground rupture initiated along the Johnson Valley fault and propagated to the north along the Homestead Valley, Emerson, and Camp Rock faults. These faults are part of a series of northwest-trending faults located east of the San Andreas fault and between the east-west-trending Garlock fault on the north and the east-west-trending Pinto Mountain fault on the south.

The Big Bear earthquake occurred beneath the steep forested terrain of the San Bernardino Mountains. No primary ground rupture has been reported in this event. However, aftershock data and focal mechanism solutions are consistent with predominantly strike-slip faulting on a northeast-trending rupture plane.

Earthquake Sequence

The region of the Landers earthquake has a history of seismic activity. Earthquakes in the region have included the 1946 M6.5 Desert Hot Springs earthquake; the 1975 M5.2 Galway Lake earthquake; the 1979 M4.9 Homestead Valley-Johnson Valley earthquake, which also resulted in ground rupture; and the 1986 M6.1 Palm Springs earthquake. Since 1986, this region of southern California
has seen an increased amount of seismic activity relative to the preceding historical record.

Most recently, a precursor to the Landers event was the M6.1 Joshua Tree earthquake that occurred on April 22, 1992 (see EERI Newsletter, May 1992). The Joshua Tree earthquake ruptured northward from its epicenter east of Desert Hot Springs on the southern extension of the Johnson Valley fault, but was apparently stopped by the east-west Pinto Mountain fault, which offsets the northern Johnson Valley fault about 2 km to the west.

The Big Bear earthquake was not preceded by any precursor events similar to those preceding the Landers event.

The Landers earthquake had an unusually shallow preliminary focal depth of 1-3 km. The earthquake began on the north side of the Pinto Mountain fault, resuming the northward rupture of the Johnson Valley fault but with a 2 km westerly offset relative to the Joshua Tree rupture. The Landers rupture propagated northward on the Johnson Valley fault, but then began a series of easterly steps across to the Homestead Valley, Emerson, and Camp Rock faults, with the strike of each successive fault bending further to the west, as shown on Figure B-1 (K. Sieh, Caltech).

Aftershocks closely follow the trend of the surface faulting, as seen on Figure B-2 (E. Hauksson, Caltech, and L. Jones, USGS). The epicenters of the aftershocks form a continuous north- to northwest-trending line extending from the San Andreas fault on the south to the Camp Rock fault on the north.

The Big Bear earthquake occurred at a focal depth of about 10 km and ruptured northeastward from near Yucaipa toward the Camp Rock and Emerson faults. The rupture zones of the two earthquakes form a triangle about 70 km on a side, with the Landers rupture on the right side, the Big Bear rupture forming part of the left side, and two strands of the San Andreas fault (the Mission Creek and Banning faults) on the base (Figure B-2).

The aftershocks of the Landers earthquake have extended south of the Pinto Mountain fault as far as the San Andreas fault. The aftershocks of the Big Bear earthquake have extended southwest as far as the San Andreas fault, where a magnitude 4.4 earthquake occurred near Yucaipa. This earthquake's focal mechanism is consistent with strike-slip faulting on the San Andreas fault.

Immediately following the Landers earthquake, there was a substantial increase in the rate of occurrence of small earthquakes in the Long Valley Caldera at Mammoth Lakes and in other regions on the east side of the Sierra Nevada, and at Lassen Peak and Mt. Shasta in the Cascade Range further north. The western Mojave Desert has also experienced an increase in seismic activity, including an M5.1 earthquake on July 11, 1992, near the junction of the Garlock and Sierra Nevada faults.

### Surface Faulting in the Landers Earthquake

The total length of surface faulting extended approximately 70 km, from west of Landers to the Rodman Mountains. Minor faulting was also noted by the CDMG and USGS south of the east-west Pinto Mountain fault. Sympathetic faulting has also been reported on the Lenwood, Calico, Pisgah, Old Woman Springs, and Superstition Hills faults. In addition, 18 mm of creep was triggered on the San Andreas fault in the Durmid-Mecca Hills area.

Primary ground rupture occurred along a nearly continuous series of right-stepping, northwest-trending en echelon faults, in most places connected by a north- to northeast-trending fault (Riedel shears).

The main disturbance zone of the
ground rupture was approximately 3 to 40 m across. Even where the fault trace was narrow without significant steps, subsidiary faulting and cracking appeared in several places extending about 7 to 15 m from either side of the fault. Primary ground rupture was right-lateral strike-slip with an average of approximately 3 meters of horizontal movement along most of the ruptured fault length, and with a maximum of about 6 to 7 m of strike-slip movement on the Emerson fault across a road near Bessemer Mine Road, as shown on Figure 8-3. Oblique and vertical displacement of about 1 m occurred mainly where the fault bends.

Across the area west of Landers, the fault cut across a broad alluvium plain. North of Landers, fault rupture largely coincided with mountain fronts, older fault scarps in alluvium, and other indicators of geologically recent fault activity. About 80 percent of the surface rupture generally coincided with previously mapped fault traces. The remaining 20 percent that was previously unmapped was mainly in alluvial filled valleys.

Rupture Model of the Landers Earthquake

From the analysis of both regional and worldwide seismograms, it appears that large bursts of seismic energy were released at two locations: one in the epicentral region near Landers, and the other (and largest) 40 km northwest of the epicenter on the Emerson Fault, coinciding with the largest surface offset. These two rupture events are separated in time in worldwide seismograms. The second event had a seismic moment about three times as large as the first; the total seismic moment was about $1 \times 10^{27}$ dyne-cm. The change in strike of the fault rupture from northerly in the first event to about 30 degrees west of north for the second event is also apparent in the worldwide seismograms.

The distribution of slip along the fault inferred by waveform inversion of seismograms from the TERRAscope network is shown in Figure B-4 (H. Kanamori, Caltech). It is practically identical to the measured surface slip. It shows large slip beginning about 3 km

**Figure B-3** Road near Bessemer Mine Road shows an offset of 5.5 m caused by fault slip. (T. Freeman, Woodward-Clyde Consultants)

**Figure B-4** Distribution of slip along the rupture zone of the Landers earthquake inferred by waveform inversion from the TERRAscope array. (H. Kanamori, Caltech)
north of the epicenter on the Landers fault and dying out abruptly about 18 km north of the epicenter. Large slip resumes on the Homestead Valley fault about 27 km north of the epicenter, and continues on the Emerson and Camp Rock faults, extending to about 60 km north of the epicenter. These two regions of large slip correspond closely in time separation and strength with the two pulses seen in the worldwide seismograms.

**Strong Ground Motions**

Peak accelerations from subsets of stations from the CSMIP, USGS, and TERRAscope networks are shown as a function of closest distance to the surface rupture in Figure B-5. The peak acceleration attenuates smoothly to a value of about 0.1 g at about 50 km, but then has a more gradual decay from 50 to 150 km before rapidly attenuating again (the most distant values are from digital TERRAscope recordings). The shape of this attenuation function is like the one observed in the 1989 Loma Prieta earthquake in the San Francisco Bay area. The slow decrease in the ground motions between 50 and 150 km may be due to the effect of waves reflected from the base of the crust. Given the similarity in the shapes of the attenuation trends of the Landers and Loma Prieta earthquakes, more damage might have been expected at large distances from the epicenter in the heavily populated regions of southern California, as occurred in San Francisco and Oakland during the Loma Prieta earthquake. However, the Landers and Big Bear earthquakes did not rupture toward the population centers, as happened in the Loma Prieta earthquake, but instead ruptured toward the desert. Also, soft soils (like those on the edges of San Francisco Bay) that amplified relatively small rock motions of the Loma Prieta earthquake are less prevalent in southern California.

**Soil Failure**

Apart from ground cracks caused by surface fault ruptures, instances of significant soil failure were almost non-existent. The only significant reported earth structure damage has been limited to causeways constructed on Big Bear Lake where lateral spreading was observed.

The only known instances of soil liquefaction occurred near Converse Flat and the east Baldwin Lake area near the Big Bear epicenter. The incidence of rock slides was lower than expected, especially near the Landers earthquake, suggesting that the near-fault ground motions may not have been very severe in most locations. Surface faulting or other forms of ground failure caused significant amounts of structural damage.

*Figure B-5 Peak horizontal acceleration shown as a function of closest distance to the surface rupture. (P. Somerville and N. Smith, Woodward-Clyde Consultants)*

*Individuals involved in compiling information for this article include Paul Somerville, Yoshi Moriwaki, Tom Freeman, Dave Schug, and O.S. Ghuman of Woodward-Clyde Consultants; and Gary Rasmussen of Gary S. Rasmussen & Associates. Sandy Gwinn provided valuable administrative support.*
Building Response - Some Bad, Some Good, No Big Surprises

The areas affected by the large magnitude, relatively long duration Landers earthquake and the immediately following Big Bear earthquake are lightly populated. The extensive surface rupture and related ground displacements caused damage to structures astride or adjacent to the disruption. Ground shaking caused widespread nonstructural and contents damage. Most of the structural damage that occurred could be attributed to known flaws: insufficient or nonexistent anchors and connections, unreinforced or inadequately reinforced masonry. Buildings designed and built according to modern codes performed well.

Commercial Structures

Almost no commercial structures are located in the sparsely populated Landers region. The closest significant commercial buildings were located in the towns of Yucca Valley and Joshua Tree. Newer buildings of wood-frame and stucco construction generally performed well with damage limited to cosmetic cracking and disruption to internal contents. However, several larger structures with concrete masonry unit (CMU) exterior walls and panelized wood roofs were damaged, including a building supply store approximately 5 miles due south of the fault rupture, where minor spalling of the grouted cells supporting the interior glu-lam beams and cracks of the roof membrane were observed.

Similar damage to exterior CMU walls was noted at an adjacent supermarket which was of similar vintage and construction. Compressional cracking along the outside edge of the sidewalk in front of the store and separation of the asphalt parking lot from the rear of the store suggest that the entire market and adjoining structures may have shifted to the south. The market is approximately 1 km due east of a southerly extension of the mainshock rupture zone.

At a department store located approximately 1/2 mile east of the supermarket, one bay of the roof collapsed due to the steel deck roof pulling away from the west wall of the store (Figure C-1).

The damaged bowling alley in Yucca Valley which served as a backdrop to many media reports from the area is a steel frame structure with tapered roof girders enclosed by CMU walls on the west and north sides, a lobby along the front and a stud wall along the east side. During the earthquake, the stud wall pulled away from the building and fell on the adjacent vacant lot, apparently due to inadequate roof-to-wall connections. Damage to the building is estimated at $1.2 million.

In Joshua Tree, the most severely damaged modern structure was a convenience store of single-story CMU construction with a wood frame roof. During the earthquakes, the west wall pulled away from the rest of the building and leaned against the adjacent retaining wall. No positive roof-to-wall connections were observed.

As expected, unreinforced masonry (URM) structures performed very poorly. Several URM buildings in Joshua Tree that were previously damaged during the April 22, 1992 earthquake suffered further serious damage.

Other structures in the Landers epicentral area include churches, schools, and small warehouses which generally appear to have performed well. Observed damage was limited to nonstructural items and architectural finishes.
In the mountainous Big Bear area, the vast majority of commercial structures are one and two-story structures which are wood-frame, masonry, or a combination of the two. Most significant structural damage occurred to URM structures. Typical URM damage included out-of-plane failure of URM walls and parapet failures.

A 1940's two-story, concrete shear wall structure was severely damaged. The front of the building was bowing outward slightly, although no wall cracking was evident from the outside. Public works officials had roped off the building and indicated that the floor and roof separated from the wall by up to six inches.

Residential Structures

The earthquake inflicted structural damage to many homes throughout the area. In the town of Landers alone, 150 structures were declared uninhabitable.

Many of the structures in the Landers epicentral area are single-story wood frame single family residences. Several of these were damaged due to surface faults and related ground movements (Figure C-2). At least two homes were left atop pressure ridges, another experienced surface rupture directly beneath the foundation of the garage and residence. Buildings on lots directly adjacent to large offsets showed significant variation in damage: near an eight foot offset, one home was seriously damaged, another showed no significant structural damage. None of these buildings suffered complete collapse.

Large numbers of mobile homes, which unfortunately continue to be installed without lateral restraints, were knocked off their supports, causing floor and wall damage and devastation within. For example, only 10 of 110 mobile homes at the Yucca Valley Country Club Estates were reported intact. Over 400 mobile homes in Yucca Valley alone were damaged. Similar statistics were reported in the neighboring communities.

According to one construction firm, the average cost for realignment of double wide mobile homes is about $17,000. Included in this cost are all structural, piping, and plumbing repairs as well as new connections and support system for resisting lateral loads.

In the Big Bear area, there were several notable failures related to cripple wall foundations in relatively new houses. In several instances failure was due to improper nailing of the plywood. In a large two-story house with a cripple wall failure, calculations showed the failed plywood shear walls to be severely overloaded, even though they were sufficient to meet the requirements of the single-family dwelling code. One building, lacking adequate connections to concrete piers, slid about four and a half feet down a slope impacting a structure below.

Roof damage from collapsed masonry or stone chimneys was common. Interior chimneys confined by roof and ceiling framing appear to have performed better than exposed chimneys. Some of the exposed chimneys crumbled to the ground, although the majority were observed to fail near the roof line. Of 25 damaged masonry chimneys looked at closely by the San Bernardino County Dept. of Building and Safety, 24 were improperly constructed. Among the flaws noted were absence of reinforcing steel, discontinuous reinforcing, poor grouting, and inadequate ties to the wood framing (Figure C-3).

Schools

Despite the long duration and strong ground shaking, schools suffered no structural damage. There was some non-structural damage, generally limited to acoustical ceilings and interior contents. For example, the newly constructed Landers Elementary School building is located 1/2 mile east of the southern end of the fault rupture. Although some non-structural damage was observed, this modern steel frame building...
Hospitals

There was no structural damage reported at any hospital as of July 7, except for some displacement of a precast concrete balcony facade at the Eisenhower Medical Center in Rancho Mirage. Nonstructural damage included a broken water line in the kitchen at the JFK Hospital in Indio. An elevator at Desert Hospital in Palm Springs shut down due to damage in the shaft. Counter weights at five of eight elevators came out of their tracks at Loma Linda University Medical Center and seismic expansion joints were damaged. Two elevators were disabled due to counterweights at St. Bernardino Medical Center. Superficial cracking of interior drywall was widely reported.

Nonstructural Damage

In the Landers and Big Bear areas significant damage and disruption to building contents occurred during the violent shaking. Of particular interest was nonstructural damage to a supermarket in Yucca Valley. According to the store manager, this grocery store was architecturally remodeled within the last couple of years. Ceiling hung displays over the checkout lines failed, apparently due to springs nuts twisting and slipping free from the end of the supporting steel channel member. Heavily loaded display cases overturned, blocking egress routes. Fortunately, the store was unoccupied at the time except for a few individuals in the bakery department.

Fluorescent strip lights attached to the underside of the dropped ceiling at a nearby building supply store broke free from the ceiling and crashed to the floor. It appeared that required safety splay wires attaching the light fixtures to the roof were not installed.

Similar nonstructural damage was observed throughout the Big Bear area. Damage to dropped ceilings was widespread. In several instances, fluorescent light fixtures were observed to be missing code required safety wires.

Nonstructural damage to building contents occurred throughout much of the Los Angeles metropolitan area as well. Bookshelves and file cabinets overturned over 100 miles from the epicenter of the Landers event.

Fire Following the Earthquakes

Two residential fires occurred in Landers following the 4:58 tremor. Both structures burned down completely. The fires were probably caused by gas leaks from overturned water heaters and/or electrical arcing. In Yucca Valley, two mobile homes fell off their supports and caught fire. One unit burned down completely. The San Bernardino County Fire Department had sufficient water supply in spite of numerous water pipe breaks.

According to the Big Bear City fire department, there were a total of eight structure fires in the Big Bear area, seven of which were residential. Although the majority of the fires were probably related to gas leaks caused by structural or appliance damage, the potential for fire was reduced because gas valves were shut off in many vacation homes.

In the town of Fawnskin, the emergency door to the fire station malfunctioned after the Big Bear earthquake. The trucks had been moved outside the station after the Landers quake, and thus were not trapped.

Additional fire fighting units were requested from outlying areas immediately following the earthquake, but were of limited help due to difficult mountainous access and road damage around the Big Bear area. In general, an adequate water supply was available in Big Bear.

(Information summarized in this report was submitted by Ray Kincaid for the EQE International team of investigators; Jeffrey A. Johnson, CSSC; Chris Poland, Degenkolb Associates; and David Breiholz, SEAOSC.)
Lifelines: Surface Faulting Disruptive in Epicentral Regions

With the exception of water systems, lifelines throughout the epicentral regions performed well. No significant damage to water and gas systems or highways was reported outside of the epicentral regions.

**Water Systems**

Water distribution systems suffered damage to pipelines and storage tanks in the Landers epicentral area, where local groundwater wells and storage tanks supply all the water. Water customers were without water for several hours to two weeks. Hundreds of water line breaks were reported in the Landers area. Much of the pipeline damage occurred in the fault zone, where the pipes were not able to survive the large displacements.

At least six water tanks were damaged, ranging in size from 42,000 gallons (160,000 liters) to 417,000 gallons (1.6 megaliters). Four damaged tanks were removed from service. Damage included bulging at the base of the tank (elephants foot), shell and roof damage, shell splitting at access hatches, and severed piping. There was no reported damage to water wells or booster pumping plants other than loss of power supply and ground subsidence adjacent to wells.

Damage to water systems was less severe in the Big Bear area. According to the City of Big Bear Lake Public Works Director, there were approximately 50 water pipe repairs made over a period of two days. Water storage tanks appeared to be undamaged.

Wastewater disposal in the Yucca Valley area is handled by private individual sewage disposal facilities. In the Big Bear Lake area a regional waste water agency collects sewage from the several communities, treats the water and discharges the treated water to Lucerne Valley for irrigation. Some damage occurred within the secondary treatment plant, however, with adequate storage, the biological treatment process was maintained and there was no loss in operation of the system. There was no operational damage to the collection and discharge lines.

Water pipe breaks reportedly occurred in buildings as far away as Westminster, Santa Ana, and San Diego.

**Electric Power System**

The major electric power agency in the Landers area experienced loss of service to 550,000 customers due to localized damage within the distribution system. Most of the service was restored to the customers by late the same night of the earthquakes. There was no operational damage to their high voltage system.

The high voltage power transmission system performed well. The positive performance can be attributed to the distance between the fault trace and historically vulnerable switchyards. Significant damage was limited to severe deformation of a high voltage transmission tower located astride the north end of the Camp Rock-Emerson surface fault rupture (Figure D-1). The fault passed directly between the legs of the bolted steel frame 220kV tower, moving two of the legs approximately 9 feet (3 meters). This resulted in substantial deformation of the steel tower and failure of several braces. No damage was sustained by the lines or ceramic insulators and the tower continued to provide adequate support. The lines were later disconnected from the electrical grid as a precaution during repairs. The fault also passed near two 500kV towers resulting in slight deformation of several tower braces, caused by several inches of relative displacement of the tower legs.

**Highways, Bridges, and Other Transportation Lifelines**

Highways were generally open throughout the epicentral region, with some exceptions. The surface expression of the faulting in the vicinity of Yucca Valley and Landers had a significant effect on area roadways. In this area the horizontal displacement ranged from 5 to 9.5 feet (1.5 to 3.0 meters) wide. State Highway No. 247 (Old Woman Springs Road) was disrupted in ten locations. Traffic was not fully restored until eight days later. Other county roads in the area, mostly gravel
Gas Systems

There was no damage to two high pressure gas transmission lines passing through the area, one 6-inch (152 mm) line south of the primary rupture zone and the other a 30-inch (760 mm) line north of the primary rupture zone. There was some nonstructural damage to a compressor station on the 30-inch (760 mm) line.

The cities of Yucca Valley and Joshua Tree have an underground natural gas distribution system. No significant damage to the underground gas system was observed.

Homes in the town of Landers are heated using propane gas from above ground tanks. Homes are typically served by small unanchored propane tanks. Some of these tanks slid far enough to fall off their concrete pads and rupture the attached piping. Unbraced hot water tanks toppled breaking their propane line connections in some cases. Fires resulted in several instances. Horizontal propane tanks at the Landers Elementary School rotated approximately 18 inches about their central axis. Flexible piping between the tanks and rigid underground piping prevented damage.

In the town of Big Bear, the natural gas system did not suffer any breaks in its main lines, although many end-user gas connections were broken due to shifting of houses off of their foundations. Some areas around Big Bear rely on propane tanks for fuel. Damage to unanchored tanks was similar to that in the Landers area.

(Compiled from reports submitted by CALTRANS, LeVal Lund for ASCE TCLEE, and EQE International.)
On June 29, 1992, a M5.6 earthquake struck near the Nevada-California border, 12 miles east of Lathrup Wells and 22 miles SE of Yucca Mountain. Focal depth was estimated as 12 km. The event may be associated with the Rock Valley Fault system. The site is just off of the southern border of the Nevada Test Site. Damage to a Dept. of Energy unreinforced masonry office building included cracks in the outside walls, damage to interior steel frame doors, and broken glass. The building is about six miles from a proposed underground radioactive waste site. The site had been considered relatively free of seismic activity over the past 10,000 years.

The initial earthquakes occurred early in the morning when most area residents were in their homes. Many residential structures shifted off their foundations. Due to the time of day, there was minimal exposure to the commercial buildings that suffered partial structural collapse. There was one fatality attributed directly to the earthquake, 21 persons were hospitalized, and 328 were treated at local hospitals and health care centers immediately after the earthquakes.

The lone fatality was due to the collapse of a residential masonry chimney on a 3-year old child who was sleeping in the living room. Many of those hospitalized complained of cardiac symptoms. The remaining cases ranged from moderate to minor. These cases were released after initial emergency room treatment with some requiring follow-up treatment.

Table 1 provides a breakdown, by type, of the 146 injuries treated at two of the local hospitals immediately after the earthquake. As in other recent California earthquakes such as Coalinga and Loma Prieta, the majority of hospital treated injuries were lacerations and abrasions of the arms and legs. Unspecified arm and leg injuries constituted the next largest category. This particular injury distribution is likely the result of falls and contact with building contents. The age distribution of the injuries reflects what is believed to be the overall age distribution of the surrounding region.

Table 1 describes only those injuries treated after the first shocks. A smaller number of injuries occurred after the subsequent aftershocks. These injuries are currently being documented. Because knowing the circumstances surrounding earthquake injuries is essential in developing realistic earthquake casualty estimation models, preparedness programs, and health service response plans, follow-up interviews and in-depth physical setting analyses are being conducted to document the cause of each injury. Information is being collected on building type, occupant actions, physical setting performance, and other contributing risk factors.

The lone fatality was due to the collapse of a residential masonry chimney on a 3-year old child who was sleeping in the living room. Many of those hospitalized complained of cardiac symptoms. The remaining cases ranged from moderate to minor. These cases were released after initial emergency room treatment with some requiring follow-up treatment.

**TABLE 1**

<table>
<thead>
<tr>
<th>Type of Injury</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lacerations, abrasions</td>
<td>55</td>
<td>38</td>
</tr>
<tr>
<td>Other arm &amp; leg injuries</td>
<td>35</td>
<td>24</td>
</tr>
<tr>
<td>Cardiac symptoms</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Fractures</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Sprains</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Head injuries</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Back injuries</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Bruises, contusions</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Anxiety reactions</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Eye injuries</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Burns</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>146</td>
<td>99*</td>
</tr>
</tbody>
</table>

*(Due to rounding)*

(This report provided by Michael E. Durkin, with the following acknowledgement: Initial casualty data was provided by the American Red Cross. Follow-up data collection is being conducted with assistance from the USGS.)

**Correction**

The last paragraph of the CALTRANS report on the Joshua Tree earthquake in the June 1992 Newsletter is corrected as follows:

Many of the bridges damaged by the 1986 Palm Springs Earthquake were seismically retrofitted, and they performed well. Some soils effects were observed such as settlement behind abutments, the soil being pushed forward by abutments, and air spaces between the soil and columns. The Colton Interchange is a prestressed concrete box girder located about 60 miles west of the earthquake. It was seismically retrofitted in 1991 and was heavily instrumented by the California Division of Mines and Geology. This was the only bridge whose response to the earthquake was recorded. A peak acceleration of 0.22 g was recorded near the center hinge.)