4.12 Earthquakes

An earthquake is a sudden, rapid shaking of the ground caused by the fracture and movement of rock beneath the Earth's surface. Most severe earthquakes take place where the huge tectonic plates that form the Earth's surface collide and slide slowly over, under, and past each other. They can also occur along any of the multitude of fault and fracture lines within the plates themselves.

The faults most likely to affect Oklahoma are the New Madrid Fault, centered in the Missouri Boot heel region, and the Meers Fault, located in southwestern Oklahoma near Lawton.

4.12.1 Hazard Profile

As the Earth's crust moves and bends, stresses are built up, sometimes for hundreds of years, before suddenly breaking or slipping. This abrupt release of accumulated tension can be devastating to human communities on the surface.

Although located in the relatively quiet Central Plains Province, nearness to the New Madrid MO, the western OK Meers or the Central OK Nemaha faults exposes some Oklahoma communities to tremors

The destructiveness of an earthquake depends upon a number of factors, including the magnitude of the tremor, direction of the fault, distance from the epicenter, regional geology, local soils, and the design characteristics of buildings and infrastructure, such as roads, bridges, and pipelines.

Earthquake intensity can be significantly affected by the stability of underlying soils. For example, during the Northridge, California earthquake, three times as much damage was done to single-family homes and buried utilities in ground failure zones than in nearby areas where the footing was more solid. In addition, the intensity of West Coast tremors is dissipated by the relative "warmth" of the region's geology. By contrast, the thick Pennsylvanian sandstone and limestone strata of the central United States are much more efficient conductors of tremors. Consequently, a 6.8-magnitude earthquake in the New Madrid Fault would have a much wider impact than a comparable event on the California coast.

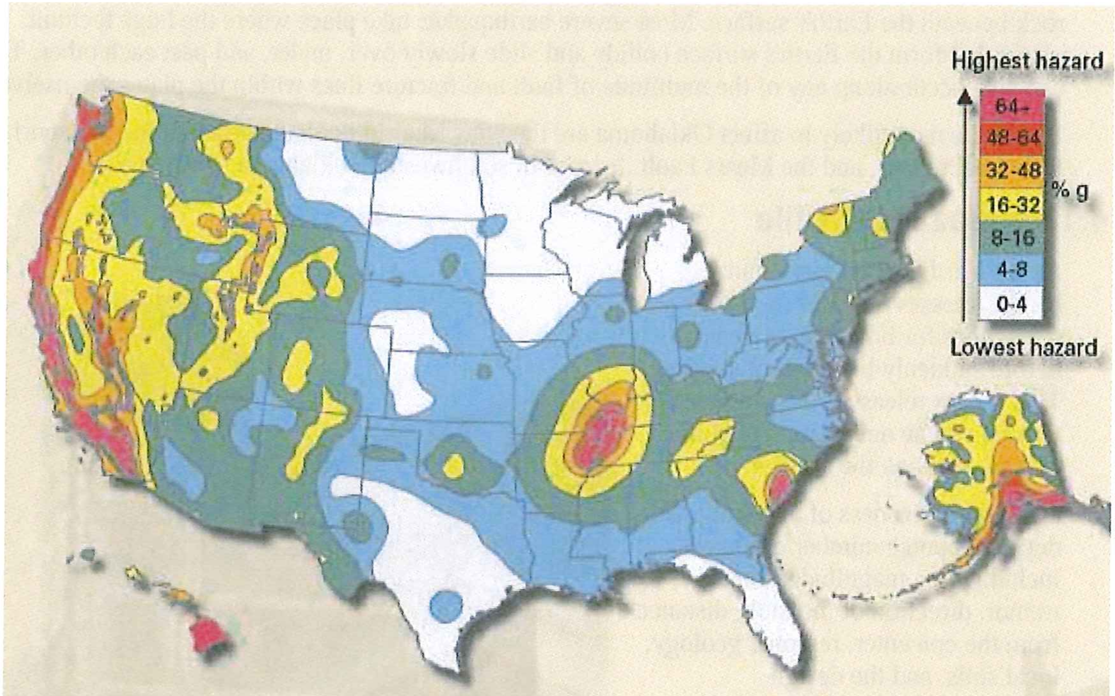
Urbanization is probably the most important factor in translating earthquake magnitude into human impacts. In the United States, Alaska has the greatest number of large earthquakes—over a dozen above 7.3 magnitudes between 1899 and 1999. However, these severe quakes resulted in relatively little loss of life or damage, since all but one occurred in uninhabited areas.

Location

Oklahoma has experienced an average of 50 earthquakes each year since records have been kept by the Oklahoma Geological Survey. Most of these earthquakes were so small that they could not be felt by people. Only about two or three per year have been large enough to be felt and most were so small they caused no damage. As shown in the figure below, the majority of Oklahoma earthquakes are concentrated in the area of the Meers Fault in Garvin, Grady, and McClain counties, where the Ouachita, Arbuckle and Wichita mountains converge. Canadian County, its

Communities and Public School systems are at low risk from earthquakes from either this zone or the New Madrid Fault in southeastern Missouri.

Figure 4–29: Seismic Hazard Locations in the United States



Colors on this map show the levels of horizontal shaking that have a 2-in-100 chance of being exceeded in a 50-year period. Shaking is expressed as a percentage of g (g is the acceleration of a falling object due to gravity. – Source: USGS, 2008 US National Seismic Hazard Maps

Canadian County is located in an area of low-level seismicity, west of the recently active Wilzetta fault in Lincoln County and north of the historically active Meers fault. Of these 28 events, 13 were in the vicinity of El Reno, 9 were near Calumet, 3 close to or in Union City, 2 near Mustang and 1 at Okarche. The two most recent felt earthquakes were on September 10, 2004, and March 11, 2010: a 3.4 magnitude tremor near W. Reno Rd. and S. Ranch Rd., and a 2.8 event east of OK Hwy 37 and the Caddo County line, respectively.

Measurement

Modern seismological technology has greatly enhanced the capability of scientists to sense earthquakes. Before the development of today's delicate sensors, only "felt" earthquakes were captured in the historical record.

Two standard measures are used to classify an earthquake's extent: *magnitude* and *intensity*. These measures are sometimes referred to as the Richter Scale (magnitude) and the Modified Mercalli (intensity).

Magnitude is an Arabic number representing the total amount of energy released by the earthquake source. It is based on the amplitude of the earthquake waves recorded on seismographs that have a common calibration. The magnitude of an earthquake is thus represented by a single, instrumentally determined value.

Intensity, expressed as a Roman numeral, is based on the earthquake's observed effects on people, buildings and natural features. It varies depending on the location of the observer with respect to the earthquake's epicenter. In general, the intensity decreases with distance from the fault, but other factors such as rupture direction and soil type also influence the amount of shaking and damage. The Modified Mercalli and Richter Scales are compared in Table 4-40.

Table 4–40: Comparison of Mercalli and Richter Scales

Mercalli	Richter	Description
I	0-4.3	Vibrations are recorded by instruments. People do not feel any Earth movement.
II		A few people might notice movement if they are at rest and/or on upper floors of tall buildings.
III		Shaking felt indoors; hanging objects swing. People outdoors might not realize that an earthquake is occurring.
IV	4.3-4.8	Dishes rattle; standing cars rock; trees might shake. Most people indoors feel movement. Hanging objects swing. Dishes, windows, and doors rattle. A few people outdoors may feel movement.
V		Doors swing; liquid spills from glasses; sleepers awake. Almost everyone feels movement. Dishes are broken. Pictures on the wall move. Small objects move or are turned over. Trees shake.
VI	4.8-6.2	People walk unsteadily; windows break; pictures fall off walls. Everyone feels movement. Objects fall off shelves. Furniture moves. Plaster in walls may crack. Trees and bushes shake. Damage is slight in poorly built buildings. No structural damage.
VII		Difficult to stand; plaster, bricks, and tiles fall; large bells ring. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.
VIII	6.2-7.3	Chimneys fall; branches break; cracks in wet ground. Drivers have trouble steering. Houses that are not bolted down might shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Well-built buildings suffer slight damage. Poorly built structures suffer severe damage. Water levels in wells might change.
IX		General panic; damage to foundations; sand and mud bubble from ground. Well-built buildings suffer considerable damage. Houses that are not bolted down move off their foundations. Some underground pipes are broken. The ground cracks. Reservoirs suffer serious damage.
X		Most buildings destroyed; large landslides; water thrown out of rivers and lakes. Some bridges are destroyed. Dams are seriously damaged. The ground cracks in large areas. Railroad tracks are bent slightly.
XI	7.3-8.9	Roads break up; large cracks appear in ground; rocks fall. Most buildings collapse. Some bridges destroyed. Underground pipelines destroyed. Railroad tracks badly bent.
XII		Total destruction; "waves" seen on ground surface; river courses altered; vision distorted. Almost everything is destroyed. Objects are thrown into the air. Large amounts of rock may move.

Extent/Severity

Until recently, Canadian County was the location of Oklahoma's largest historical earthquake—the 5.5 El Reno event of April 9, 1952. This record event was overtaken on November 5, 2011 when a 5.6 earthquake occurred in Lincoln County which did some damage and was felt as far away as Illinois, Kansas, Arkansas, Tennessee and Texas.

Canadian County considers a reading of 4.8 and below on the Richter Scale a minor severity quake and a reading above 4.8 to be one of major severity.

Frequency

Canadian County experienced 28 earthquakes between 1995 and 2009, followed by cluster of 11 quakes in on March 11-12, 2010, and two more in June. Given this frequency, Canadian County can expect 1.9 earthquakes each year, and a "felt" event every 20 years, none of which does any noticeable damage. If the 13 quakes of 2011 are included, to make 41 events over 16 years, the average would be 2.5 events per year.

The Meers Fault has had two major ruptures in the last 3,000 years, the last one about 1,600 years ago. If the fault has a 1,500-year periodicity, it could be due for a major event in the next one or two hundred years.

The most likely major earthquake event that could impact the area would probably originate in the New Madrid Fault Zone, which has been relatively quiet for 150 years. Seismologists estimate the probability of a 6 to 7 magnitude earthquake in the New Madrid area in the next 50 years to be higher than 90 percent.

According to Randy Keller of the Oklahoma Geological Survey, a major quake in the New Madrid area would cause some minor damage in the eastern part of the state. Oklahoma would, however, likely become involved in aiding the victims of a serious New Madrid earthquake, since the State is one of nine associate members of the Central United States Earthquake Consortium.

Impact

The impact of this hazard depends on the intensity of the earthquake. A 5.7 magnitude event centered on the Nemaha fault in the El Reno area would likely do similar damage to structures in Canadian County as the recent Lincoln County quake—that is, cause structural damage to buildings and buckle some roads, but would probably not cause significant injury or death to populations living within the county.

4.12.2 History/Previous Occurrences

As stated above, the largest earthquake felt in the United States in historical times occurred in Missouri, along the New Madrid Fault. There, in 1811 and 1812, three earthquakes larger than a magnitude 8 destroyed the town of New Madrid, caused the land to roll in visible waves, lifted and lowered land as much as 20 feet, and formed and emptied lakes. The tremors rang bells in church steeples as far away as Boston, Massachusetts. These earthquakes were probably the first ones felt by residents in Oklahoma in historical times. Intensity VII earthquakes hit the New Madrid area again in January 1852 and June 1862. A map showing earthquake events from 1980-2009 can be found in Figure 4-30.

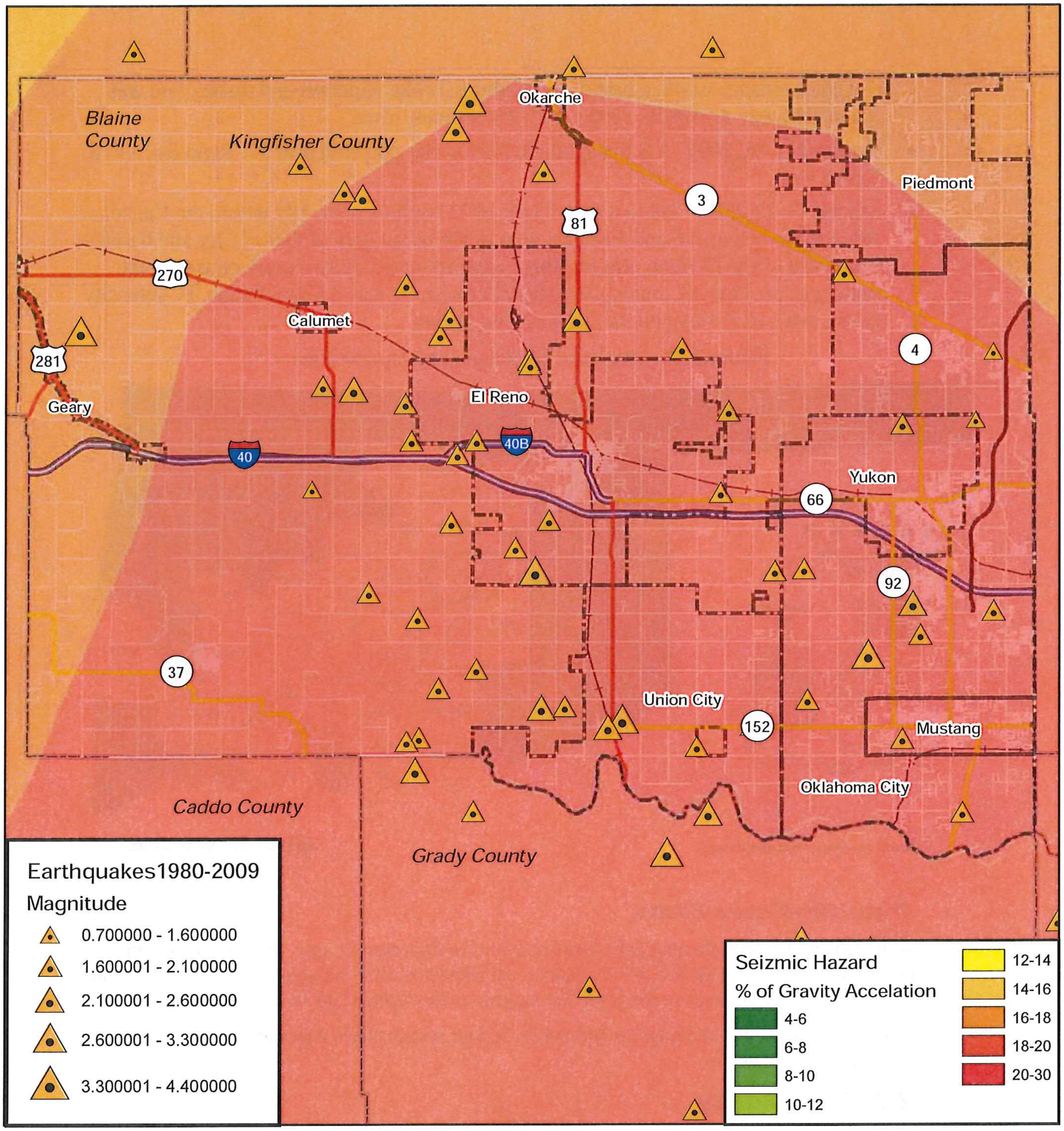
The earliest documented quake in what is now Oklahoma occurred on October 22, 1882, near Ft. Gibson, Indian Territory. The *Cherokee Advocate* reported that "the trembling and vibrating were so severe as to cause doors and window shutters to open and shut, hogs to squeal, poultry to run and hide, and cattle to low."

Canadian County Earthquakes

Canadian County is located in an area of low-level seismicity, west of the recently active Wilzetta and Nemaha faults in Lincoln and Oklahoma Counties and north of the historically active Meers fault in southwestern Caddo County. Of the 28 events that have been reported between 2000 and 2009, 13 were in the vicinity of El Reno, 9 near Calumet, 3 in Union City, 2 near Mustang and 1 at Okarche. The two most recent felt earthquakes were on September 10, 2004, and March 11, 2010: a 3.4 magnitude tremor near W. Reno Rd. and S. Ranch Rd., and a 2.8 event east of OK Hwy 37 and the Caddo County line, respectively. Historic earthquake events by county are shown in Figure 4-31.

Until recently, the largest earthquake on record in the state—a VII-intensity event that registered 5.5 on the Richter scale—happened near El Reno on April 9, 1952. This and other large Oklahoma earthquakes are summarized briefly below:

- **December 28, 1929**- A 4.0 magnitude, VI intensity quake struck El Reno in Canadian County.
- **April 9, 1952**- The largest earthquake on record in the state—a VII-intensity event that registered 5-5 to 5.7 on the Richter scale—happened near El Reno. It was apparently caused by slippage along the Nemaha Fault. The tremor toppled chimneys



LEGEND

- Interstate
- US Highway
- State Highway
- Turnpike
- Railroads
- City Limits

0 2.5 5 Miles

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Figure 4-30

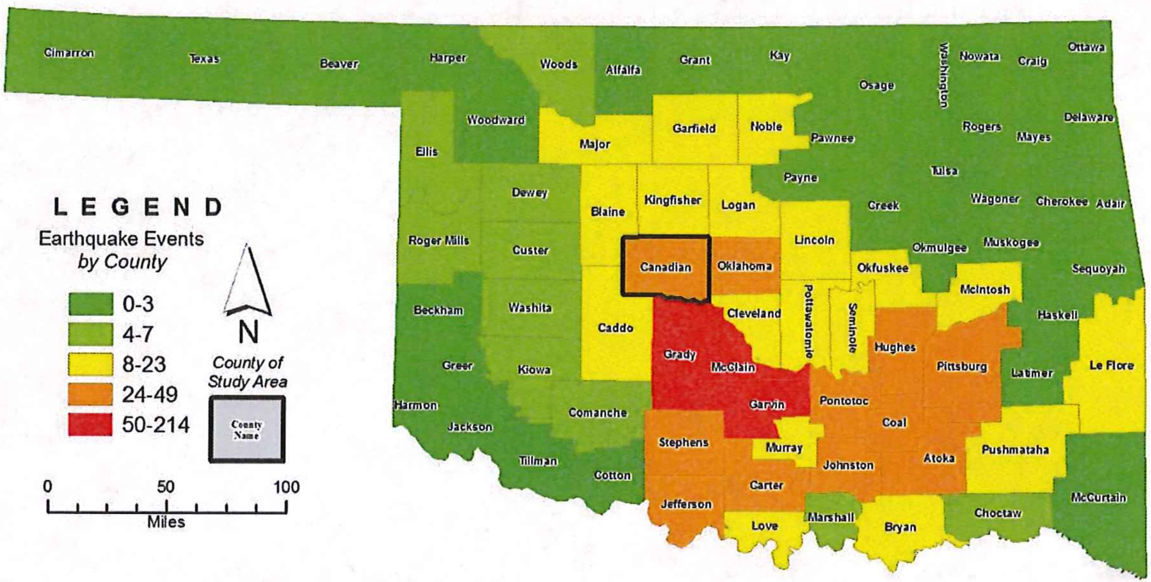
Canadian County

Historic Earthquakes 1980 - 2009

and smokestacks, cracked bricks on buildings, broke windows and dishes, and was felt as far away as Austin, Texas, and Des Moines, Iowa.

- **September 10, 2004**- A 3.4 magnitude tremor was centered near W. Reno Rd. and S. Ranch Rd.
- **March 11-12, 2010**- There was a cluster of 11 tremors generally within the Canadian River basin between 6 and 10 miles west of the urban core of Union City and 6 miles southwest of the El Reno airport. These were followed by two more quakes in the same area on June 23. Among the March 11 tremors was 3.4-magnitude, IV-intensity quake and two 2.8-magnitude, III-intensity events.

Figure 4-31: Historical Oklahoma Earthquake Data



Source: Oklahoma Geological Survey

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Probability/Future Events

Although earthquakes are relatively frequent events in Canadian County, their intensities are usually low, usually in the 1.5 to 2.5 range on the Richter Scale – enough to rattle dishes, but do little damage. Earthquakes in the 4.0 to 4.4 ranges can be expected about once every 30 years.

Canadian County, its Communities and Public School systems have a moderate probability of a future earthquake event.

4.12.3 Vulnerability

This section summarizes information about Canadian County's vulnerability to earthquakes, including the impact on people, structures and buildings, critical facilities, and infrastructure. This information, as well as information provided by the County, Incorporated Communities and Public Schools, was used to determine the Vulnerability Criteria identified in Tables 4-2 and 4-3. HAZUS modeling was used to help generate these data. Canadian County was determined to be at low risk to the earthquake hazard. (See Table 4-2 Hazard Risk Analysis, and Table 4-3, Summary of Hazard risk Analysis Ranking Criteria for an explanation of how the rankings were derived.)

Population

Most earthquake injuries and fatalities occur within buildings from collapsing walls and roofs, flying glass, and falling objects. As a result, the extent of the county's risk depends not just upon the location of known faults and underlying geology and soils, but also on the design and construction of structures. Education and outreach programs should be in place to prepare all populations in Canadian County, including its communities and public school systems students, for an earthquake event.

Structures/Buildings

Buildings constructed to earlier seismic standards (or to no standard) can pose major threats to life and the continued functioning of key public services during an earthquake disaster. Un-reinforced masonry structures are the most vulnerable, while wood frame structures typically perform well.

Schools made of brick materials and not retrofitted to resist seismic forces are vulnerable to falling brickwork and causing injuries as a result. All damages to school sites are dependent on the intensity of the earthquake

Critical Facilities

Of special concern are the design and construction of critical facilities such as hospitals and transportation networks, oil and gas pipelines, electrical power and communication facilities, and water supply and sewage treatment facilities. All could be damaged in minor ways by a 5.7 earthquake, but their functions would likely not be significantly impacted.

Infrastructure

Canadian County's infrastructure is at low risk of being impacted by an earthquake due to the location of the community in a low seismically active area.

4.12.4 Earthquake Scenario

HAZUS, a software application developed by the Federal Emergency Management Agency and the National Institute of Building Sciences, provides a methodology to estimate earthquake losses on a regional scale. Building and population statistics from the U.S. Census are combined with estimated replacement values for local infrastructure to estimate potential damages and losses to be expected within the region from a specified earthquake event.

The historic, 5.7 magnitude El Reno earthquake event of April 9, 1952, was used as the input event in the HAZUS model run for Canadian County, its Communities and Public School systems.

HAZUS estimates that 881 buildings in the County would receive slight damage, 432 buildings moderate damage, 87 structures extensive damage and 15 structures complete damage. The total economic loss for the earthquake is estimated at 48.21 (millions of dollars), which includes building and lifeline related losses. The total building-related losses were 41.21 (millions of dollars); 12% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 65% of the total loss.

Of the 17 injuries estimated, 3 would require hospitalization, and one person would be killed. It is expected that 15 people would seek temporary shelter as a result of the event.

Essential facilities, including schools, hospitals, emergency operation centers, police and fire stations would be minimally affected for the duration of the event day. This includes possible school closings and temporary loss of fire, police and hospital resources. Functional losses to these facilities would be minimal.

Transportation system damages and economic losses associated with these systems are estimated at 21.68%. Ground failure would be the single source for damages to transportation components. All utility system facilities, pipeline activity, electric power and potable water should be at 80.79% following the event. HAZUS estimates that zero tons of debris would be generated by the earthquake.

4.12.5 Future Trends

Population

Population in the future growth areas will have the same vulnerability as the current population.

Structures/Buildings

Structures built in the future can be designed to withstand the effects earthquakes potentially have, as well as from tornadoes and high wind damages.

Critical Facilities

The same hazard-resistant standards used to reduce the vulnerability of critical facilities to tornado and wind damage will also lessen, if not eliminate, losses due to earthquake.

Infrastructure

Infrastructure can—and should—be designed to ride through the magnitude of seismic events expected for Canadian County. By designing infrastructure to hazard-resistant standards the lives and assets of building occupants and the continuity of their work will be protected and risk reduced.

4.12.6 Conclusion

Canadian County jurisdiction is classified at low risk from earthquakes. The County experienced 28 earthquakes between 1995 and 2009, followed by cluster of 11 quakes in on March 11-12, 2010, and two more in June. If the 13 quakes of 2010 are included, to make 41 events over 16 years, the earthquake frequency would be 2.5 events per year. As calculated using HAZUS software, an earthquake similar to the 1952 El Reno earthquake would cause an estimated 48.21 (millions of dollars) in damage in Canadian County's jurisdiction. Historically, the overwhelming majority of Oklahoma earthquakes are too small to be felt and cause no visible damage.

Data Limitations

While the HAZUS software is very comprehensive, structural integrity and code requirements for a jurisdiction can greatly affect the actual damage taken by structures. Earthquake resistant construction is not something routinely considered in Oklahoma, so damages are not as precise as they might be in a jurisdiction such as California, where earthquakes are more dangerous and seismic analyses more sophisticated.

Update Changes

Identified significant changes made from previous Multi-Hazard Mitigation Plans from Canadian County, Calumet, El Reno, Mustang, Piedmont, and Union City are outlined in Appendix E. Changes are based on criteria outlined for Plan Updates in the Local Multi-Hazard Mitigation Planning Guidance document of July 1, 2008.

4.12.7 Sources

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