Assessment of Risks and Vulnerability to Earthquake Hazards in Nevada

NEVADA BUREAU OF MINES AND GEOLOGY OPEN-FILE REPORT 07-1

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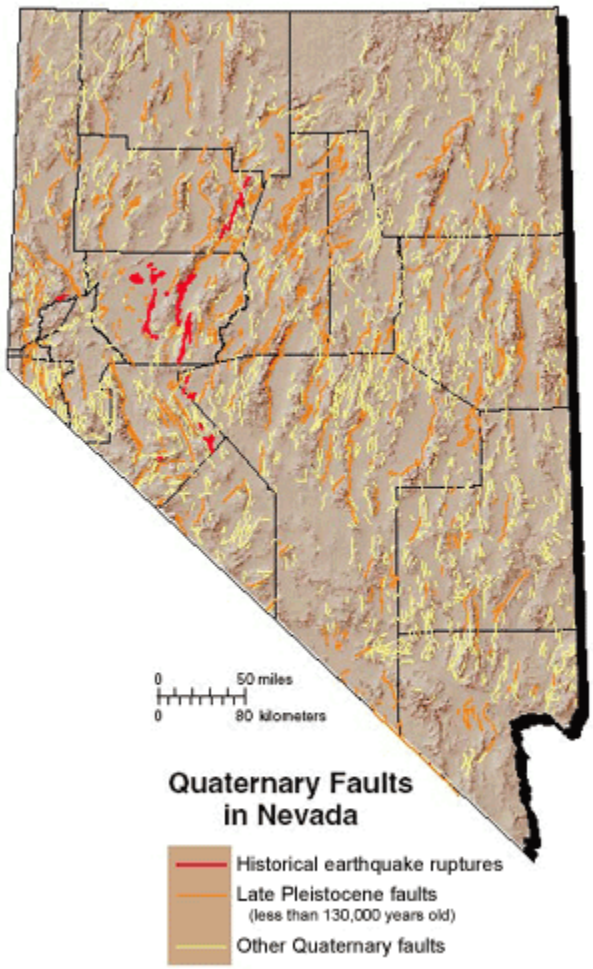
INTRODUCTION

From Section 3 of the State of Nevada Hazard Mitigation Plan (NHMP), posted at:
http://dem.state.nv.us/documents/NHMP/NHMP_Section_3_18Oct07.pdf

3.3.4 Earthquakes *(High Risk Hazard)*



Quaternary Fault Map of Nevada (dePolo and others, 2000, NBMG SP27, page 24)

3.3.4.1 *Nature*

An earthquake is sudden shaking usually caused by rapid, subsurface fault movement. This releases strain accumulated within the Earth's crust. Earthquakes are one of the largest natural hazards and have the potential to create catastrophic, comprehensive disasters. The effects of an earthquake can be damaging far beyond the site of its occurrence and they usually occur without warning. After just a few seconds, earthquakes can cause massive damage and extensive casualties. The most common effect of earthquakes is ground motion, which is the vibration or shaking of the ground. Other potentially damaging effects include surface offset, landslides and rockfalls, and the ground becoming fluidized.

The severity of ground motion generally increases with the size of an earthquake and decreases with distance from the fault or epicenter. Ground motion causes waves in the Earth's interior, also known as body waves, and along the earth's surface, known as surface waves. There are two primary kinds of body waves. P (primary) waves are longitudinal or compressional waves similar in character to sound waves that cause back-and-forth

oscillation along the direction of travel. S (secondary) waves, also known as shear waves, are slower than P waves and cause structures to vibrate from side-to-side. There are also two kinds of surface waves: Raleigh waves, which cause a rolling motion like ocean waves and Love waves, which shake from side-to-side. Buildings and other structures need to be designed to withstand the shaking from earthquakes, and people need to be mindful of the potential threat from the contents of buildings being shaken down.

In addition to ground motion, several secondary hazards can occur from earthquakes, such as surface faulting. Surface faulting is the offset of the Earth's surface caused by movement along a fault. Displacements along faults during a single earthquake vary both in terms of length and width, but can be significant (e.g., up to 20 feet), as can the length of the surface rupture (e.g., up to 70 miles). Surface faulting can cause severe damage to buildings, highways, railways, pipelines, and tunnels.

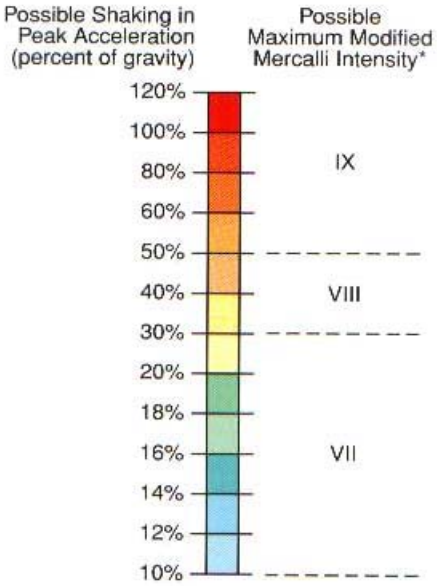
Earthquake-related ground failure due to liquefaction is another secondary hazard. Liquefaction occurs when seismic waves pass through saturated granular soil, causing the granules to collapse into the empty spaces between grains. This causes water pore pressure to increase sufficiently to make the soil to behave like a fluid for a brief period. Liquefaction causes lateral spreads (horizontal movements of commonly 10 to 15 feet, but up to 100 feet), flow failures (massive flows of soil, typically hundreds of feet), and loss of bearing strength (structures sink into the ground or tip). Liquefaction can cause severe damage to property.

The effects of earthquake waves at the surface can be measured using the Modified Mercalli Intensity (MMI) Scale, which consists of rankings based on observed human behavior, building effects, and ground deformation. The size of an earthquake is measured by the earthquake magnitude Scale (M), that is based on the size and duration of seismic waves, accounting for distance from the event.

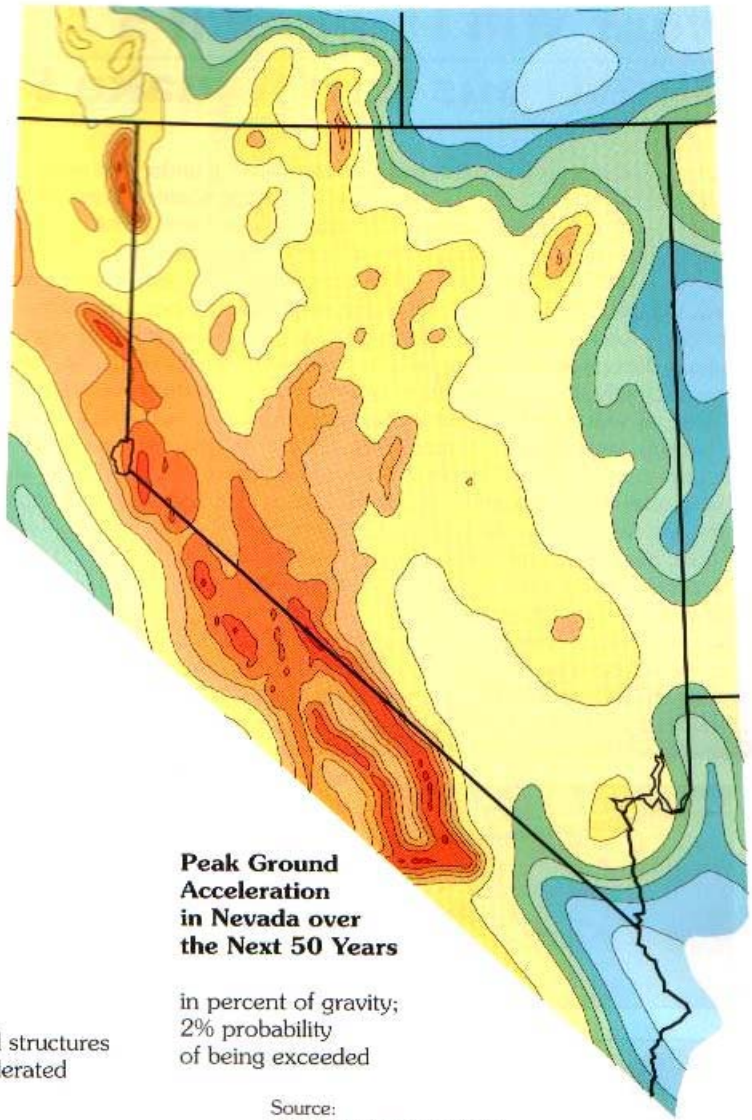
VULNERABILITY ASSESSMENT AND ANALYSIS OF POTENTIAL LOSSES

The earthquake hazards in Nevada are huge. To assess risks and vulnerability, the Nevada Bureau of Mines and Geology ran FEMA's loss-estimation model, HAZUS-MH, using earthquakes that have occurred in the geological past near each county seat. The results, using Version 1 of HAZUS-MH, were reported in Nevada Bureau of Mines and Geology Open-File Report 06-1 (http://www.nbmg.unr.edu/dox/of061/of061.htm). More recently, the Nevada Bureau of Mines and Geology updated this report, using Version 2 of HAZUS-MH (HAZUS MR2) and some updated information on critical facilities, which are reported here [Open-File Report 07-1 (http://www.nbmg.unr.edu/dox/of071.pdf)]. The results are summarized in Tables 3-6, 3-7, and 3-8.

Shaking Potential Map for Nevada



* See page 4 for descriptions of Intensity VII and VIII. In Intensity IX, general panic occurs and there may be damage to some well-built structures.



Peak Ground Acceleration in Nevada over the Next 50 Years

in percent of gravity;
2% probability
of being exceeded

Source:
Frankel and others (1997)

Engineers use computer models and model structures to see how buildings hold up to being accelerated sideways by a seismic wave.

The notion of a map like this is very much like rolling the dice and calculating odds. If a rarer, but damaging, earthquake occurs in a part of Nevada that has less frequent earthquakes (yellow to blue colors), the shaking will be every bit as strong as earthquakes we anticipate in western Nevada.

If we correlate this shaking potential map with possible damage, all of Nevada could experience damaging shaking. This is why Nevadans need to take messages of earthquake preparedness seriously.

When an earthquake occurs, another probability becomes important! The chance, given strong shaking, that something bad will happen to you. This is the probability you can do something about. **By securing shaking hazards around your home and workplace, you can put the odds in your favor that you, your loved ones, your customers, and your valuable and important possessions will be safe from earthquakes.**

Table 3-6 indicates that damage from major earthquakes could range from hundreds of thousands of dollars in sparsely populated rural counties to tens of billions of dollars in urban areas. Ten of thousands of buildings could suffer extensive or complete damage. Fatalities could reach into the hundreds. Thousands of people may need public shelter. Importantly, many earthquakes are likely to cause significant, simultaneous damage in multiple counties. In particular, a major earthquake anywhere in the Reno-Carson City urban corridor is likely to cause significant damage not only in Carson City but also Douglas, Storey, and southern Washoe counties.

Table 3-7 demonstrates that essential facilities will be severely stressed following major earthquakes. The HAZUS program predicts that few hospitals in the epicenter areas will have sufficient beds to accommodate the injured people, which means that plans needs to be in place for transporting injured people to other jurisdictions. Fire stations, police stations, and schools will most likely be operating at reduced capacity, and there will be significant damage to utilities and transportation systems.

Table 3-8 summarizes vulnerability (or risk) from earthquakes for the 17 counties in Nevada in several ways. One way of assessing vulnerability is in terms of total losses. Using a measure of economic loss in dollars, the top nine counties are ranked as follows:

Highest dollar loss from scenario earthquake chosen: Clark County ($9.0 billion)
2nd highest: Washoe County ($3.7 billion)
3rd highest: Carson City ($740 million)
4th highest: Douglas County ($550 million)
5th highest: Elko County ($210 million)
6th highest: Lyon County ($95 million)
7th highest: Mineral County ($85 million)
8th highest: Lander County ($79 million)
9th highest: White Pine County ($76 million)

Not surprisingly, the counties with the largest populations are generally the ones with the most at risk.

The figures in the Appendix give a graphical indication of the damage expected in each of Nevada's 17 counties for a particular earthquake scenario, summarized in the figure's title. Colored contour areas represent peak ground acceleration (PGA) of the earthquake, an indicator of shaking intensity, scaled from 0 (blank) to 0.7 *g* (bright red), where *g* is the normal gravitational acceleration at the Earth's surface. Known faults (brown), and the rupturing fault (magenta) are also shown. The PGA color scale may be interpreted roughly as follows:

PGA	Color	Meaning
upto 0.10	none	
0.11-0.20	Light blue	
0.21-0.30	Dark blue	
0.31-0.40	Green	
0.41-0.50	Yellow	
0.51-0.60	Orange	
0.61-0.70	Red	
over 0.70	Black	

Table 3-6. Summary of HAZUS MR2 loss-estimation output for earthquake scenarios that may affect counties in Nevada (adapted from Nevada Bureau of Mines and Geology Open-File Report 06-1).

County	County Seat	Earthquake Scenario	Building-Related Economic Loss (1)		Buildings with Major Damage (1)		Fatalities		People Needing Public Shelter		Earthquake	
		Magnitude	(multi-county region) $ billion	(county alone)	(multi-county region)	(county alone)	(multi-county region)	(county alone)	(multi-county region)	(county alone)	Magnitude (compare with probabilities)	Probability within 50 years within 50 km (2)
Carson City	Carson City	6.5	0.6 to 2.5	$740 million	~3,800	~2,800	30 to 110	~45	170 to 700	~270	6.5 6.0	50-55% ~70%
Churchill	Fallon	6.5	0.0 to 0.2	$73 million	~400	~300	<20	~2	10 to 40	~17	6.5 6.0	20-25% 30-40%
Clark	Las Vegas	6.6	4.5 to 18	$9.0 billion	~30,000	~30,000	200 to 900	~460	3,000 to 11,000	~5,400	6.5 6.0	<5% 10-20%
Douglas	Minden	7.1	0.7 to 2.8	$550 million	~3,600	~1,300	30 to 110	~25	150 to 600	~92	7.0 6.5 6.0	10-12% 50-60% 60-70%
Elko	Elko	6.5	0.1 to 0.4	$210 million	~800	~800	10 to 40	~18	40 to 140	~72	6.5 6.0	6-8% 10-15%
Esmeralda	Goldfield	6.7	< 0.1	$290 thousand	~3	~2	<20	none	none	none	6.5 6.0	5-10% 20-30%
Eureka	Eureka	7.2	< 0.1	$4.5 million	~100	~48	<20	none	none	none	7.0 6.5 6.0	<0.5% 4-6% 10-15%
Humboldt	Winnemucca	6.5	< 0.1	$50 million	~490	~490	<20	none	10 to 20	~2	6.5 6.0	5-10% 15-20%
Lander	Battle Mountain	7.5	0.1 to 0.2	$79 million	~1,400	~1,200	<20	~6	10 to 20	~10	7.5 7.0 6.5 6.0	0.1-0.2% ~1.5% ~10% 15-20%
Lincoln	Pioche	6.5	< 0.1	$5.2 million	~40	~40	<20	none	none	~1	6.5 6.0	2-3% 6-10%
Lyon	Yerington	6.9	0.1 to 0.4	$95 million	~900	~760	<20	~3	10 to 40	~13	7.0 6.5 6.0	12% 40-45% ~60%
Mineral	Hawthorne	7.5	0.1 to 0.4	$85 million	~1,300	~660	<20	~3	20 to 60	~21	7.5 7.0 6.5 6.0	<0.5% 10-12% 30-40% ~60%
Nye	Tonopah	7.0	< 0.1	$480 thousand	~140	~1	<20	none	none	none	7.0 6.5 6.0	<1% 5-10% 20-30%
Pershing	Lovelock	7.3	0.0 to 0.2	$64 million	~840	~780	<20	~4	10 to 30	~11	7.5 7.0 6.5 6.0	~0.1% 1-2% ~10% 10-20%
Storey	Virginia City	6.5	0.7 to 2.9	$8.2 million	~3,500	~56	20 to 80	none	190 to 800	none	6.5 6.0	50% 65-70%
Washoe	Reno	6.9	2.0 to 8.2	$3.7 billion	~11,000	~9,600	100 to 400	~180	700 to 3,000	~1,400	7.0 6.5 6.0	12-15% ~50% 65-70%
White Pine	Ely	6.8	0.0 to 0.2	$76 million	~430	~430	<20	~4	10 to 20	~12	7.0 6.5 6.0	<0.5% 1.5-2% 4-6%

(1) Buildings with major damage are those listed in the HAZUS report as suffering extensive or complete damage; losses include business interruption.

Table 3-7. Predicted hospitalization needs, functionality of essential facilities, and damage to utilities and transportation within the counties for earthquake scenarios, using FEMA's HAZUS MR2 model.

County	Earthquake Scenario Magnitude	# People requiring hospitalization	Functionality of Essential Facilities						Utility Losses ($ million)	Transportation Losses ($ million)
			# Hospital beds (total)	# Beds available at Day 1	Day 7	Fire Stations	Police Stations	Schools		
Carson City	6.5	169	128	11	48	1 @ 17%	2 @ 17%	15 @ 19% 1 @ 2%	30	5.7
Churchill	6.5	9	40	11	26	2 @ 49%	2 @ 49%	10 @ 49%	33	6.1
Clark	6.6	1783	3,022	878	1,697	31 @ 48%	21 @ 50%	292 @ 53%	350	40
Douglas	7.1	189 (incl. Carson)	128 (in Carson)	25	72	3 @ 35%	4 @ 27%	12 @ 32%	16	9.4
Elko	6.5	64	65	34	39	6 @ 84%	9 @ 62%	24 @ 65%	6.8	6.6
Esmeralda	6.7	0	42 (in Nye)	34	39	none	2 @ 80%	1 @ 100%	1.2	4.4
Eureka	7.2	0	25 (in Lander)	25	25	none	1 @11%	3 @ 74%	7.6	2.8
Humboldt	6.5	9	52	7	24	1 @ 27%	2 @ 16%	13 @ 55%	3.7	9.3
Lander	7.5	22	25	4	13	2 @ 56%	2 @ 56%	4 @ 56%	42	6.2
Lincoln	6.5	0	20	8	15	3 @ 81%	2 @ 92%	9 @ 72%	8.0	2.4
Lyon	6.9	14	63	6	24	10 @ 79%	8 @ 53%	17 @ 74%	88	8.6
Mineral	7.5	14	35	1	6	1 @ 6%	2 @ 10%	5 @ 28%	55	3.4
Nye	7.0	0	42	12	21	3 @ 99%	3 @ 99%	18 @ 98%	2.1	1.8
Pershing	7.3	16	37	3	11	none	2 @ 29%	3 @ 41%	230	14
Storey	6.5	109 (incl. Washoe)	1279 (in Washoe)	763	1,121	none	1 @ 33%	4 @ 66%	16	0.3
Washoe	6.9	662	1,279	196	602	5 @ 60%	9 @ 36%	110 @ 30%	280	69
White Pine	6.8	15	40	1	5	1 @ 13%	1 @ 14%	7 @ 22%	50	3.3

Utility losses include potable water, waste water, oil systems, natural gas, electric power, and communications.
Transportation losses include highways, railways and airports.
Some volunteer fire stations are not counted in the HAZUS analysis.

updated 5-Sep-07

Table 3-8. Vulnarability to earthquakes in Nevada counties.

County	Population (2000 Census)	Population (2006 estimate)	Building Exposure ($ million)	Building-Related Economic Loss for Scenario Earthquake ($ million)	Loss as % of exposure for Scenario (%)	Approximate Probability in 50 years (%)	Rank by Economic Loss x Probability	Rank by Loss as % Exposure x Probability
Carson City	52,547	57,701	3,332	740	22	50 to 55	2	1
Churchill	23,982	27,371	1,233	73	6	20 to 25	5	5
Clark	1,375,765	1,874,837	84,829	9,000	11	1 to 4	3	9
Douglas	41,259	51,770	3,698	550	15	~10	4	4
Elko	45,291	48,339	2,237	210	9	6 to 8	6	7
Esmeralda	971	1,262	59	0.29	0	~5	15	15
Eureka	1,651	1,460	118	4.5	4	<0.5	16	16
Humboldt	16,106	17,751	823	50	6	5 to 10	9	8
Lander	5,794	5,655	248	79	32	0.1 to 0.2	14	14
Lincoln	4,165	3,987	233	5.2	2	2 to 3	13	13
Lyon	34,501	54,031	1,699	95	6	12 to 15	7	6
Mineral	5,071	4,399	337	85	25	<0.5	12	12
Nye	32,485	44,795	1,369	0.48	0.04	<1	17	17
Pershing	6,693	6,955	250	64	26	0.[illegible] to [illegible]	11	10
Storey	3,399	4,110	209	8.2	4	~50	8	3
Washoe	339,486	409,085	25,015	3,700	15	12 to 20	1	2
White Pine	9,181	9,542	552	76	14	0.1 to 1.5	10	11

The 2006 population was estimated by the State Demographer (http://www.nsbdc.org/what/data_statistics/demographer/).
Refer to Nevada Bureau of Mines and Geology Open-File Report 06-1 for details on the earthquake scenarios and approximate probabilities. Rank is calculated assuming a probability between the tabulated ranges.

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APPENDIX

Gallery of figures showing damage expected in Nevada counties for selected earthquake scenarios.