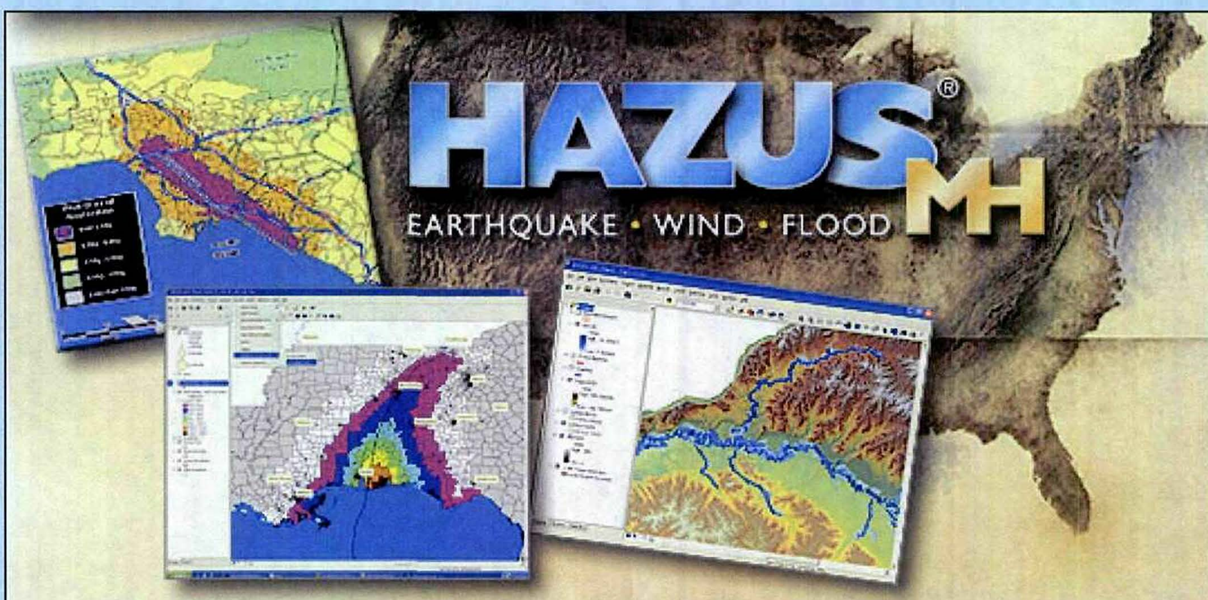
Colorado HAZUS

Earthquake Loss Estimates



COLORADO
GEOLOGICAL SURVEY

HAZUS Final Report

Loss Estimates for Earthquake Scenarios in Colorado using HAZUS-MH

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Report Outline

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E. County Scenario Maps (link to folder with random and worst-case maps)
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1. Introduction

1a. Perceived Seismic Hazard in Colorado

Colorado's largest historical earthquake surprised residents in the northern part of the state during the evening of November 7, 1882. Ground shaking was felt throughout much of Colorado and Wyoming, extending east to Salina, Kansas and west to Salt Lake City, Utah. Without modern seismometers in place, the exact magnitude and location of this earthquake was difficult to pinpoint, but geologists one hundred years later have consulted newspapers and personal accounts to estimate where the ground shaking originated. Placed at a magnitude 6.6 and centered near Estes Park in north-central Colorado, this earthquake is historical proof that strong earthquakes can and do occur in Colorado. If there were to be a repeat of this event today, damages and losses would be significantly greater due to increases in population and infrastructure throughout the state. A program called HAZUS-MH (Hazards U.S. – Multi-Hazard) developed by the Federal Emergency Management Agency (FEMA) can estimate losses from natural disasters such as earthquakes. HAZUS estimates that a magnitude 6.6 earthquake near Estes Park would result in $2.8 billion in direct economic losses, 193 casualties requiring hospitalization, 35024 buildings sustaining at least moderate damage, 2656 displaced households, and 2844 households without electricity. Other known faults in Colorado produce HAZUS estimates that are even more devastating, exceeding $20 billion in losses and 5000 casualties.

A strong earthquake in Colorado would be comparable to Hurricane Katrina considering the lack of government preparedness and the myriad of unforeseen consequences brought on by such a large-scale event. Unlike hurricanes, however, earthquakes give no warning of their approach and provide no time for evacuations. The ground shakes violently and destroys structures that are not built to withstand seismic activity, trapping, injuring, or killing people who are inside. Structures become unsafe, forcing residents to seek temporary or permanent shelter elsewhere. Water and electricity are cut off, roads and bridges become impassable, and fires can ignite from ruptured gas lines. Huge amounts of debris are generated from damaged structures that must be removed before emergency access and rebuilding can begin. Earthquakes can be major disasters, and they pose a very real threat to many areas of Colorado. The first step towards preparedness is to create awareness of what could happen – that is what this report seeks to accomplish.

Although Colorado is hundreds of miles away from the closest plate boundary, where earthquakes normally concentrate, our state has witnessed over 15 damaging earthquakes since the mid-1800's when historical records began in Colorado (**Figure 1,** see **Appendix A** for information about earthquake magnitudes and intensities). When all recordable magnitudes are included, there have been over 500 earthquakes in Colorado since documentation began (**Figure 2**). In 1882, the strongest historical earthquake in Colorado shook cities across the Intermountain West with an estimated magnitude of 6.6 and an epicenter in the vicinity of Rocky Mountain National Park. In the 1960's, multiple earthquakes up to a magnitude 5.3 shook the Denver area in the vicinity of the Rocky Mountain Arsenal and caused damage in several communities. Magnitude 3 to 4 earthquakes are actually quite common throughout the state. (See **References** for links to Colorado earthquake information websites.)

Earthquakes are caused by sudden releases of energy along faults in the earth's crust. Faults normally concentrate along tectonic plate boundaries but are also found anywhere that has experienced deformation, or changes, in the upper portion of the crust. Colorado's tumultuous geologic history has riddled the crust with numerous faults, but geologists have historically categorized them as ancient and inactive, posing no seismic threat. While this is the case for many Colorado faults, field studies since the 1960's have classified over 90 faults in Colorado as Quaternary faults, having moved more recently than 1.6 million years ago (**Figure 2**). Five identified Holocene faults, with movement more recent than 15,000 years, are now recognized as well. (See **Appendix B** for more details about Colorado faults included in this study.)

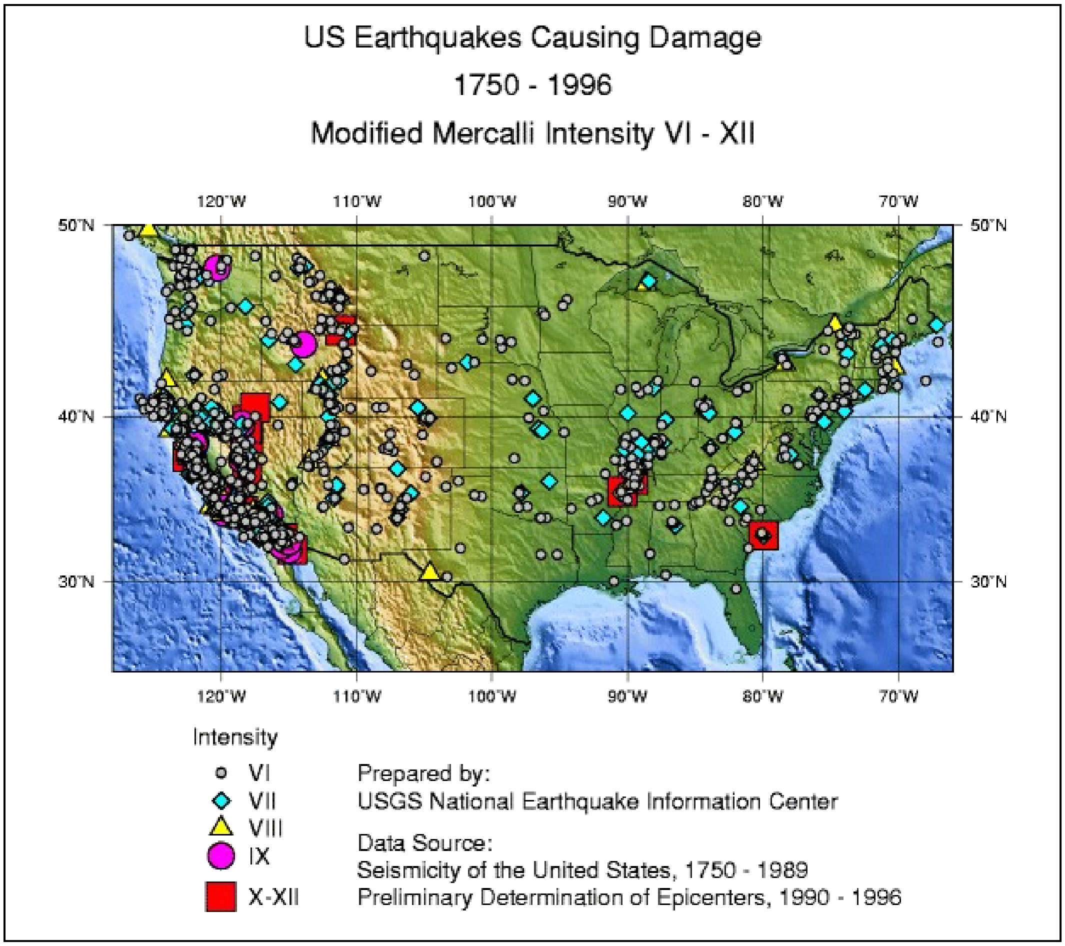

Figure 1 – From the United States Geological Survey, http://earthquake.usgs.gov/regional/states/us_damage_eq.php

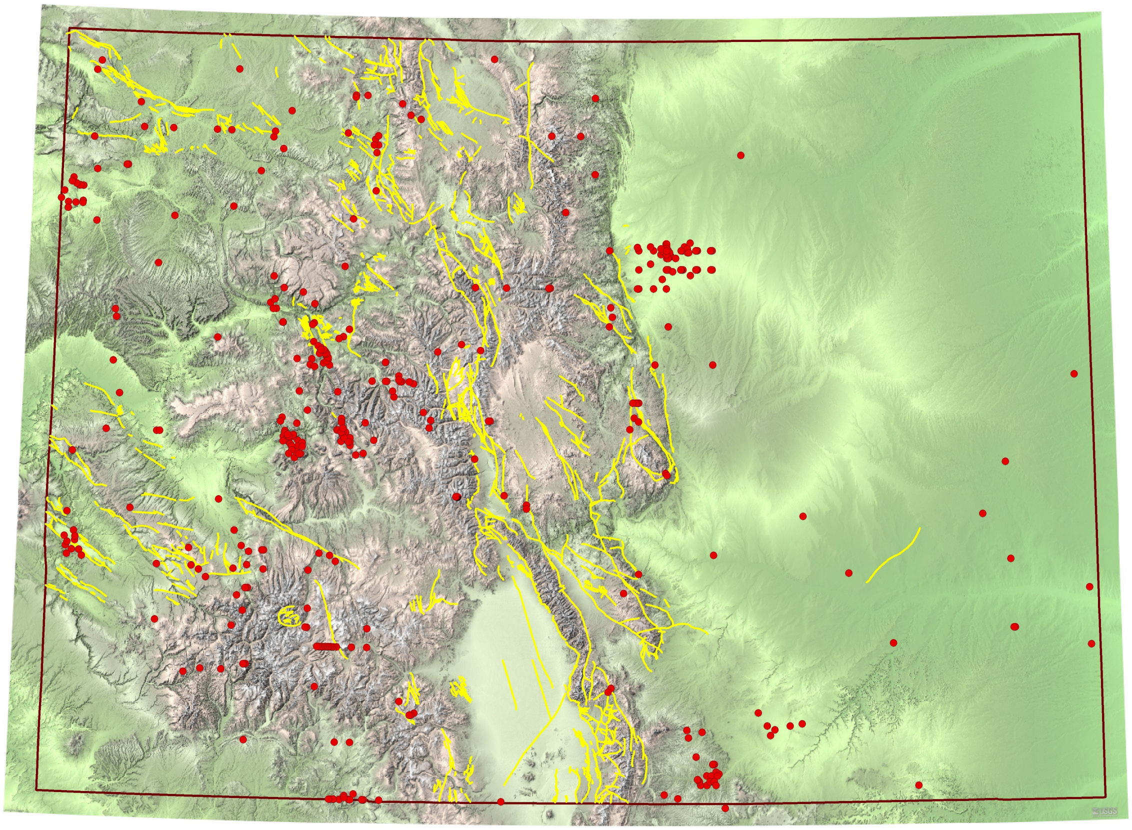

Figure 2 – Shaded relief map of Colorado showing historical seismicity 1870-2004 as red dots and known Quaternary faults as yellow lines.

Despite our growing knowledge about faults and historical earthquakes in Colorado, information about the *probability* of strong earthquakes is lacking. Seismic hazard maps (**Figure 3**) produced by the United States Geological Survey (USGS) show very low probabilities of ground shaking because of low levels of historical seismicity and the recognition of only three potentially active faults in the state (Cheraw, North Sangre de Cristo, and South Sawatch Faults). These faults are included in the USGS database because they are the only ones to have been studied with enough detail to obtain slip rate and recurrence interval estimates, which average movement along the fault through time. Colorado has thus been ranked behind states such as Alabama, Ohio, New Jersey, and Connecticut in estimates of Annualized Earthquake Losses (AEL) calculated by FEMA. Exclusion of other potentially damaging faults from databases that calculate seismic hazard can result in lower hazard estimates than exist in reality. Lack of fault-specific data should *not* result in a lack of earthquake awareness and preparedness in this state.

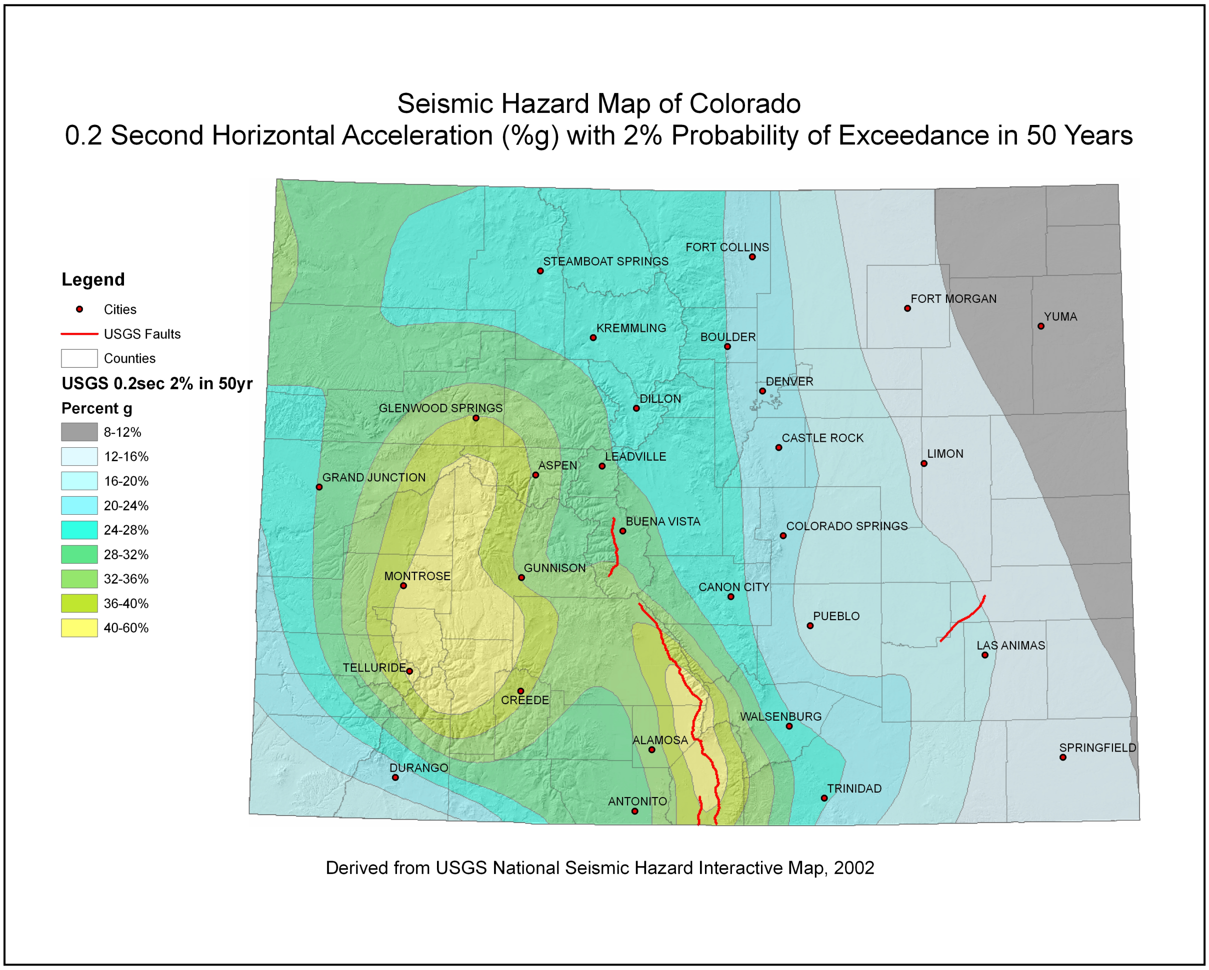

Figure 3 – Hazard map derived from the USGS Seismic Hazards Mapping Program interactive maps. The contours illustrate ground shaking values that have a 2% probability of occurring in a 50-year period. Red lines indicate the three faults included in the USGS fault database: South Sawatch, North Sangre de Cristo, and Cheraw Faults.

1b. Goal of HAZUS-MH Earthquake Loss Estimation in Colorado

In response to the need for more earthquake information, the Colorado Geological Survey (CGS), in collaboration with the Federal Emergency Management Agency (FEMA) District VIII Natural Hazards Specialist, has conducted a series of scenarios that estimate losses that could occur in the event of an actual earthquake. These scenarios used a sophisticated program called HAZUS-MH (Hazards U.S. Multi-Hazard) that was developed by FEMA under contract with the National Institute of Building Sciences (NIBS). HAZUS estimates earthquake damage and loss by calculating ground shaking and its anticipated effects on structures and populations. Included in this report are preliminary scenario results and maps on a state and county level that illustrate what would happen if an earthquake were to occur at a specific time, location, and magnitude. The goal of these earthquake scenarios is to increase awareness of the potential consequences that a strong earthquake would have in Colorado. It is our hope at CGS that local governments and emergency managers can use these loss estimates to better plan for mitigation, response, and recovery in the event of an earthquake. These preliminary scenarios can serve as a foundation for more detailed and accurate scenarios at the county or city level.

2. HAZUS-MH Methodology

2a. HAZUS Loss Estimation Methodology

HAZUS-MH (MR1, 2005 edition) is the updated version of HAZUS software developed throughout the 1990's by the NIBS and FEMA as part of the National Earthquake Hazards Reduction Program (NEHERP). HAZUS-MH is capable of estimating losses from earthquakes, hurricane winds, and floods. The standardized loss estimation software has become a routine component of state and local government emergency management procedures and is mandatory for response and recovery in an actual emergency. HAZUS uses geographic information system (GIS) software to organize and map hazard scenario results. When an epicenter and earthquake magnitude are chosen in a study region, loss estimation calculations use inventory data and hazard parameters to assign ground shaking values to buildings and grid cells throughout the region. Ground shaking values then lead to calculations of probable damage states of buildings and corresponding casualty estimates based on building and occupancy type. Further estimates of economic loss, repair costs, public shelter needs, and induced physical damage such as fires and debris generation are also calculated. After each scenario, HAZUS can compile reports in various formats that summarize losses. Results can be mapped in GIS to show the extent and magnitude of physical damages or socioeconomic losses. For further information about HAZUS history and capabilities, see the FEMA HAZUS website (http://www.fema.gov/hazus/) and the NIBS program overview (http://nibs.org/hazusweb/overview/overview.php).

2b. Data Inventory

HAZUS accesses databases containing a national inventory of building and demographic information. The default inventory for HAZUS was compiled by business information powerhouse Dun & Bradstreet and earthquake engineering firms Risk Management Solutions, Inc., Dames & Moore, and EQE International. This inventory includes the general building stock, essential facilities, transportation lifeline systems, and utility lifeline systems.

The general building stock dataset includes residential, commercial, educational, industrial, religious, agricultural, and government buildings. Databases include information about building type (**Table 1**), number of stories, seismic design code, occupancy type (residential, business, educational, etc.), and time of occupancy (day or night). Also included are building replacement values, business disruption costs, and repair rates and costs. Buildings in the default database are not considered individually but as groups in census tracts according to building type and occupancy class. Building classes are then characterized by probabilities of damage that were calculated from observations of different structure types during ground shaking.

Table 1 – Building Types

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1 2	W1 W2	Wood, Light Frame (≤ 5,000 sq. ft.) Wood, Commercial and Industrial (> 5,000 sq. ft.)		1 - 2 All	1 2	14 24
3 4 5	S1L S1M S1H	Steel Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
6 7 8	S2L S2M S2H	Steel Braced Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
9	S3	Steel Light Frame		All	1	15
10 11 12	S4L S4M S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
13 14 15	S5L S5M S5H	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
16 17 18	C1L C1M C1H	Concrete Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
19 20 21	C2L C2M C2H	Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
22 23 24	C3L C3M C3H	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
25	PC1	Precast Concrete Tilt-Up Walls		All	1	15
26 27 28	PC2L PC2M PC2H	Precast Concrete Frames with Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
29 30	RM1L RM2M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise Mid-Rise	1-3 4+	2 5	20 50
31 32 33	RM2L RM2M RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
34 35	URML URM M	Unreinforced Masonry Bearing Walls	Low-Rise Mid-Rise	1 - 2 3+	1 3	15 35
36	MH	Mobile Homes		All	1	10

From HAZUS-MH Technical Manual, Chapter 3.

The essential facilities inventory includes data about medical care facilities, fire stations, police stations, and schools. These facilities have key roles in emergency response following a disaster and should be functional after an earthquake. Schools are included because they are commonly used as public shelters for displaced households in emergencies. Since there are relatively few facilities in each census tract, damage to essential facilities is evaluated on a building-by-building basis and can thus be individually mapped for specific scenarios.

Transportation lifeline systems include highways, railways, light rail, bus systems, ports, ferries, and airports. These can be further broken down into components such as highway bridges, segments, and tunnels or airport terminals and runways.

The utility lifeline systems inventory includes potable water, wastewater, electric power, communications, oil, and natural gas information for pipelines and facilities. Due to post-911 security issues, most utility pipeline information has been removed from the mapping tables but is still present for damage analysis.

The population and demographic inventory for HAZUS is from the 2000 U.S. Census. Each county is broken down into census tracts, and information is available about population, number of households, age distribution, gender, race, household income, population distribution during daytime versus nighttime, renters versus house owners, construction dates of residential units, property value, and student population. Some of this information may seem superfluous, but it is vital for social earthquake loss estimates such as displaced households and people seeking public shelter. The HAZUS model is based on statistical behavior of certain gender and age groups during actual earthquakes, along with renter versus owner willingness to leave damaged structures.

As thorough as HAZUS default databases are, there are additional data types that are missing from inventories. High potential loss facilities such as dams and nuclear power plants are not included because more detailed engineering information would be needed to make accurate loss estimates. Military facilities are also missing but would add significant dollar amounts to loss estimates in regions such as Colorado Springs. New buildings, constructed after 2000, are not in the dataset. Explosive growth throughout Colorado is therefore not accurately portrayed in these preliminary scenarios. HAZUS allows for inventory improvements by including building inventory tools and advanced engineering modules where the user can add region-specific inventories. The loss estimates presented in this report use only the default datasets but could be improved through inventory streamlining in the future.

2c. Analysis

The scenario results and maps presented in this report represent three years of HAZUS analysis by CGS for the state of Colorado. As improvements in the HAZUS software became available, scenarios were re-run to create the best possible loss estimates with the inventories provided. CGS added Colorado-specific data in the form of soil maps and landslide maps, so our scenarios represent a Level 2 hazard analysis as described on the FEMA website (**Figure 4**).

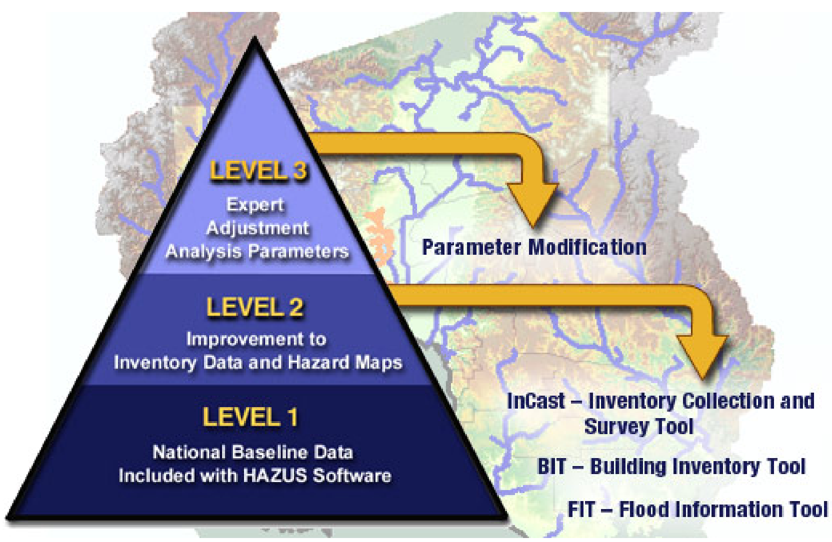

Figure 4 - From FEMA's HAZUS Overview, http://www.fema.gov/hazus/hz_overview.shtm.

Because earthquake probability is poorly understood in Colorado, CGS chose to run deterministic scenarios. These essentially describe what would happen if an earthquake were to occur with a specific epicenter and magnitude. Deterministic scenarios gave us the opportunity to analyze potential earthquake consequences throughout the state, along actual faults as well as randomly chosen epicenters. This report includes three types of scenarios: state-wide scenarios for maximum credible earthquakes (MCE's) on selected faults, county scenarios for epicenters selected in the center of each county, and county "worst-case scenarios" for MCE events on selected faults that result in the highest losses in each county.

Parameters chosen for each scenario include latitude and longitude of the earthquake epicenter, earthquake magnitude, fault geometry, type of fault motion (normal, reverse, strike-slip), and attenuation function. Attenuation is a measure of how seismic waves are dampened with distance from the epicenter, and its rate changes according to rock type, density, and variation in the crust. This attenuation function has turned out to be a central factor in Colorado earthquake modeling because Colorado lies in a poorly understood zone between what is characterized by the USGS as the Western U.S. (WUS) zone and the Central Eastern U.S. (CEUS) zone. According to the USGS seismic hazard mapping program, most of Colorado lies in the CEUS attenuation zone and only the Rio Grande Rift zone in the San Luis Valley lies in the WUS zone (**Figure 5**). We have therefore used the CEUS function for all of our scenarios except for the five counties in and around the San Luis Valley (Alamosa, Conejos, Costilla, Rio Grande, and Saguache) and the major North Sangre de Cristo fault that borders the valley.

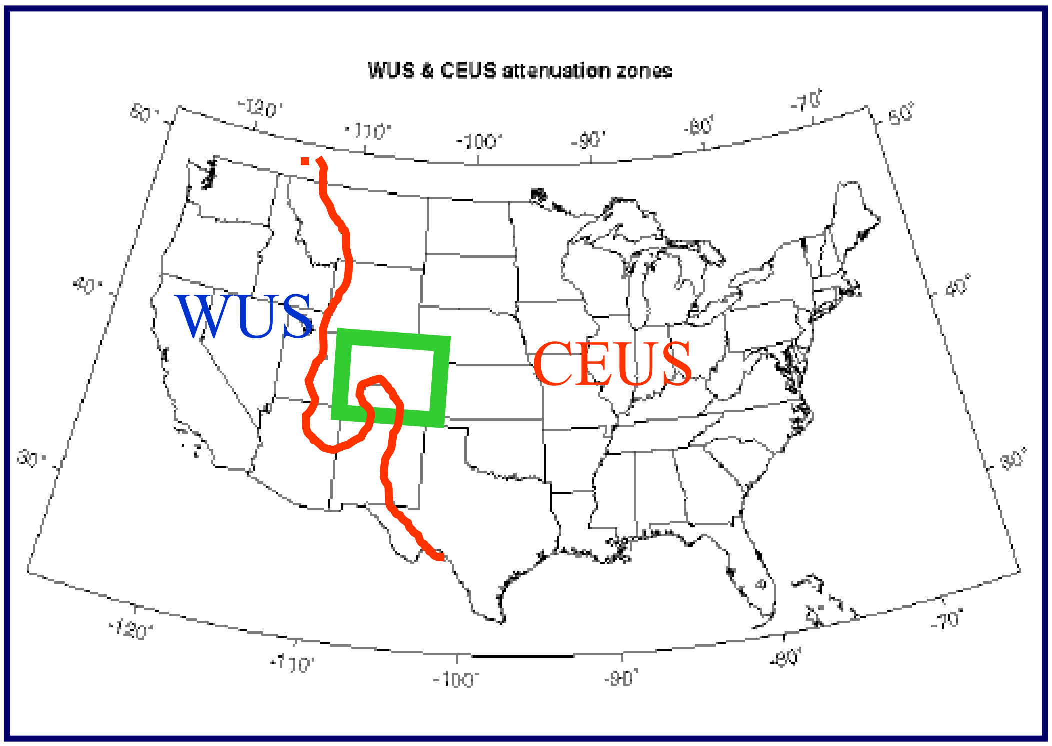

Figure 5 - From USGS documentation for the 1996 Seismic Hazard Maps, http://earthquake.usgs.gov/research/hazmaps/publications/hazmapsdoc/june96doc.html

CGS obtained and modified soil and landslide maps to more accurately portray ground behavior in an earthquake. We derived our soil map from the state geologic map by Ogden Tweto (USGS, 1979). Rock types were classified into 5 groups, following 1997 NEHRP and Universal Building Codes (hard rock, rock, very dense soil and soft rock, stiff soils, and soft soils). HAZUS could then calculate ground shaking based on rock and soil class more accurately than with its default single soil type. CGS also imported landslide maps in an effort to portray ground failure due to shaking, especially in the many steep landslide-prone areas of our state. We classified regions on the landslide maps to correspond with susceptibility values that HAZUS would recognize. Unfortunately the landslide maps did not appear to significantly affect results. The soil maps, however, play a major role in determining ground shaking patterns and damage, as can be seen on the Peak Ground Acceleration (PGA) maps included in this report.

The faults and epicenters chosen for this study include 18 mapped Quaternary faults and two epicenters from historical earthquake events (**Figure 6**). Faults were chosen for HAZUS scenarios based on field studies of greater detail compared to other faults, proximity to highly populated urban areas, or mapped lengths that correspond to high MCE magnitudes. (See **Appendix B** for details about faults and epicenters chosen for analysis.)

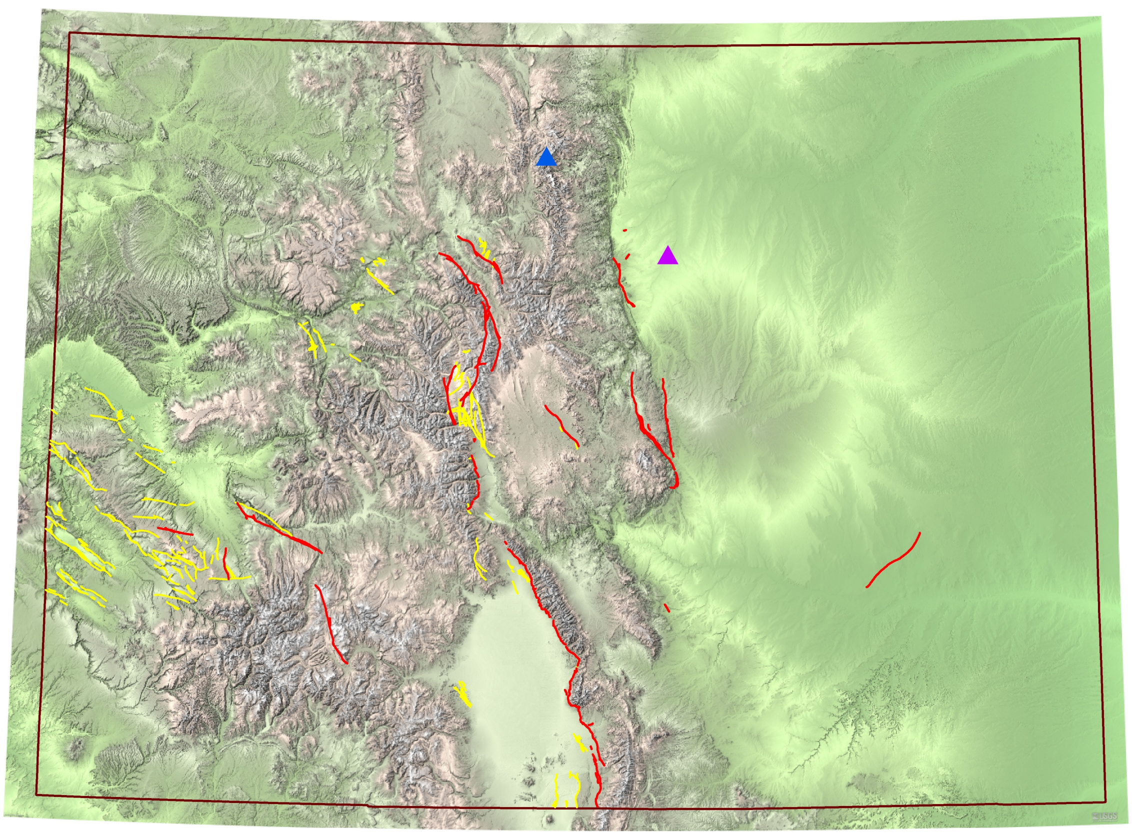

Figure 6 - Known Quaternary faults (yellow) and selected Quaternary faults for HAZUS scenarios (red). Two historical epicenters, the Rocky Mountain Arsenal Epicenter (purple triangle) and the 1882 Rocky Mountain National Park Epicenter (blue triangle) were also included in scenarios.

2d. Explanation of Results

HAZUS is capable of producing a variety of results depending on the modules that are chosen during analysis. These results can then be viewed through automatically generated reports or mapped to the desired degree of detail. Results are organized into categories of direct physical damage (to buildings, essential facilities, transportation systems, utility systems), induced physical damage (debris generated, fires ignited, inundation, HazMat contamination), direct economic losses (all inventory value lost and repair costs), indirect economic losses (loss of income generation), and social losses (casualties, displaced households, and shelter needs).

2d.i. Results Tables

The summary tables provided in this report (**Appendices C and D**) show scenario results that CGS believes are most important. Our results are not stated as ranges because they are estimates, and a certain degree of uncertainty is assumed to be part of any such estimate. These assumptions are further addressed in the next section. In the summary tables, **Economic Loss** is stated in millions of dollars and is the sum of building, utility, and transportation direct economic loss estimates. **Economic Loss Ratio** is a percentage calculated by dividing total economic loss by the region's total inventory value, then multiplying by 100. This loss ratio often provides a more relevant figure for representing the direct economic impact of a disaster. **Buildings with at least Moderate Damage** estimates the number of buildings with a probability of damage state at the moderate level or above (see **Appendix F** for descriptions of building damage states). Also provided is the percentage of moderately or greater damaged buildings in relation to the total number of buildings in a given region, illustrating the regional effects of an earthquake. **Casualties Requiring Hospitalization** is a sum of Severity Levels 2, 3, and 4 estimated by HAZUS (**Table 2**).

Table 2 – Injury Severity Levels

Injury Severity Level	Injury Description
Severity 1	Injuries requiring basic medical aid that could be administered by paraprofessionals. These types of injuries would require bandages or observation. Some examples are: a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness. Injuries of lesser severity that could be self treated are not estimated by HAZUS.
Severity 2	Injuries requiring a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life threatening status. Some examples are third degree burns or second degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration or exposure.
Severity 3	Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. Some examples are: uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.
Severity 4	Instantaneously killed or mortally injured

From HAZUS Technical Manual, Chapter 13.

The program calculates casualties for three times of day: 2am, 2pm, and 5pm to represent populations in various infrastructure types at nighttime, daytime, and commuting time. Our summary tables include the Level 2-4 sum for the time of day with greatest casualties, which varied between regions and scenarios. Casualty estimates take into consideration building type and occupancy during these different times of day, potential highway bridge occupancy, as well as statistics from previous earthquakes. **Displaced Households** is an estimate of the number of households that will vacate their residence due to loss of building function, habitability, *perceived* habitability, or utility functionality. These households will need to find alternative short-term and possibly long-term shelter. The number of **People Seeking Public Shelter** is also estimated and included in our summary tables because this number is extremely important to emergency response organizations. HAZUS estimates are based on statistics showing that only a portion of displaced persons will seek public shelter due to the availability of friends' and family members' homes, hotels, or vehicles for short-term shelter. Statistics also show that most pre-disaster homeless will seek public shelter, and that people living in single-family homes are more likely to tolerate damage and stay in their homes than those renting parts of multi-family structures. **Households without Water** estimates the number of households that will not have running potable water through calculations of damage state probabilities and functionalities for potable water facilities and pipelines. **Households without Electric Power** considers damage probabilities and functionalities for electricity facilities and distribution circuits. Zeroes that are present in these final two columns bring to light the incomplete and patchy nature of the default inventory. Many counties do not have sufficient water or power inventory information to form an accurate estimate.

2d.ii. Reports

Automatically-generated reports can be saved following each HAZUS scenario. These reports can focus on specific types of damage or can include all modules that were analyzed. CGS saved a Global Summary Report for each scenario run. An example summary report is included in **Appendix G**. Since these reports are approximately 20 pages each, we have chosen to not include them all. Instead, results were extracted and compiled into our results tables as described in the previous section.

2d.iii. Results Maps

The organization of HAZUS into ArcView GIS software allows the user to map an impressive variety of results. Any inventory item, imported hazard map, or loss estimate calculation completed by HAZUS can be mapped. Since inventories and results are organized into data tables, loss estimation results can also be displayed as spreadsheets.

Included in this report are statewide maps showing peak ground acceleration (PGA) in colored grid cells for each fault and epicenter analyzed. **Figure 7** is an example of one PGA map; the full collection of statewide PGA maps is in **Appendix C**. PGA values are expressed in %g, where *g* is acceleration due to gravity. For example, the maximum PGA represented on a map might be 1.25, which means that the most violent ground shaking was 125% of the force produced by gravity. Forces this strong are able to toss objects into the air. Yellows, oranges, and reds on the PGA maps represent ground acceleration values in excess of 20%g, usually the threshold for structural damage. Ground shaking is obviously strongest in areas closest to the epicenter and ruptured fault, but patterns are also evident that correspond to soil types that CGS imported into HAZUS. Softer soils amplify seismic waves and perform poorly for foundations when compared to solid rock. The blue-to-red prismatic color ramp was used throughout all of our PGA maps, but specific color shades correspond to slightly different values to accommodate the variety between scenarios.

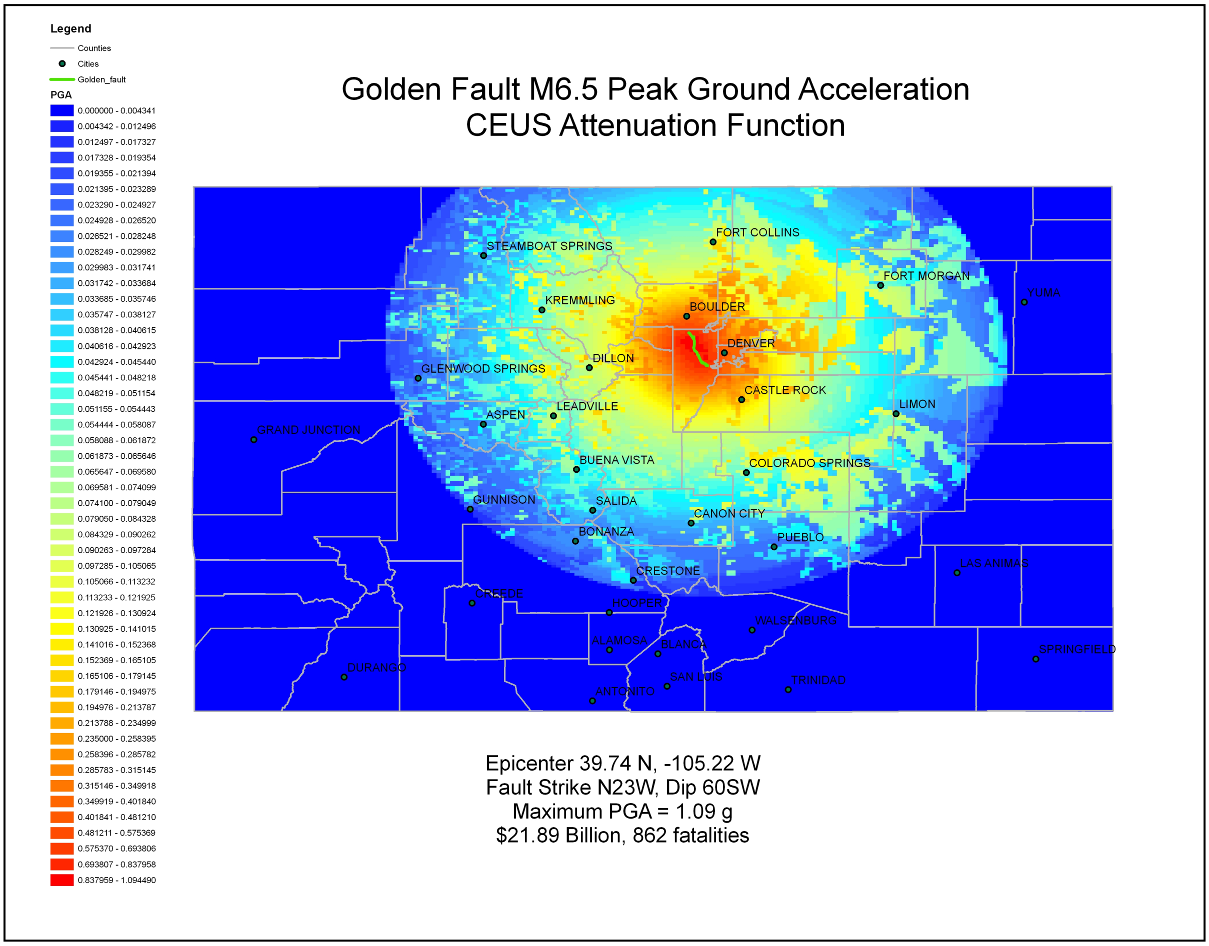

Figure 7 – Sample PGA map for a scenario on the Golden Fault, Magnitude 6.5.

For scenarios at the county level, maps are included in this report (**Appendix E**) that show damage to a variety of facilities and losses within census tracts. A similar blue-to-red color ramp was used when mapping facilities, with oranges and reds representing more damage. Given the exhaustive possibilities for mapping HAZUS results, we have chosen a standard set of results to map for each county. Facilities illustrated on county scenario maps are: schools, hospitals, fire stations, and police stations; highway bridges; airport facilities; waste water facilities; electric power facilities; and building-related economic loss per census tract. Values that are mapped for each facility represent the probability that structural damage will be extensive or greater (see **Appendix F** for descriptions of damage states). Each map legend contains a label "Probability Damage > Extensive" and a list of percentage values. Facilities mapped as red symbols have a 50% chance or higher of sustaining extensive to complete damage for the earthquake magnitude and epicenter with which they are mapped. We chose to map the probability of damages being at least extensive rather than "at least slight" or "at least moderate" because structures that sustain extensive damage are likely to be structurally unsafe and will require partial to total rebuilding. Mapping worst-case facility damage for worst-case earthquake scenarios allows for visualization of the full impact of what is possible. Counties consisting of more than one census tract also have a map showing building-related economic loss per census tract. Census tract polygon colors range from gray to red to illustrate low to high amounts, respectively, of monetary loss due to damaged buildings and loss of business activity within those buildings. Economic losses are stated in thousands of dollars, so $650250 in a map legend means that a census tract sustained over $650 million in losses.

2e. Assumptions and Limitations

It is important to understand that HAZUS is a loss *estimation* methodology and that uncertainties are inherent in this type of analysis. Earthquake engineers and scientists continue to learn about earthquakes and their effects on buildings and societies. Any modeling effort such as this requires simplifications and approximations of reality for scenario analyses to be possible. Incomplete, inaccurate, or outdated inventory and demographic data also add to the uncertainty of results. Uncertainty in loss estimates provided by HAZUS are off by *at best* a factor of two and possibly greater. The soil maps added into our scenarios increase accuracy of results, but the lack of up-to-date region-specific inventories and the unknowns surrounding our choice of attenuation function keep uncertainty levels high. Only a real earthquake event in the state will truly test loss estimation results. Nevertheless, aggregate results such as total economic loss and numbers of casualties still provide a credible estimate of the potential consequences of an earthquake in Colorado.

Uncertainty is also introduced with the understanding that maximum credible earthquake (MCE) magnitudes used in HAZUS scenarios are calculated from mapped fault lengths. The longer the fault, the larger the MCE magnitude. These MCE magnitudes are possible if the entire fault length ruptures in a single earthquake event. Many longer faults such as the Sangre de Cristo Fault in Colorado, the Wasatch Fault in Utah, and the San Andreas Fault in California are actually combinations of many smaller fault segments. History has shown that large portions of a fault can rupture in a single event, such as the 1906 San Francisco Earthquake that offset 290 miles of the San Andreas Fault (http://quake.wr.usgs.gov/info/1906/index.html). However, it is more probable that fault segments will rupture in separate smaller earthquake events. Behavior of faults in Colorado is so poorly understood that CGS feels it is safe to use MCE magnitudes obtained from mapped fault lengths.

A similar fault-related simplification was introduced by our choice of earthquake epicenter at the midpoint of each fault. An earthquake's epicenter, the location where a fault initially ruptures, is not a predictable point nor is it statistically shown to usually be at the midpoint or endpoints of faults. On longer faults, the epicenter location can have a large effect on damages and losses that result because ground shaking is most violent in the area immediately around the epicenter. If an epicenter is located in a downtown area of a highly populated city, more damage will result than if the epicenter had been out in rural farmlands, even when the same fault was responsible for the earthquake. Our choice of a fault's midpoint for each scenario epicenter is a simplification necessary for large numbers of scenarios to be run. (See **Appendix B** for further discussion of epicenters.)

The scenario results and maps presented in this report should therefore be viewed as approximations of what could be possible in an actual earthquake. Maps showing probabilities of damage to various facilities are meant to illustrate how emergency response capabilities and utility functionality could affect a county. Maps showing ground shaking show the regional extent and possible patterns of damaging ground motions. Numbers presented in our summary tables should be considered as our best estimates-to-date. County and city planners should recognize that results calculated by HAZUS could be *overestimates or underestimates* of what could actually occur.

3. Statewide Scenarios and Ground-Shaking Maps

With the most recent version of HAZUS-MH and improved computer processing speed, we were able to run scenarios with all Colorado counties at once. We ran these statewide scenarios for MCE's centered on midpoints of selected faults and for the historical epicenters from the 1882 Earthquake and Rocky Mountain Arsenal earthquakes. HAZUS computes ground shaking using a calculation involving attenuation function, soil type, and distance away from the epicenter. Its radius of ground shaking extends to approximately 200 km away from a fault rupture, and this elliptical radius is visible on the ground acceleration (PGA) maps included in **Appendix C**. With all counties included in these scenarios, ground shaking and its associated damages is calculated in any affected county and added to the total loss estimate. These loss estimates are summarized in the Statewide Summary Table in the appendix and are ranked by total economic loss in **Table 3** below.

The severity ranking in Table 3 illustrates how faults that are close to urban centers in the Front Range are capable of causing much higher losses than those in less populated areas. Smaller earthquake magnitudes such as a M6.5 on the Golden Fault can cause greater damage than larger magnitudes such as a M7.5 on the N Sangre de Cristo Fault solely because of the proximity of the fault to high-inventory regions. This illustrates the concept of seismic *risk* versus *hazard*. Seismic hazard is associated with ground shaking probabilities while seismic risk considers the population and built environment that could sustain losses due to ground shaking. Colorado's Front Range carries a high seismic risk but a highly uncertain seismic hazard.

Loss estimates for statewide scenarios also illustrate the large impact that attenuation function has on scenario results. The N Sangre de Cristo fault is the only fault in Colorado that lies within the WUS attenuation zone according to the USGS (**Figure 5**). It is also Colorado's longest fault (128 miles) and one of the few that displays evidence of Holocene movement (within the past 15,000 years). This fault has the potential to create the highest ground shaking in Colorado, with a MCE magnitude of 7.5. When computed with a WUS attenuation function, the N Sangre de Cristo Fault is estimated to cause $767 *Million* in total economic loss. When computed with a CEUS attenuation function, the loss estimate jumps to $8.02 *Billion*. This is over 10 times greater than losses estimated with the WUS function! The CEUS-WUS discrepancy is echoed in other scenarios to a lesser degree where CEUS results are, on average, 3 to 4 times greater than WUS results. Clearly, an attenuation function appropriate for Colorado is sorely needed before seismic characteristics can be understood and predicted in this state.

Table 3 – State-wide Scenario Rankings

Rank	Fault	Earthquake Magnitude	Economic Loss in State
1	Rampart Range	7	$23.1 Billion
2	Golden	6.5	$21.9 Billion
3	Ute Pass	7	$16.8 Billion
4	Rocky Mountain Arsenal	6.25	$14.9 Billion
5	Walnut Creek	6	$9.70 Billion
6	N Sangre de Cristo	7.5 CEUS	$8.02 Billion
7	Frontal	7	$6.73 Billion
8	Mosquito	7	$6.19 Billion
9	South Sawatch	7.25	$4.74 Billion
10	Chase Gulch (East-Side)	6.75	$3.76 Billion
11	North Sawatch	7	$3.62 Billion
12	Williams Fork	6.75	$3.48 Billion
13	1882 Rocky Mtn National Park	6.6	$2.76 Billion
14	Cheraw	7	$1.26 Billion
15	Cimarron	6.75	$808 Million
16	N Sangre de Cristo	7.5 WUS	$767 Million
17	Valmont	5	$712 Million
18	Busted Boiler	6.5	$694 Million
19	Cannibal	7	$675 Million
20	Goodpasture	6	$479 Million
21	Roubideau Creek East	5.5	$94.2 Million

See Appendix C summary table for further details on statewide scenario results.

4. Random Earthquakes by County

4a. Purpose of Random Earthquake Scenarios

Earthquakes inherently carry a high degree of uncertainty, not only in time but also in location. Regions that receive a lot of attention from seismologists and geologists can still bring surprises, such as the 1999 Hector Mine M7.1 earthquake in California that occurred along a fault that was not considered to be active (no evidence of rupture within the past 10,000 years -http://pasadena.wr.usgs.gov/hector/report.html). Many historical earthquakes in the United States have occurred far away from plate boundaries where faults still have not been mapped over 100 years later. Examples include the 1886 Charleston, South Carolina earthquake with an intensity (MMI) of X; the 1755 Cape Ann/Boston, Massachusetts earthquake with MMI of VIII; and the 1811-1812 New Madrid, Missouri earthquakes with estimated magnitudes up to M8.1. And we cannot forget our very own 1882 earthquake that occurred somewhere near Estes Park at an estimated magnitude of M6.6. Since a seismometer network was not in place in the 1800's (and still is lacking in Colorado), the epicenter of the 1882 earthquake is extremely difficult to pinpoint. Our state's largest historical earthquake, therefore, is not associated with any known fault and may never be understood well enough to be accurately located.

Uncertainties and surprises in earthquake occurrences have led the USGS to include what they call "Background Source Zones" when calculating and creating their national seismic hazard maps. The Rocky Mountain region is a zone of interest because of its extremely short record of historical seismicity. Including a background, or random, earthquake source in hazard mapping is a way of saying that a region has the potential for damaging earthquakes even if significant earthquakes have not occurred very often in the past.

4b. Colorado's Random Earthquake Scenarios

CGS has run HAZUS scenarios for this random (background) earthquake in each Colorado county (see summary table in **Appendix D** and maps in **Appendix E**). Each scenario was run for a M6.5 event with an epicenter located in the geographic center of the county. The fault geometry for each scenario assumed a N30°W fault strike (its mapped alignment relative to North) and a 60°SW dip (the subsurface steepness of the fault plane, with 0° being horizontal and 90° being vertical). Normal faulting was chosen as the type of displacement for each scenario. We chose these parameters because most faults that have been studied in Colorado are normal faults oriented towards the northwest, with relatively steeply-dipping fault planes. A magnitude of 6.5 was chosen to portray consequences of a significant but highly uncertain event.

Due to the variation in urban center distribution within each county, loss estimates using a random epicenter at each county's geographic center yielded a variety of results. Counties such as Denver, Mesa, and Pueblo have cities located close to their geographic centers, which resulted in devastating HAZUS loss estimates.

These random earthquake scenario results serve to illustrate potential consequences of earthquakes from unknown sources. We have included a random scenario for each county in Colorado because many counties are not within the radius of damage from an actual fault analyzed in HAZUS. Fault locations and characteristics are so poorly understood in Colorado that there could quite easily be other faults that do not reach the surface, or have not yet been discovered or recognized as active. The USGS uses background, or random, earthquakes in their seismic hazard analyses, so a thorough analysis in Colorado should be equally as inclusive.

5. Worst-Case Scenarios by County

5a. Why a Worst-Case Scenario?

The majority of HAZUS scenarios performed by CGS were deterministic scenarios for county-level regions analyzed with parameters for actual faults. Our sources for potential seismicity included eighteen faults and two epicenters from historical earthquakes (see **Appendix B**). For the faults and fault scarp, we selected epicenters at the midpoint of each fault trace, recognizing that this is a simplification because fault rupture could initiate anywhere along a fault. Whenever possible, we used fault geometry derived from field studies of each fault to ensure that HAZUS calculations involved realistic information.

We organized scenarios by fault or epicenter, running scenarios for county regions that would be affected by the 200-km radius of ground shaking that HAZUS allows. Earthquake magnitudes for each fault-county combination included the MCE derived from fault length and incrementally smaller magnitudes down to M5.0, the lowest allowable HAZUS magnitude. Lower magnitudes yielded results that are valuable in light of the higher probability attached to lower magnitude events. However, we have included only results from the MCE magnitude scenarios in this report to illustrate worst-case, yet possible, scenarios. Region-specific scenarios showing the range of loss estimates from different magnitudes can be performed for local governments if desired. Due to high uncertainties in our understanding of earthquake probabilities in Colorado, scenarios and maps that visualize worst possible situations can inform emergency managers and planners that there is too much at stake for seismic hazards to be ignored.

5b. Scenario Results

Appendix D includes the Earthquake Summary Table showing random earthquakes and at least one worst-case scenario earthquake for each county. Some counties contain several faults or are close enough to several faults that two or more worst-case scenarios were included in the table. **Table 4** contains a ranking of worst-case county scenarios based on the Economic Loss Ratio. As explained above, this ratio is a percentage of a region's total inventory value (buildings, transportation, and utilities) that is lost during an earthquake. Ranking scenarios by loss ratio is a more accurate depiction of the impact that a disaster can have on a county level than pure dollar amounts of economic loss, since county inventory values vary so widely. $500 million lost in Denver County has an entirely different effect than $500 million lost in Hinsdale County. The scenarios included in Table 4 are only those with loss ratios greater than 10%.

Table 4 – County Scenario Rankings by Loss Ratio

Rank	County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)
1	Summit	Frontal	7.00	1,345.36	32.15%
2	Chaffee	S Sawatch	7.25	665.16	28.26%
3	El Paso	Rampart	7.00	9,013.76	27.67%
4	Lake	N Sawatch	7.00	302.50	27.53%
5	Lake	Mosquito	7.00	298.86	27.20%
6	Teller	Ute Pass	7.00	523.85	26.83%
7	Summit	Mosquito	7.00	1,056.71	25.26%
8	El Paso	Ute Pass	7.00	8,216.92	25.23%
9	Alamosa	N Sangre de Cristo	7.5 CEUS	433.09	23.54%
10	Denver	Golden	6.50	7,510.48	19.24%
11	Chaffee	N Sangre de Cristo	7.5 CEUS	425.76	18.09%
12	Jefferson	Golden	6.50	5,881.32	16.42%
13	Custer	N Sangre de Cristo	7.5 CEUS	138.38	15.77%
14	Adams	Rocky Mtn Arsenal	6.25	3,148.06	14.97%
15	Denver	Rocky Mtn Arsenal	6.25	5,557.58	14.24%
16	Otero	Cheraw	7.00	415.54	14.16%
17	Douglas	Rampart	7.00	1,848.03	13.49%
18	Ouray	Busted Boiler	6.50	104.19	13.33%
19	Montrose	Cimarron	6.75	497.40	13.18%
20	Arapahoe	Golden	6.50	3,900.99	12.10%
21	Denver	Rampart	7.00	4,652.06	11.92%
22	Arapahoe	Rampart	7.00	3,835.78	11.90%
23	Eagle	Frontal	7.00	571.47	11.40%
24	Fremont	N Sangre de Cristo	7.5 CEUS	393.64	10.47%
25	Hinsdale	Cannibal	7.00	35.15	10.12%

Scenarios for the North Sangre de Cristo fault included in Table 4 were run with a CEUS attenuation function. We analyzed counties in the San Luis Valley for both CEUS and WUS functions, and due to the discrepancy in ground shaking produced by the two functions, the CEUS scenarios always resulted in greater losses.

6. Use of HAZUS Loss Estimates

6a. Ignorance is NOT Bliss

The statewide, random county, and worst-case county scenarios presented in this report illustrate the magnitude of destruction and loss that could result from strong earthquakes in Colorado. These scenarios are hypothetical, but at the same time they represent our best knowledge-to-date about what *could* happen in our state. Until further fault studies increase our understanding of earthquake probabilities, these HAZUS scenarios are our only source of information about potential seismic impacts throughout the state.

Areas such as Colorado, with a sparse record of historical earthquakes, are especially prone to voluntary ignorance about seismic hazards. It is easy and comfortable to assume that because our state has had only one significant earthquake (the 1882 M6.6 in northern Colorado) since settlement, we do not have a seismic hazard worthy of much attention. It is also assumed that since Colorado is hundreds of miles away from the closest plate boundaries, we will not experience much movement of the earth's crust. But it is precisely regions such as Colorado that could sustain considerable losses from an earthquake because we are not prepared. The purpose of these HAZUS scenarios was to increase awareness of realistic potential consequences *and* to use this information to better prepare for a disaster.

6b. Mitigation, Preparedness, Response, and Recovery

Natural hazards mitigation involves organized efforts to reduce long-term risks to people and property. The goal of mitigation is to save lives, keep lifelines functional and intact, and keep buildings as undamaged and accessible as possible. Earthquake hazards mitigation actions include upgrading or retrofitting buildings, planning proper land use, changing and enforcing building codes, and identifying vulnerable facilities (Table 5). Prioritization of mitigation strategies is necessary for them to be realistically implemented. HAZUS scenarios can be powerful tools for evaluating cost effectiveness of different mitigation efforts. Scenarios at the county or city level can estimate losses before and after hypothetical building retrofitting, and the changes in loss estimates can be weighed against the cost of retrofitting. This application of HAZUS could be useful throughout Colorado where many historical buildings are made of unreinforced masonry, a building type proven to perform very poorly in earthquakes. Scenarios can similarly be run before and after hypothetical building code changes to see how higher seismic building codes for all building types would reduce risk. FEMA has prepared an excellent publication titled "A Guide to Using HAZUS for Mitigation" that can be downloaded from http://www.fema.gov/hazus/pdf/hazus_for_mitigation.pdf for further information.

Table 5 – Potential Uses of HAZUS for Mitigation

Uses of HAZUS	Type of Loss Estimate	Data Requirements	Audience	Output	Comments
1. Raise public awareness of earthquake threat and consequences	Regional Scenario	Level 1 or Level 2 with soils map	General public, elected officials, emergency managers, land use planners	Casualties, economic loss	
2. Create political under-standing and build constituen-cies	Local or Regional Scenarios	Level 2, soils map, building inventory, regional utilities or transportation systems	General public, elected officials, emergency managers, land use planners	Casualties, utility disruption, regional transportation damage dollar loss	
3. Understand relative risk, planning, siting, and access issues	Local or Regional Scenarios	Level 2, detailed geology, lifelines, transportation	Land use plan-ners, regional agencies, growth management agencies, utilities	Peak Ground Acceleration (PGA)/ Peak Ground Velocity (PGV)/ Peak Ground Deformation (PGD)	Requires input from a geologist
4. Understand extent of injuries and fatalities	Multiple Scenarios	Level 2, detailed geology and building inventory, essential facilities, schools, hospitals	Medical agencies, emergency managers, risk managers	Casualties by structure type	Requires input from a geologist
5. Assess performance of emergency shelters	Local Scenario	Level 2, detailed geology and building inventory	Land use plan-ners, risk manag-ers, emergency planners	Structural damage	Requires input from a geologist
6. Assess performance of fire stations	Local Scenario	Level 2, detailed geology, fire station inventory, water system	Fire officials, emergency managers, planners	Number of ignitions, area burned, essential facilities damage, water utility damage	Requires input from a geologist, water system engineer, struc-tural engineer to classify structures
7. Identify infrastructure vulnerability	Regional Scenario	Level 2, detailed geology and building inventory	Utility companies, emergency planners, transpor-tation agencies	Utility damage and recovery, transpor-tation system damage	Requires input from a geologist, structural engi-neers and archi-tects
8. Understand overall building damage	Local Scenario	Level 2, detailed building inventory, essential facilities, schools, hospitals	Land use plan-ners, elected officials, emer-gency and facility managers	Damage by building type and location, utility, transportation system damage	Requires input from engineers, architects, building officials and planners
9. Set mitigation program priorities	Local Scenario	Level 2, detailed geology, building inventory	Land use plan-ners, risk manag-ers, fire safety officials	Multiple runs of building damage	Requires input from a geologist, structural engi-neers and archi-tects

From FEMA's Guide to Using HAZUS for Mitigation, 2002.

Reducing earthquake losses must begin before the earthquake. In addition to mitigation efforts, proper preparedness can help reduce the impact and severity of a disaster. Emergency managers can use HAZUS loss estimates to increase their understanding of the scope of damages in their region. Probabilities of damage and functionality of essential facilities can help emergency personnel realize current limitations and formulate emergency response plans. Projected numbers of casualties can help predict demand on medical resources. Estimates of displaced households and people seeking public shelter can assist planners in organizing shelter availability and readiness. Projected patterns of water shortages and power outages can help emergency response personnel to set priorities for effective recovery.

In the event of an earthquake, HAZUS scenarios can provide rapid estimates of projected losses for emergency responders and government agencies. Estimates of dollar losses can help State and Federal governments plan for immediate and long-term assistance. HAZUS-generated maps can provide guidance about areas where greatest damages are likely to be and can show the probable functionality of essential facilities shortly after the earthquake. The exposure of utility and transportation lifelines to ground shaking can be mapped, along with the distribution of probable economic losses in the affected region. Induced effects of an earthquake, such as debris generated and fires ignited, can also be estimated to help response and recovery efforts.

6c. Customized HAZUS Scenarios

The scenarios included in this report are a standardized set of desktop exercises intended to motivate interest in more detailed region-specific scenarios. The accuracy of a HAZUS loss estimate is only as good as the inventory being used, and only the national default dataset has been used so far with Colorado scenarios. The best way to improve HAZUS results would be to update building, utility, transportation, and demographic inventories for county- or city-level regions. Considering Colorado's explosive growth rate, county scenarios along the Front Range would especially benefit from updated inventories. Since data currently being used is from the year 2000 Census, six years of urban growth is not represented in our loss estimates.

Other data missing from current inventories includes high potential loss facilities such as dams and power plants. Specific engineering parameters would be needed for these to be included in loss estimates, but for certain counties they would be valuable scenarios to consider. Colorado poses an interesting challenge to loss estimates related to water reservoirs, dams, and pipelines due to the extensive pipeline network bringing water from the Western Slope to the Front Range. Earthquakes in the western and central mountains could potentially affect the Front Range water supply if pipelines were disrupted. Military facilities are also missing from the inventory and would add to potential losses in certain counties.

CGS has the capability to perform a variety of customized scenarios for local governments if requested. In addition to inventory improvements listed above, these region-specific scenarios can include better soil and landslide susceptibility maps and can further experiment with attenuation functions. Mitigation scenarios such as cost-benefit analyses of building retrofitting would be useful tools for high-risk counties. Earthquake magnitudes lower than the maximum credible magnitude can be analyzed for a complete range of potential losses.

References and Links

Colorado Earthquake Information

Colorado Division of Emergency Management Earthquake Information:
http://www.dola.state.co.us/oem/PublicInformation/earthquake.htm

CGS Earthquake Homepage: http://geosurvey.state.co.us/Default.aspx?tabid=108

CGS Earthquake, Fault, and Fold Internet Map Server:
http://geosurvey.state.co.us/Default.aspx?tabid=270

Kirkham, R.M. and Rogers, W.P., 1999, Colorado earthquake information: 1867-1996: Colorado Geological Survey Bulletin 52, CD-ROM.

Kirkham, R.M. and Rogers, W.P., 1981, Earthquake potential in Colorado: Colorado Geological Survey Bulletin 43, 171 p.

Matthews, V., 2003, The challenges of evaluating earthquake hazard in Colorado, in Boyer, D.B., Santi, P.M., Rogers, W.P., Engineering Geology in Colorado – Contributions, Trends, and Case Histories, Association of Engineering Geologists Special Publication No. 15, 22p.

Matthews, V., 2002, We don't have earthquakes in Colorado do we?: RockTalk, Colorado Geological Survey, v. 5, no. 2, 12 p.
http://geosurvey.state.co.us/pubs/rocktalk/rtv5n2.pdf

Matthews, V., 1973, A reappraisal of the seismic-risk classification of Colorado: Mountain Geologist, v. 10, p. 111-115.

Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey, scale 1:500,000.

USGS Colorado Earthquake Information: http://earthquake.usgs.gov/regional/states.php?regionID=6&region=Colorado

USGS Earthquake Hazards Mapping Program:
http://earthquake.usgs.gov/research/hazmaps/products_data/48_States/index.php

Widmann, B.L., Kirkham, R.M., and Rogers, W.P., 1998, Preliminary Quaternary fault and fold map and database of Colorado: Colorado Geological Survey Open-File Report 98-8, 331 p.

HAZUS Background and Applications

California Geological Survey "Estimation of Future Earthquake Losses in California":
http://www.consrv.ca.gov/cgs/rghm/loss/index.htm

FEMA HAZUS Overview: http://www.fema.gov/hazus/hz_overview.shtm

FEMA Earthquake Model Overview: http://www.fema.gov/hazus/hz_eq.shtm

Guide to Using HAZUS for Mitigation:
http://www.fema.gov/hazus/pdf/hazus_for_mitigation.pdf

Helena, Montana HAZUS Analysis Project:
http://www.hazus.org/BigSkyHUG/Documents/Helena_Area_HAZUS_Analysis_Project.pdf

NIBS Program Overview: http://nibs.org/hazusweb/overview/overview.php

NIBS Earthquake Methodology: http://nibs.org/hazusweb/overview/pubs.php

Natural Hazards Center "Worst-Case Thinking, An Idea Whose Time Has Come":
http://www.colorado.edu/hazards/o/jan05/jan05a.html

Nevada Bureau of Mines and Geology Open-File Report 06-1:
http://www.nbmg.unr.edu/dox/of061/of061.htm

Southern California Earthquake Center Puente Hills Earthquake Study:
http://www.scec.org/research/050525puentehills.html

Wyoming Geological Survey Seismological Study:
http://www.wrds.uwyo.edu/wrds/wsgs/hazards/quakes/seischar/Platte.pdf

More references and links are found in Appendices.

HAZUS:
Appendix A

Appendix A
Earthquake Magnitudes and Intensities

The size and location of an earthquake can be measured through two different methods. ***Magnitude*** depicts the energy released by an earthquake, which is quantified by a network of seismographs around the world. Seismographs record the timing, strength, and types of seismic waves reaching them, and when at least three receive a signal the magnitude and origin of the waves can be determined. Earthquake magnitude is traditionally stated as Richter magnitude, where each number indicates local ground shaking 10 times stronger than the previous number. On this scale, M 3.0 is generally the threshold where an earthquake is felt, and M5.5 is the threshold where damage starts to occur. ***Intensity*** is a measure of an earthquake's effects upon people and property. Earthquake intensity is most commonly classified using the Modified Mercalli Intensity Scale that assigns a roman numeral to an event (**Table A-1**). Reports and observations obtained from newspapers, diaries, interviews, and inspections of structural damage and natural features are compiled for all areas where an earthquake was felt. Highest intensities are usually observed closest to the epicenter, but the entire pattern of observed intensities can reveal information about the nature of the earthquake (**Figure A-1**). Since instrumental recordings by modern seismographs were not available before the 1930's, studies of historical earthquakes rely on intensity values to better understand a region's earthquake history.

Table A-1: Modified Mercalli Intensity Scale

I	Not felt except by very few under favorable conditions.
II	Felt by only a few people at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt noticeably by those indoors, especially on upper floors of buildings. May not be recognized as an earthquake. Vibration feels like a truck passing by. Standing cars may rock slightly.
IV	Felt indoors by many, outdoors by some. At night, some people are awakened. Dishes, windows, and doors rattle. Feels like a heavy truck striking the building. Standing cars are noticeably rocked.
V	Felt by nearly everyone, with many awakened at night. Some dishes and windows are broken. Unstable objects are overturned. Pendulum clocks may stop. Trees might shake, and liquids might spill out of open containers.
VI	Felt by all, with many frightened. People have trouble walking. Some heavy furniture is moved and objects fall from shelves. Slight damage to structures, including cracked and fallen plaster.
VII	People have difficulty standing. Drivers can feel their cars shaking. Loose bricks fall from buildings. Slight to moderate damage in well-built buildings; considerable damage in poorly built structures.

VIII Drivers have trouble steering. Houses might shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Hillsides might slide if wet. Water levels in wells might change.

IX All buildings, including well-built structures, suffer considerable damage. Houses shift off of foundations. Some underground pipes are broken.

X Most buildings and foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown onto the banks of rivers and lakes. Large fissures can break ground. Railroad tracks are bent slightly.

XI Most buildings collapse. Many bridges are destroyed. Underground pipelines are destroyed. Railroad tracks are badly bent.

XII Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples.

(Table derived from USGS and FEMA descriptions of intensity)

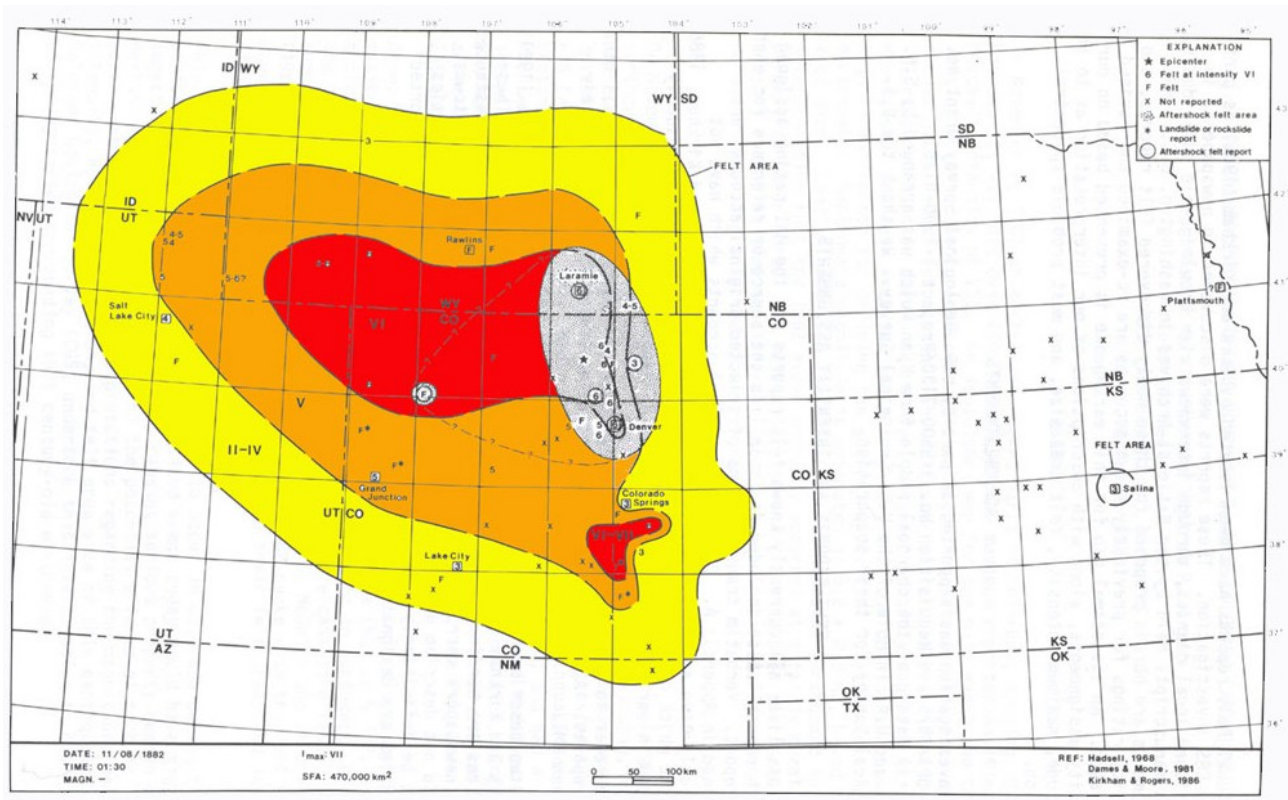

Figure A-1 – Sample Isoseismal Map, showing intensity contours for the 1882 Northern Colorado Earthquake, from Kirkham and Rogers (1986).

Ground shaking produced by an earthquake can also be depicted as Peak Ground Acceleration (PGA). This value is given in % g, or the percentage of gravitational force that a particle on the ground experiences during earthquake ground motions. PGA is an important measure of ground shaking because building codes incorporate a maximum allowed horizontal force that can be related to PGA. Relationships between earthquake intensity, potential damage, and PGA are not absolute but can be approximated (**Table A-2**). Ground acceleration is highly affected by surface material, with softer soils amplifying seismic waves up to two times greater than rock. Colors represented in the table are consistent with PGA values mapped for our statewide HAZUS scenarios.

Table A-2: Generalized Relationships Between PGA and Intensity

Perceived Shaking	Not Felt	Very Weak	Weak	Light	Moderate	Strong	Very Strong	Violent	Extreme
Potential Damage	None	None	None	Very Slight	Slight	Moderate	Extensive	Complete	Complete/Collapse
Peak Ground Acceleration (%g)	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
Modified Mercalli Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+

Additional Information:

USGS Earthquake Hazards Information:

- Measuring earthquake severity: http://pubs.usgs.gov/gip/earthq4/severitygip.html
- What is peak ground acceleration? http://earthquake.usgs.gov/research/hazmaps/haz101/faq/parm01.php
- What is %g and its relationship to building damage? http://earthquake.usgs.gov/research/hazmaps/haz101/faq/parm02.php
- Clickable list of earthquake topics: http://earthquake.usgs.gov/learning/topics.php

HAZUS:
APPENDIX

Appendix B
Colorado Faults Analyzed in HAZUS Scenarios

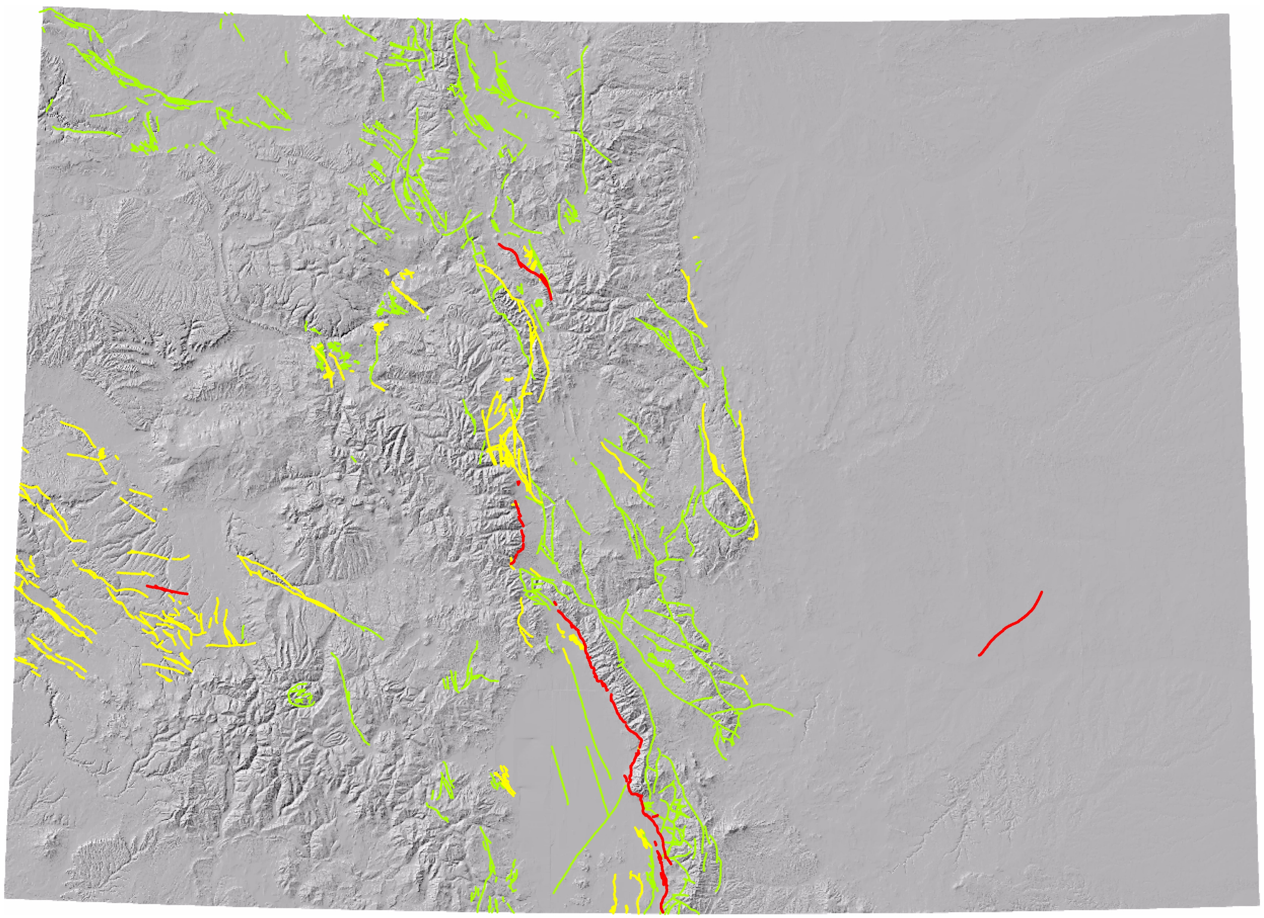

Figure B-1 – Digital elevation model with known Cenozoic faults (<65 Ma) in green, Quaternary faults (<1.6 Ma) in yellow, and Holocene faults (<15 Ka) in red. Ma = Million years ago, Ka = Thousand years ago.

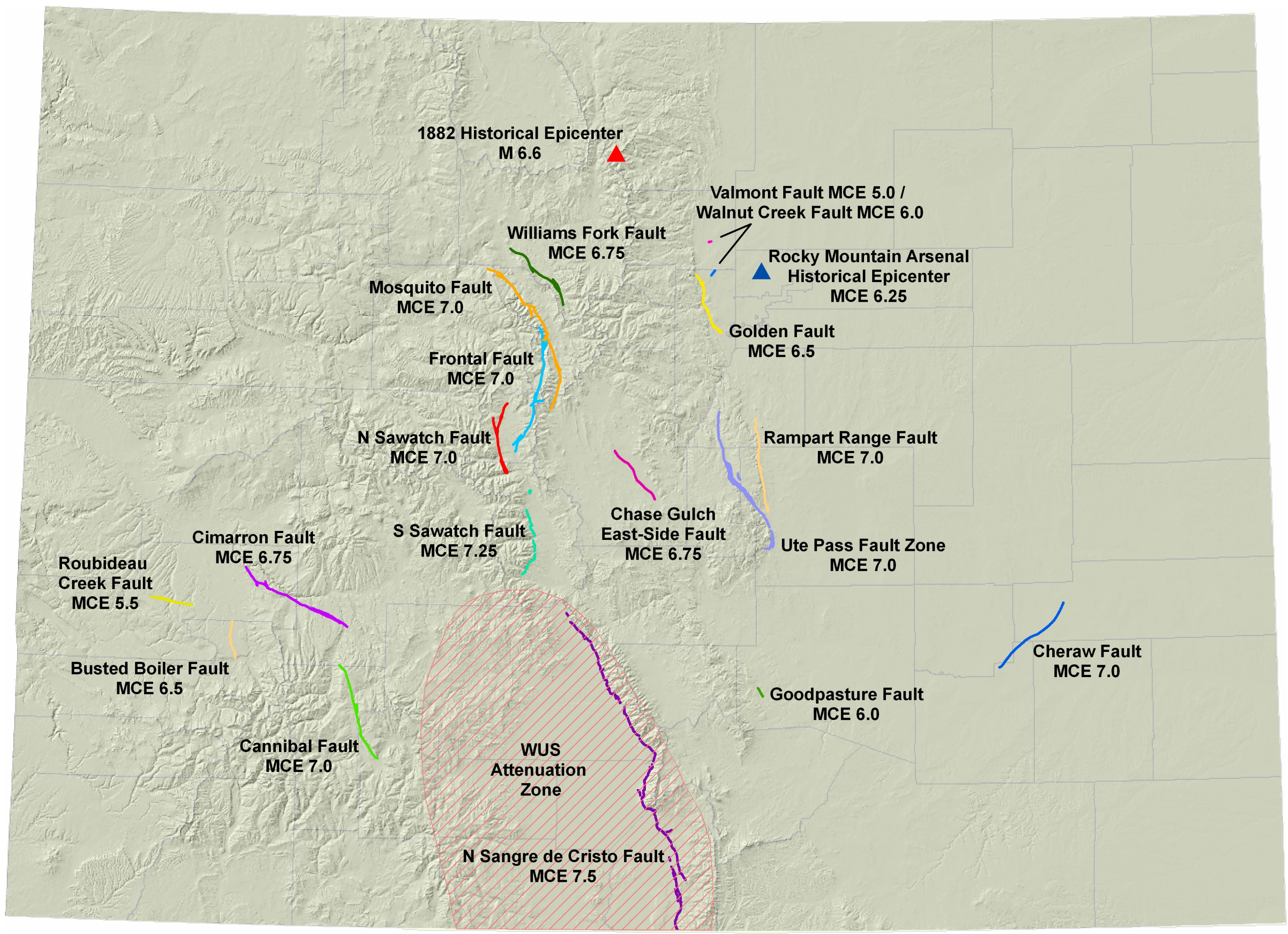

Figure B-2 – Faults included in HAZUS analysis were selected from Quaternary and Holocene faults. MCE is the Maximum Credible Earthquake tor each fault. The San Luis Valley comprises the WUS Attenuation Zone, with the rest of Colorado analyzed as a CEUS Attenuation Zone.

Fault Parameters for HAZUS Scenarios

Geographic coordinates use North American Datum 1983

1882 Historical Earthquake – Rocky Mountain National Park Epicenter:

Epicenter: (40.41, -105.74); Strike = 45 (N45°E); Dip = +60 (60°NW); Max. Magnitude = 6.6

Busted Boiler Fault:

Epicenter (38.24, -107.86); Strike = 175 (N5°W); Dip = +60 (60°SW); Max. Magnitude = 6.5

Cannibal Fault:

Epicenter (37.94, -107.16); Strike = 160 (N20°W); Dip = +60 (60°SW); Max. Magnitude = 7.0

Chase Gulch Fault:

Epicenter (39.00, -105.62); Strike = 157 (N23°W); Dip = -60 (60°NE); Max. Magnitude = 6.75

Cheraw Fault:

Epicenter (38.28, -103.42); Strike = 44 (N44°E); Dip = +66 (66°NW); Max. Magnitude = 7.0

Cimarron Fault:

Epicenter (38.41, -107.48); Strike = 122 (N58°W); Dip = -70 (70°NE); Max. Magnitude = 6.75

Frontal (Gore) Fault:

Epicenter (39.68, -106.16); Strike = 156 (N24°W); Dip = -75 (75°NE); Max. Magnitude = 7.0

Golden Fault:

Epicenter (39.74, -105.22); Strike = 157 (N23°W); Dip = +60 (60°SW); Max. Magnitude = 6.5

Goodpasture Fault:

Epicenter (38.05, -104.91); Strike = 148 (N32°W); Dip = -60 (60°NE); Max. Magnitude = 6.0

Mosquito Fault:

Epicenter (39.38, -106.16); Strike = 9 (N9°E); Dip = +70 (70°NW); Max. Magnitude = 7.0

Rampart Range Fault:

Epicenter (39.06, -104.92); Strike = 171 (N9°W); Dip = +60 (60°SW); Max. Magnitude = 7.0

Rocky Mountain Arsenal Historical Epicenter:
Epicenter (39.90, -104.90); Strike = 130 (N50°W); Dip = +60 (60°SW); Max. Magnitude = 6.25

Roubideau Creek Fault:
Epicenter (38.41, -108.19); Strike = 106 (N74°W); Dip = -65 (65°NE); Max. Magnitude = 5.5

N Sangre de Cristo Fault:
Epicenter (37.90, -105.63); Strike = 161 (N19°W); Dip = +60 (60°SW); Max. Magnitude = 7.5

N Sawatch Fault:
Epicenter (39.15, -106.39); Strike = 147 (N33°W); Dip = -72 (72°NE); Max. Magnitude = 7.0

S Sawatch Fault:
Epicenter (38.75, -106.18); Strike = 148 (N32°W); Dip = -70 (70°NE); Max. Magnitude = 7.25

Ute Pass Fault:
Epicenter (38.92, -105.00); Strike = 152 (N28°W); Dip = +50 (50°SW); Max. Magnitude = 7.0

Valmont Fault:
Epicenter (40.03, -105.20); Strike = 75 (N75°E); Dip = -80 (80°SE); Max. Magnitude = 5.0

Walnut Creek Fault:
Epicenter (39.88, -105.15); Strike = 31 (N31°E); Dip = +80 (80°NW); Max. Magnitude = 6.5

Williams Fork Fault:
Epicenter (39.87, -106.15); Strike = 140 (N40°W); Dip = -60 (60°NE); Max. Magnitude = 6.75

Fault parameters are best understood if faults are envisioned as geometric planes, where rock masses on either side remain locked until stress is suddenly released and an earthquake occurs. A fault is a three-dimensional feature commonly mapped as two-dimensional lines, or fault traces, where the fault intersects the ground surface. The fault parameters used in HAZUS analyses were compiled from a variety of sources. Fault geometries such as strike, dip, and length were obtained from the CGS Colorado Late Cenozoic Fault and Fold Database, an Internet Map Server available to the public via the link below. This map server is a collection of all available information regarding Colorado's Cenozoic-or-younger faults. Many of the faults selected for HAZUS analysis have had field studies conducted along them, such as paleoseismic trenching or detailed mapping. Mapping a fault's surface exposure provides information about its length and strike, or orientation relative to north. The Maximum Credible Earthquake (MCE) is inferred from the mapped length of a fault based on magnitude-length relationships developed by Wells and Coppersmith (1994). Fault dip, the steepness of the fault plane under the surface, is derived from field studies where dip was directly measured, or it is estimated from other characteristics of the fault such as type of displacement or material displaced.

The epicenter chosen for HAZUS analysis is the approximate midpoint of each mapped fault trace. An earthquake's epicenter is the surface location above the subsurface point where fault rupture first initiated. Higher ground shaking levels normally occur immediately around an epicenter and are gradually dampened as distance from the epicenter increases. Epicenter locations are never predictable before an earthquake because a fault under stress can rupture at any given point along its length and depth. Fault planes that dip beneath the surface at an angle other than vertical will have epicenters that are not located directly along the fault trace. Epicenter location has a major effect on damages caused by an earthquake, as discussed in the text (Section 2e). We recognize that our choice of epicenter location at the midpoint of a fault trace is an approximation necessary for the use of HAZUS loss estimation methodology.

Two epicenters from historical earthquakes in Colorado were also analyzed to estimate losses if a repeat event were to occur today. The November, 1882 Earthquake occurred somewhere in northern Colorado, most commonly believed to have had an epicenter in the vicinity of Rocky Mountain National Park. The 1882 epicenter and magnitude (M6.6) chosen for our HAZUS analysis is from Kirkham and Rogers (1986). The other historical earthquake event analyzed in HAZUS was actually a swarm of earthquakes that occurred throughout the 1960's and early 1970's in the vicinity of the Rocky Mountain Arsenal northeast of Denver. These earthquakes are believed to have been induced by high-pressure injection of waste water into wells at the arsenal. Epicenters were distributed over a 15 km-long swath that yields a MCE of 6.25 according to Wells and Coppersmith (1994) curves. Our HAZUS epicenter was selected from the approximate center of the swath.

For more information:

Faults:
CGS Earthquakes Homepage: **http://geosurvey.state.co.us/Default.aspx?tabid=108**
CGS Colorado Late Cenozoic Fault and Fold Database and Internet Map Server: **http://geosurvey.state.co.us/Default.aspx?tabid=453**
CGS Colorado Earthquake Map Server: **http://geosurvey.state.co.us/Default.aspx?tabid=270**

CGS Earthquake Publications List: **http://geosurvey.state.co.us/Default.aspx?tabid=296**

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CEUS Attenuation Functions
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HAZUS: Appendix C

See https://coloradogeologicalsurvey.org/publications/hazus-statewide/

Appendix C
Statewide Scenario Results and Maps

Fault	Earthquake Magnitude	Economic Loss in State ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Busted Boiler	6.5	694.02	0.19%	8,239 (1%)	107	693	179	12	3,295
Cannibal	7	674.66	0.19%	10,762 (1%)	46	458	117	1	561
Chase Gulch	6.75	3,760.43	1.04%	50,498 (4%)	263	4,373	1,111	304	1,198
Cheraw	7	1,260.53	0.35%	17,472 (1%)	141	1,317	354	3,055	6,291
Cimarron	6.75	807.50	0.22%	10,070 (1%)	142	1,037	262	708	1,863
Frontal	7	6,733.82	1.87%	73,922 (5%)	737	8,765	2,111	1,569	10,100
Golden	6.5	21,890.05	6.08%	213,115 (16%)	4,134	42,952	10,769	6,421	232,559
Goodpasture	6	478.59	0.13%	5,842 (<1%)	16	203	56	0	1,521
Mosquito	7	6,189.80	1.72%	70,083 (5%)	609	7,785	1,901	411	11,782
Rampart Range	7	23,046.35	6.40%	237,595 (17%)	5,058	46,717	11,343	22,364	157,654
Rocky Mountain Arsenal	6.25	14,867.04	4.13%	151,902 (11%)	2,507	28,461	7,416	1,702	112,994
Roubideau Creek East	5.5	94.23	<0.01%	665 (<1%)	1	10	2	0	0
N Sangre de Cristo	7.5 WUS	767.07	0.21%	11,639 (1%)	91	721	190	239	476
N Sangre de Cristo	7.5 CEUS	8,020.95	2.23%	93,178 (7%)	1,655	15,918	4,105	1,397	5,132
North Sawatch	7	3,617.52	1.01%	46,739 (3%)	287	4,086	1,002	695	5,880
South Sawatch	7.25	4,742.32	1.32%	62,251 (5%)	463	6,127	1,551	2,146	7,841
Ute Pass	7	16,774.21	4.66%	179,782 (13%)	3,314	31,676	7,757	19,057	126,754
Valmont	5	711.46	0.20%	1,853 (<1%)	4	77	19	0	0
Walnut Creek	6	9,704.00	2.70%	94,660 (7%)	894	12,483	3,219	0	106,167
Williams Fork	6.75	3,482.99	0.97%	42,225 (3%)	254	3,807	936	125	2,865
1882 Rocky Mtn National Park	6.6	2,761.30	0.77%	35,024 (3%)	193	2,656	658	0	2,844

HAZUS: Appendix D

See https://coloradogeologicalsurvey.org/publications/hazus-statewide/

Appendix D
County Scenario Summary

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Adams	Random	6.50	853.52	4.06%	12,185 (12%)	105	931	246	1,013	923
Adams	Golden	6.50	1,589.25	7.56%	21,656 (21%)	257	2,194	597	0	5,691
Adams	Rocky Mtn Arsenal	6.25	3,148.06	14.97%	34,723 (34%)	623	4,764	1,231	811	80,388
Alamosa	Random	6.5 WUS	152.22	8.28%	1,628 (35%)	15	144	40	316	0
Alamosa	N Sangre de Cristo	7.5 WUS	142.06	7.72%	1,342 (29%)	19	137	37	51	0
Arapahoe	Random	6.50	2,350.41	7.29%	28,526 (19%)	317	4,927	1,197	0	1,126
Arapahoe	Golden	6.50	3,900.99	12.10%	42,239 (28%)	885	9,835	2,373	190	4,752
Arapahoe	Rampart	7.00	3,835.78	11.90%	42,105 (28%)	892	9,250	2,191	374	0
Archuleta	Random	6.50	341.25	17.51%	2,110 (44%)	16	129	30	11	2,723
Archuleta	Cannibal	7.00	42.09	2.16%	461 (10%)	1	10	2	0	0
Baca	Random	6.50	119.80	6.54%	1,011 (53%)	8	68	14	112	1,725
Baca	Cheraw	7.00	2.14	0.12%	42 (2%)	0	0	0	0	0
Bent	Random	6.50	72.32	6.69%	826 (44%)	7	49	12	0	1,787
Bent	Cheraw	7.00	18.08	1.67%	192 (10%)	0	3	0	0	0
Boulder	Random	6.50	3,282.58	15.83%	28,018 (30%)	434	5,290	1,267	315	55,571
Boulder	Golden	6.50	1,489.54	7.18%	15,073 (16%)	136	1,880	445	0	7,554
Chaffee	Random	6.50	288.32	12.25%	2,770 (39%)	17	132	32	2	3,302
Chaffee	S Sawatch	7.25	665.16	28.26%	5,321 (76%)	121	919	233	1,953	6,057
Chaffee	N Sangre de Cristo	7.50	425.76	18.09%	3,935 (56%)	134	759	195	2,207	2,061
Cheyenne	Random	6.50	51.12	3.52%	427 (45%)	2	15	2	0	786
Cheyenne	Cheraw	7.00	8.57	0.59%	35 (4%)	0	0	0	0	0
Clear Creek	Random	6.50	175.44	10.74%	1,483 (33%)	11	64	13	0	3,337
Clear Creek	Golden	6.50	42.88	2.63%	342 (8%)	1	6	1	0	0
Conejos	Random	6.5 WUS	26.37	2.27%	656 (21%)	1	10	2	0	0

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Conejos	N Sangre de Cristo	7.5 WUS	9.88	0.85%	451 (15%)	2	5	1	0	0
Costilla	Random	6.5 WUS	20.66	2.04%	482 (33%)	2	16	5	2	0
Costilla	N Sangre de Cristo	7.5 WUS	51.60	5.10%	714 (48%)	13	101	24	188	476
Crowley	Random	6.50	91.11	13.66%	966 (74%)	28	143	37	200	1,211
Crowley	Cheraw	7.00	55.19	8.28%	693 (53%)	12	54	14	5	881
Custer	Random	6.50	148.28	16.90%	1,489 (60%)	10	83	17	78	1,363
Custer	N Sangre de Cristo	7.50	138.38	15.77%	1,572 (63%)	19	128	27	31	1,085
Delta	Random	6.50	287.66	10.12%	3,453 (33%)	23	194	49	0	5,515
Delta	Cimarron	6.75	53.14	1.87%	861 (8%)	1	9	2	0	0
Denver	Random	6.50	14,227.75	36.44%	73,314 (51%)	5,841	37,053	9,900	94,819	182,596
Denver	Golden	6.50	7,510.48	19.24%	56,664 (39%)	1,959	20,014	5,360	5,511	60,801
Denver	Rampart	7.00	4,652.06	11.92%	38,815 (27%)	993	12,255	3,229	287	0
Denver	Rocky Mtn Arsenal	6.25	5,557.58	14.24%	45,403 (32%)	1,257	13,992	3,809	909	6,803
Denver	Walnut Creek	6.00	3,152.92	8.08%	26,336 (18%)	395	5,779	1,599	0	290
Dolores	Random	6.50	26.18	5.08%	474 (45%)	1	11	2	0	694
Dolores	Cannibal	7.00	0.90	0.17%	28 (3%)	0	0	0	0	0
Douglas	Random	6.50	2,036.54	14.87%	23,914 (36%)	326	1,716	312	324	38,419
Douglas	Rampart	7.00	1,848.03	13.49%	22,731 (34%)	493	1,785	327	3,183	18,030
Eagle	Random	6.50	599.67	11.96%	5,120 (36%)	70	832	168	755	7,002
Eagle	Frontal	7.00	571.47	11.40%	3,880 (27%)	120	812	163	50	1,469
El Paso	Random	6.50	4,254.96	13.06%	48,244 (31%)	903	8,292	1,968	1,173	51,038
El Paso	Rampart	7.00	9,013.76	27.67%	80,644 (52%)	2,496	19,660	4,657	18,538	135,366
El Paso	Ute Pass	7.00	8,216.92	25.23%	76,253 (50%)	2,193	17,892	4,290	18,970	118,308
Elbert	Random	6.50	72.84	3.00%	823 (12%)	6	14	2	0	549
Elbert	Rampart	7.00	98.88	4.07%	1,320 (19%)	21	36	6	0	0
Fremont	Random	6.50	299.14	7.96%	3,468 (24%)	31	293	80	0	1,783
Fremont	N Sangre de Cristo	7.50	393.64	10.47%	4,901 (34%)	89	629	170	13	790

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Garfield	Random	6.50	252.92	5.34%	2,492 (18%)	27	237	53	0	3,316
Garfield	N Sawatch	7.00	76.57	1.62%	977 (7%)	4	47	10	0	0
Gilpin	Random	6.50	133.28	18.38%	1,067 (40%)	9	46	9	0	1,826
Gilpin	Golden	6.50	40.11	5.53%	323 (12%)	1	5	0	0	0
Grand	Random	6.50	194.88	6.22%	1,615 (21%)	11	86	17	44	913
Grand	Williams Fork	6.75	184.15	5.88%	1,389 (18%)	12	94	18	125	929
Gunnison	Random	6.50	164.33	6.13%	1,494 (23%)	24	306	83	0	239
Gunnison	N Sangre de Cristo	7.50	100.28	3.74%	1,001 (15%)	19	217	59	0	0
Hinsdale	Random	6.50	45.10	12.99%	627 (58%)	3	19	3	0	330
Hinsdale	Cannibal	7.00	35.15	10.12%	576 (53%)	2	15	2	0	294
Huerfano	Random	6.50	146.52	7.55%	1,193 (33%)	5	36	9	3	2,245
Huerfano	N Sangre de Cristo	7.50	83.97	4.33%	874 (25%)	5	28	7	0	0
Jackson	Random	6.50	88.91	9.36%	610 (62%)	5	35	7	67	609
Jackson	1882 RMNP	6.60	3.66	0.39%	49 (5%)	0	0	0	0	0
Jefferson	Random	6.50	5,111.00	14.27%	50,103 (29%)	603	6,403	1,403	345	113,457
Jefferson	Golden	6.50	5,881.32	16.42%	54,824 (32%)	828	8,306	1,839	927	153,809
Kiowa	Random	6.50	45.31	3.97%	483 (72%)	7	59	10	117	584
Kiowa	Cheraw	7.00	11.36	1.00%	182 (27%)	1	4	0	0	0
Kit Carson	Random	6.50	100.24	4.45%	1,192 (43%)	10	83	18	33	519
Kit Carson	Cheraw	7.00	11.25	0.50%	179 (6%)	0	3	0	0	0
La Plata	Random	6.50	640.28	14.86%	5,520 (32%)	64	632	162	0	8,925
La Plata	Cannibal	7.00	53.12	1.23%	916 (5%)	1	18	4	0	0
Lake	Random	6.50	274.37	24.97%	1,983 (68%)	39	344	86	48	2,610
Lake	Mosquito	7.00	298.86	27.20%	2,213 (75%)	54	479	120	320	2,616
Lake	N Sawatch	7.00	302.50	27.53%	2,185 (74%)	55	458	114	693	2,573
Larimer	Random	6.50	1,357.50	7.18%	17,869 (21%)	171	1,663	407	21	1,198
Larimer	1882 RMNP	6.60	887.27	4.70%	10,171 (12%)	93	831	189	0	2,844

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Las Animas	Random	6.50	33.82	0.91%	345 (6%)	1	5	1	0	0
Las Animas	N Sangre de Cristo	7.50	31.63	0.85%	576 (10%)	1	20	6	0	0
Lincoln	Random	6.50	118.13	6.33%	818 (41%)	19	136	28	1,268	672
Lincoln	Cheraw	7.00	22.48	1.20%	371 (19%)	1	9	2	0	0
Logan	Random	6.50	346.75	11.34%	3,838 (58%)	91	629	166	372	2,095
Logan	Rocky Mtn Arsenal	6.25	2.12	0.00%	63 (1%)	0	0	0	0	0
Mesa	Random	6.50	2,122.40	23.47%	20,611 (54%)	545	4,152	1,145	18	35,626
Mesa	Cimarron	6.75	55.36	0.61%	1,265 (3%)	2	30	8	0	0
Mineral	Random	6.50	74.41	11.15%	688 (71%)	5	36	6	34	336
Mineral	Cannibal	7.00	43.13	6.46%	546 (56%)	3	19	3	1	267
Moffat	Random	6.50	36.09	1.30%	348 (8%)	1	6	1	12	251
Moffat	Frontal	7.00	5.11	0.18%	77 (2%)	0	0	0	0	0
Montezuma	Random	6.50	259.84	8.45%	2,903 (33%)	17	122	33	0	5,304
Montezuma	Cannibal	7.00	9.80	0.32%	234 (3%)	0	1	0	0	0
Montrose	Random	6.50	256.99	6.81%	3,361 (28%)	24	183	49	0	0
Montrose	Cimarron	6.75	497.40	13.18%	4,969 (41%)	130	856	213	708	1,863
Morgan	Random	6.50	1,384.96	25.63%	5,359 (62%)	132	921	244	1,316	6,410
Morgan	Rocky Mtn Arsenal	6.25	21.84	0.40%	272 (3%)	0	2	0	0	0
Otero	Random	6.50	334.00	11.38%	2,945 (44%)	39	329	88	2,804	4,935
Otero	Cheraw	7.00	415.54	14.16%	3,676 (55%)	78	588	166	3,050	5,410
Ouray	Random	6.50	147.27	18.84%	746 (40%)	6	30	6	0	1,390
Ouray	Busted Boiler	6.50	104.19	13.33%	598 (32%)	4	18	3	0	1,305
Park	Random	6.50	152.72	5.44%	2,356 (25%)	7	53	7	116	575
Park	Chase Gulch	6.75	165.45	5.90%	2,784 (29%)	8	76	14	304	1,198
Park	Mosquito	7.00	169.29	6.03%	2,308 (24%)	15	144	26	22	714
Phillips	Random	6.50	74.10	6.44%	800 (47%)	7	50	9	5	1,520
Phillips	Rocky Mtn Arsenal	6.25	0.00	0.00%	0 (0%)	0	0	0	0	0

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Pitkin	Random	6.50	375.02	16.86%	1,567 (24%)	20	204	41	0	4,611
Pitkin	N Sawatch	7.00	168.78	7.59%	1,060 (16%)	14	100	20	0	616
Prowers	Random	6.50	209.69	9.09%	2,383 (51%)	42	296	82	109	1,788
Prowers	Cheraw	7.00	60.89	2.64%	777 (16%)	5	31	9	0	0
Pueblo	Random	6.50	2,315.75	21.99%	21,293 (47%)	515	4,079	1,255	410	43,103
Pueblo	N Sangre de Cristo	7.50	483.70	4.59%	6,793 (15%)	124	739	224	0	0
Pueblo	Ute Pass	7.00	288.21	2.74%	4,327 (10%)	29	248	75	0	0
Rio Blanco	Random	6.50	51.43	3.28%	647 (27%)	4	31	7	0	0
Rio Blanco	Frontal	7.00	6.69	0.43%	132 (5%)	0	2	0	0	0
Rio Grande	Random	6.5 WUS	88.75	4.98%	1,556 (33%)	18	145	41	0	0
Rio Grande	Cannibal	7.0 CEUS	36.60	2.05%	629 (13%)	2	18	5	0	0
Routt	Random	6.50	461.55	14.82%	2,665 (34%)	70	347	69	0	3,934
Routt	Frontal	7.00	55.99	1.80%	626 (8%)	4	32	6	0	0
Saguache	Random	6.5 WUS	53.11	3.50%	1,145 (48%)	8	65	17	139	625
Saguache	N Sangre de Cristo	7.5 WUS	25.23	1.66%	421 (18%)	2	12	3	0	0
San Juan	Random	6.50	20.06	5.43%	214 (42%)	1	6	1	0	241
San Juan	Cannibal	7.00	2.36	0.64%	38 (7%)	0	0	0	0	0
San Miguel	Random	6.50	32.62	2.40%	324 (10%)	1	10	2	0	466
San Miguel	Busted Boiler	6.50	36.15	2.65%	201 (6%)	1	13	2	0	0
Sedgwick	Random	6.50	62.77	5.86%	659 (59%)	7	79	17	48	1,075
Sedgwick	Rocky Mtn Arsenal	6.25	0.00	0.00%	0 (0%)	0	0	0	0	0
Summit	Random	6.50	829.99	19.84%	4,028 (37%)	67	602	116	0	7,071
Summit	Frontal	7.00	1,345.36	32.15%	6,602 (60%)	179	1,379	267	1,491	7,862
Summit	Mosquito	7.00	1,056.71	25.26%	5,177 (47%)	117	849	162	69	6,861
Teller	Random	6.50	255.40	13.08%	2,849 (30%)	13	90	18	0	6,043
Teller	Ute Pass	7.00	523.85	26.83%	5,099 (54%)	65	514	104	87	6,384
Washington	Random	6.50	71.76	3.34%	784 (42%)	7	49	7	85	819

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Washington	Rocky Mtn Arsenal	6.25	1.09	0.00%	5 (0%)	0	0	0	0	0
Weld	Random	6.50	944.83	6.61%	13,382 (25%)	125	1,414	393	0	887
Weld	Rocky Mtn Arsenal	6.25	501.92	3.51%	6,871 (13%)	42	322	80	0	1,610
Yuma	Random	6.50	201.22	7.64%	2,069 (60%)	40	325	68	1,261	1,161
Yuma	Cheraw	7.00	3.29	0.13%	84 (2%)	0	0	0	0	0

Note: Zeroes in columns showing "Households without Water" and "Households without Electric Power" do not consistently represent zero affected households. Incomplete inventory data for water pipelines and electricity lifelines causes inaccurate calculations of affected households.

HAZUS: Appendix E

County Scenario Maps

See: https://coloradogeologicalsurvey.org/publications/hazus-statewide/

HAZUS: Appendix F

Descriptions of Building State Damage

Appendix F
Descriptions of Building State Damage

As described in Section 2b of this report, the general building stock included in the HAZUS inventory is organized into model building types. Structures that are not identified as essential facilities (schools, hospitals, police and fire stations) are grouped according to building type, occupancy, and seismic code within census tracts for HAZUS analysis. Essential facilities are analyzed individually. Building damage predictions are calculated based on structure fragility curves derived from engineering studies of building displacement resulting from ground shaking (**Figure E-1**). HAZUS predicts structural and nonstructural damage, but for the purposes of this study only structural damage is being reported.

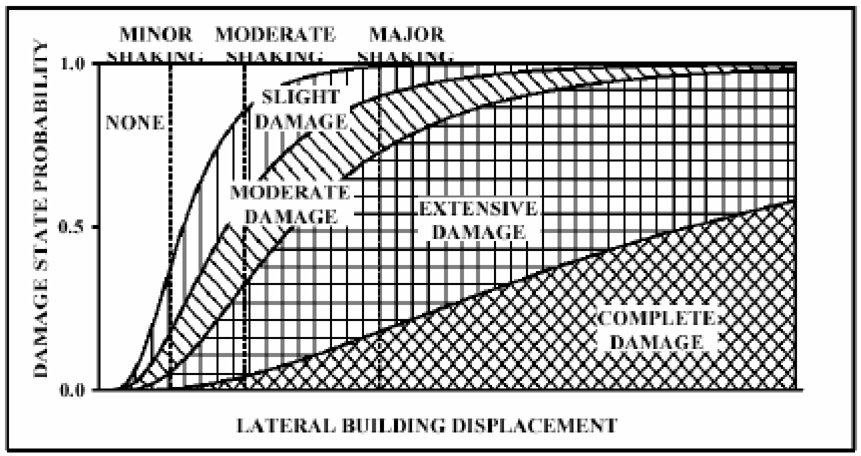


Figure E-1 – Sample fragility curve used in HAZUS calculations, from HAZUS User Manual Chapter 9.

Structural damage predictions are stated as probabilities of different damage states: None, Slight, Moderate, Extensive, and Complete. The probability damage states (PDS) for a single building group should add up to 1:

PDS None + PDS Slight + PDS Moderate + PDS Extensive + PDS Complete = 1

HAZUS also states PDS in terms of the damage state met or exceeded in a given group of buildings: At Least Slight, At Least Moderate, and At Least Extensive. We found this final category, “At Least Extensive”, to be the most meaningful for generating large amounts of preliminary scenario maps at the county level. Visualizing essential facilities color-coded with a probability of sustaining damages that are extensive or complete is a powerful tool for estimating the extent of earthquake damage.

Examples of building damage states are summarized below, copied from the HAZUS-MH Technical Manual Chapter 5. For the sake of brevity, this is not a complete list of all building types and their damage states. Three building types were chosen due to their quantity in Denver County (**Figure E-2**). Further information can be provided upon request.

Wood, Light Frame (W1):

Slight Structural Damage: Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.

Moderate Structural Damage: Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.

Extensive Structural Damage: Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of "room-over-garage" or other "soft-story" configurations; small foundations cracks.

Complete Structural Damage: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks. Approximately 3% of the total area of W1 buildings with Complete damage is expected to be collapsed.

Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms (RM1):

Slight Structural Damage: Diagonal hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; minor separation of walls from the floor and roof diaphragms.

Moderate Structural Damage: Most wall surfaces exhibit diagonal cracks; some of the shear walls have exceeded their yield capacities indicated by larger diagonal cracks. Some walls may have visibly pulled away from the roof.

Extensive Structural Damage: In buildings with relatively large area of wall openings most shear walls have exceeded their yield capacities and some of the walls have exceeded their ultimate capacities indicated by large, through-the-wall diagonal cracks and visibly buckled wall reinforcement. The plywood diaphragms may exhibit cracking and separation along plywood joints. Partial collapse of the roof may result from failure of the wall-to-diaphragm anchorages or the connections of beams to walls.

Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to failure of the wall anchorages or due to failure of the wall panels. Approximately 13%(low-rise) or 10%(mid-rise) of the total area of RM1 buildings with Complete damage is expected to be collapsed.

Unreinforced Masonry Bearing Walls (URM):

Slight Structural Damage: Diagonal, stair-step hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; movements of lintels; cracks at the base of parapets.

Moderate Structural Damage: Most wall surfaces exhibit diagonal cracks; some of the walls exhibit larger diagonal cracks; masonry walls may have visible separation from diaphragms; significant cracking of parapets; some masonry may fall from walls or parapets.

Extensive Structural Damage: In buildings with relatively large area of wall openings most walls have suffered extensive cracking. Some parapets and gable end walls have fallen. Beams or trusses may have moved relative to their supports.
Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to in-plane or out-of-plane failure of the walls. Approximately 15% of the total area of URM buildings with Complete damage is expected to be collapsed.

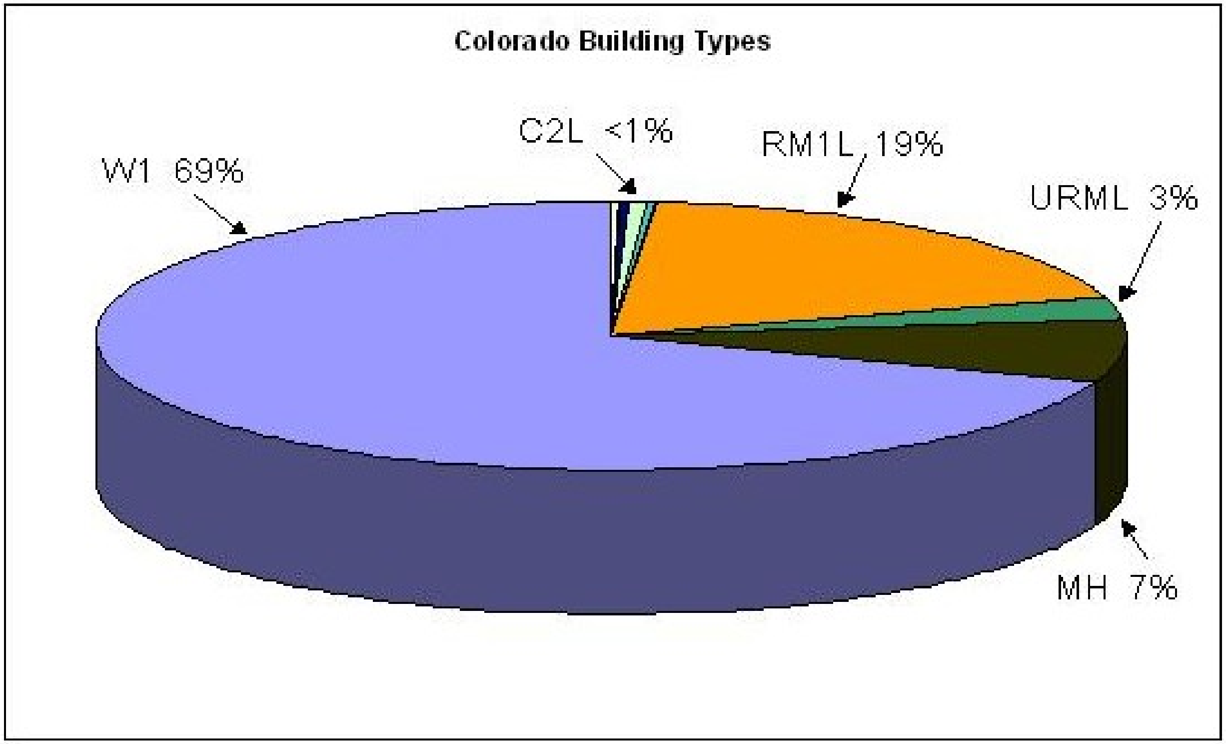


Figure E-2 – Distribution of building types in Colorado, derived from HAZUS default inventory of building stock. W1 is Wood-Light Frame, RM1 is Reinforced Masonry Bearing Walls, URM is Unreinforced Masonry Bearing Walls, MH is Mobile Homes, and C2 is Concrete Shear Walls. See Table 1 in Section 2b for a complete list of building types.

HAZUS: Appendix G

Sample Summary Report Generated by HAZUS

See: https://coloradogeologicalsurvey.org/publications/hazus-statewide/

HAZUS: Appendix H

Faults and Historical Earthquakes by County

Appendix H
Faults and Historical Earthquakes by County

The following list contains summaries for each county illustrating population data, population changes, county size, total inventory value, emergency management contact information, Cenozoic faults within county boundaries, historical earthquakes within county boundaries, and a list of HAZUS scenario results performed for the county. Demographic data is from the 2000 U.S. Census or updated county websites and Colorado Emergency Management County Information: **http://www.dola.state.co.us/oem/Mitigation/plan/04%20%20County%20Descriptions%20final.pdf**

Fault information and historical seismicity data is from the Colorado Earthquake Map Server (**http://geosurvey.state.co.us/Default.aspx?tabid=270**) and Colorado Late Cenozoic Fault and Fold Database and Internet Map Server (**http://geosurvey.state.co.us/Default.aspx?tabid=453**).

Time of most recent fault activity is in parentheses after the fault name: H = Holocene, LQ = Late Quaternary, MLQ = Middle to Late Quaternary, Q = Quaternary, LC = Late Cenozoic. Earthquake event identification numbers can be found in the earthquake database table.

Highlighted HAZUS scenarios are those listed as Worst Case Scenarios in Appendix D. Results listed include fatalities, monetary loss, and the loss ratio (total economic loss/region inventory x 100). Several counties include HAZUS results for the Anton Scarp, a feature under investigation in the Eastern Plains. Due to uncertainty of the feature's classification as a tectonic fault, results were not included in overall HAZUS results summaries.

Adams County
Population: 374,891 Growth since 1990: 37.3%
County Size: 1,198 square miles Inventory: $21,025.00 M
Contact:
Adams County Office of Emergency Management
4201 E. 72nd Ave.
Commerce City, CO 80022
(303)289-5441
Faults within County: Rocky Mountain Arsenal (uncertain)
Historical Earthquakes: 1962 to 1972 Rocky Mountain Arsenal Earthquakes (#98-99, 103-105, 107-143, 145-147, 150-152, 154-188, 190-209, 219, 228-229, 233, 237, 239-241, 246-247, 251, 253-303, 305-306, 308-309, 311-327, 330-334, 336, 339-340, 342, 344-346, 348-350); June 10, 1978 NE of Denver (#363); Mar.-Sept. 1981 NE of Denver (#369-371); Mar.-Sept. 1982 NE of Denver (#374-375); Feb. 25, 1984 NE of Denver (#380); Nov. 8, 1989 NE Denver (#446)

Faults analyzed for County: Golden (Q), Rampart (MLQ), RM Arsenal, Ute Pass (MLQ), Valmont (MLQ), Walnut Creek (Q), 1882 Historical Epicenter

HAZUS Loss Estimates:

- Golden Fault: M6.5 – 51 fatal, $1.59 Billion (-7.6%)
- Rampart Fault: M7.0 – 26 fatal, $774 Million (-3.7%)
- RM Arsenal: M6.25 – 130 fatal, $3.15 Billion (-15.0%)
- Ute Pass: M7.0 – 12 fatal, $496 Million (-2.4%)
- Valmont: M5.0 – 0 fatal, $64.1 Million (-0.3%)
- Walnut Creek: M6.0 – 20 fatal, $1.28 Billion (-6.1%)
- 1882 RMNP epc: M6.6 – 1 fatal, $150 Million (-0.7%)

Alamosa County

Population: 15,336 Growth since 1990: 9.9%

County Size: 723 square miles Inventory: $1,839.50 M

Contact:

Alamosa County Office
PO Box 178
Alamosa, CO 81101
(719)589-4848

Faults within County: Alamosa Horst Fault Zone East (LC), Alamosa Horst Fault Zone West (LC), Manassa (LC), North Sangre de Cristo (H)

Historical Earthquakes: Dec. 28, 2003 Blanca-Ft. Garland (#562-563)

Faults analyzed for County: N Sangre de Cristo (H)

HAZUS Loss Estimates:

- N Sangre de Cristo: M7.5 WUS – 4 fatal, $142 Million (-7.7%)
  M7.5 CEUS – 18 fatal, $433 Million (-23.5%)

Arapahoe County

Population: 524,414 Growth since 1990: 24.6%

County Size: 818 square miles Inventory: $32,232.30 M

Contact:

Arapahoe County Government
5334 S. Prince Street
Littleton, CO 80166

(303)795-4400
Faults within County: None known
Historical Earthquakes: None
Faults analyzed for County: Chase Gulch (LQ), Cheraw (H), Golden (Q), Rampart (MLQ), RM Arsenal, Ute Pass (MLQ), Walnut Creek (Q)
HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 9 fatal, $678 Million (-2.1%)
Cheraw:	M7.0 – 0 fatal, $57.9 Million (-0.2%)
Golden:	M6.5 – 185 fatal, $3.90 Billion (-12.1%)
Rampart:	M7.0 – 186 fatal, $3.84 Billion (-11.9%)
RM Arsenal:	M6.25 – 74 fatal, $2.63 Billion (-8.2%)
Ute Pass:	M7.0 – 67 fatal, $2.11 Billion (-6.5%)
Walnut Creek:	M6.0 – 17 fatal, $1.25 Billion (-3.9%)

Archuleta County
Population: 9,898 Growth since 1990: 85.2%
County Size: 1,364 square miles Inventory: $1,948.70 M
Contact:
Department of Emergency Management
449 San Juan St. or PO Box 1507
Pagosa Springs, CO 81147
(970)264-8300
Faults within County: None
Historical Earthquakes: Feb. 12, 1882 Pagosa Springs (#6); May 12, 1882 Pagosa Springs (#7); Jan. 23, 1966 Dulce, NM (#210, 212-218, 220, 222-227)
Faults analyzed for County: Cannibal Fault (LQ), N Sangre de Cristo (H)
HAZUS Loss Estimates:

Cannibal:	M7.0 – 0 fatal, $42.1 Million (-2.2%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $1.04 Million (-0.0%)
	M7.5 CEUS – 1 fatal, $28.1 Million (-1.4%)

Baca County
Population: 4,517 Growth since 1990: -0.9%
County Size: 2,559 square miles Inventory: $1,831.70 M

Contact:

Baca County Courthouse
741 Main Street
Springfield, CO 81073
(719)523-6532

Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:

Cheraw: ____________M7.0 – 0 fatal, $2.14 Million (-0.1%)

Bent County

Population: 9,898 Growth since 1990: 85.2%
County Size: 1,517 square miles Inventory: $1,081.00 M
Contact:

Bent County Courthouse
725 Carson Avenue or PO Box 350
Las Animas, CO 81054
(719)456-1600

Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:

Cheraw: ____________M7.0 – 0 fatal, $18.1 Million (-1.7%)

Boulder County

Population: 214,978 Growth since 1990: 29.3%
County Size: 741 square miles Inventory: $20,737.40 M
Contact:

Boulder Office of Emergency Management
1805 33rd Street
Boulder, CO 80301
(303)441-3390

Faults within County: Rock Creek (Q), Valmont (MLQ)

Historical Earthquakes: Oct. 12, 1916 Boulder (#29)
Faults analyzed for County: Frontal (LQ), Golden (Q), Mosquito (LQ), Rocky Mountain Arsenal Epicenter, Ute Pass (MLQ), Valmont (MLQ), Walnut Creek (Q), Williams Fork (H), 1882 Historical Epicenter
HAZUS Loss Estimates:

Frontal:	M7.0 – 3 fatal, $330 Million (-1.6%)
Golden:	M6.5 – 24 fatal, $ 1.49 Billion (-7.2%)
Mosquito:	M7.0 – 2 fatal, $252 Million (-1.2%)
Rocky Mtn Arsenal:	M6.25 – 11 fatal, $1.10 Billion (-5.3%)
Ute Pass:	M7.0 – 2 fatal, $245 Million (-1.2%)
Valmont:	M5.0 – 0 fatal, $411 Million (-2.0%)
Walnut Creek:	M6.0 – 10 fatal, $1.21 Billion (-5.8%)
Williams Fork:	M6.75 – 1 fatal, $233 Million (-1.1%)
1882 Earthquake:	M6.6 RMNP – 2 fatal, $328 Million (-1.6%)

Chaffee County
Population: 16,242 Growth since 1990: 28.1%
County Size: 1,039 square miles Inventory: $2,354.10 M
Contact:

Chaffee County Commissioners
PO Box 699 or 104 Crestone Ave.
Salida, CO 81201
(719)539-2218

Faults within County: Buena Vista (Q), Missouri Park (LQ), North Sawatch (LQ), Northeastern Boundary Faults (MLQ), Poncha Pass (LC), Shavano Peak (Q), South Sawatch (H), Twin Lakes Faults (Q), Upper Arkansas Valley Faults (LC)
Historical Earthquakes: Nov. 15, 1901 Buena Vista (#20); Feb.-July, 1921 Garfield (#34-47); Dec. 19, 1966 Aspen (#242); July 20, 1987 Taylor Park (#435); Sept. 14, 1987 Winfield (#437); Aug. 4, 1994 Poncha Springs (#473)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Mosquito (LQ), N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H)
HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 0 fatal, $33.9 Million (-1.4%)
Frontal:	M7.0 – 0 fatal, $17.5 Million (-0.7%)
Mosquito:	M7.0 – 0 fatal, $65.8 Million (-2.8%)
N Sangre de Cristo:	M7.5 WUS – 9 fatal, $133 Million (-5.7%)
	M7.5 CEUS – 29 fatal, $426 Million (-18.1%)
N Sawatch:	M7.0 – 2 fatal, $153 Million (-6.5%)
S Sawatch:	M7.25 WUS – 21 fatal, $426 Million (-18.1%)

M7.25 CEUS – 26 fatal, $665 Million (-28.3%)

Cheyenne County
Population: 2,088 Growth since 1990: -6.9%
County Size: 1,782 square miles Inventory: $1,450.80 M
Contact:
Cheyenne County Courthouse
51 South 1st St. or PO Box 567
Cheyenne, CO 80810
(719)767-5872
Faults within County: High Plains Grabens (Anton scarp) under investigation
Historical Earthquakes: July 6, 1989 Kit Carson (#445)
Faults analyzed for County: Anton Scarp, Cheraw (H)
HAZUS Loss Estimates:
Anton Scarp: M7.6 – 0 fatal, $27.1 Million (-1.9%)
Cheraw: M7.0 – 0 fatal, $8.57 Million (-0.6%)

Clear Creek County
Population: 9,322 Growth since 1990: 22.4%
County Size: 396 square miles Inventory: $1,632.90 M
Contact:
Clear Creek County Offices
405 Argentine St. or PO Box 2000
Georgetown, CO 80444
(303)679-2300
Faults within County: Floyd Hill (LC), Kennedy Gulch (LC)
Historical Earthquakes: Nov. 9, 1871 Georgetown (#3); 1881 Georgetown (#5); Aug. 5, 1894 Georgetown (#16)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Golden (Q), Mosquito (LQ), N Sawatch (LQ), Ute Pass (MLQ), Williams Fork (H)
HAZUS Loss Estimates:
Chase Gulch: M6.75 – 0 fatal, $9.71 Million (-0.6%)
Frontal: M7.0 – 0 fatal, $38.0 Million (-2.3%)
Golden: M6.5 – 0 fatal, $42.9 Million (-2.6%)
Mosquito: M7.0 – 0 fatal, $31.8 Million (-2.0%)

N Sawatch: M7.0 – 0 fatal, $8.96 Million (-0.6%)
Ute Pass: M7.0 – 0 fatal, $10.6 Million (-0.7%)
Williams Fork: M6.75 – 0 fatal, $31.9 Million (-2.0%)

Conejos County

Population: 8,407 Growth since 1990: 12.7%
County Size: 1,290 square miles Inventory: $1,162.40 M
Contact:
Conejos County Courthouse
PO Box 157
Conejos, CO 81129
(719)376-5772
Faults within County: Conejos River Faults (LC), Cumbres (LC), La Jara Reservoir (LC), Los Mogotes Volcano Faults (LC)
Historical Earthquakes: Oct. 7, 1952 Antonito (#82)
Faults analyzed for County: N Sangre de Cristo (H)
HAZUS Loss Estimates:
N Sangre de Cristo: M7.5 WUS – 0 fatal, $9.9 Million (-0.9%)
M7.5 CEUS – 3 fatal, $56.3 Million (-4.8%)

Costilla County

Population: 3,688 Growth since 1990: 14.8%
County Size: 1,229 square miles Inventory: $1,013.40 M
Contact:
Costilla County Courthouse
352 Main St. or PO Box 100
San Luis, CO 81152
(719)672-3372
Faults within County: Alvarado (LC), Culebra Range Faults (LC), Garcia (LQ), La Veta Faults (LC), Mesita (LQ), N Basaltic Hills Faults (Q), N Sangre de Cristo (H), S Sangre de Cristo-San Pedro Mesa Section (LQ)
Historical Earthquakes: Dec. 28, 2003 Gardner-Ft. Garland (#560-561)
Faults analyzed for County: N Sangre de Cristo (H)
HAZUS Loss Estimates:
N Sangre de Cristo: M7.5 WUS – 2 fatal, $51.6 Million (-5.1%)
M7.5 CEUS – 4 fatal, $85.2 Million (-8.4%)

Crowley County
Population: 5,838 Growth since 1990: 39.8%
County Size: 803 square miles Inventory: $666.90 M
Contact:

Crowley County Courthouse
603 Main #2
Ordway, CO 81063
(719)267-5555

Faults within County: Cheraw (H)
Historical Earthquakes: Dec. 4, 1870 Pueblo-Ft. Reynolds (#1); Nov. 28, 1955 Fowler-Sugar City (#88)
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:

Cheraw: M7.0 – 2 fatal, $55.2 Million (-8.3%)

Custer County
Population: 3,700 Growth since 1990: 81.9%
County Size: 737 square miles Inventory: $877.60 M
Contact:

Custer County Office of Emergency Management
PO Box 1351
Westcliffe, CO 81252
(719)783-2270

Faults within County: Alvarado (LC), Dead Mule Gulch (LC), Ilse (LC), Johnson Gulch (LC), Rosita (LC), Round Mountain (LC), Silver Cliff Graben (LC), Westcliffe (LC), Wet Mountain (LC)
Historical Earthquakes: Oct. 23, 1888 Wet Mountains (#12); Feb. 18, 1925 Wetmore (#52)
Faults analyzed for County: Goodpasture (Q), N Sangre de Cristo (H)
HAZUS Loss Estimates:

Goodpasture: M6.0 – 0 fatal, $6.2 Million (-0.7%)
N Sangre de Cristo M7.5 WUS – 1 fatal, $28.5 Million (-3.3%)
M7.5 CEUS – 4 fatal, $138 Million (-15.8%)

Delta County

Population: 27,834 Growth since 1990: 32.7%
County Size: 1,157 square miles Inventory: $2,841.30 M
Contact:

Delta County Office of Emergency Management
555 Palmer Street
Delta, CO 81416
(970)874-2004

Faults within County: Bridgeport (Q), Escalante (Q), Little Dominguez Creek (Q)
Historical Earthquakes: Sept. 9, 1944 Montrose-Basalt (#75-border); Jan. 12, 1967 Somerset (#243-border); Sept. 26, 1994 Somerset Coal Bump (#479); Nov. 2, 1994 Somerset Coal Bump (#480); Jan. 1, 1995 Somerset Coal Bump (#483); Mar. 14, 1995 Somerset Coal Bump (#485); Nov. 5, 2001 Paonia-Somerset (#533); Dec. 4, 2001 Paonia-Somerset (#534); Mar.-Apr. 2002 Paonia-Somerset (#538-540); June-Dec. 2002 Paonia-Somerset (#543, 546-549, 551-552); Jan.-Aug. 2003 Paonia-Somerset (#555, 557-558)
Faults analyzed for County: Cimarron (LQ, Q), Roubideau Creek (H)
HAZUS Loss Estimates:

Cimarron: M6.75 – 0 fatal, $53.1 Million (-1.9%)
Roubideau: M5.5 – 0 fatal, $5.93 Million (-0.2%)

Denver City and County
Population: 554,636 Growth since 1990: 18.6%
County Size: 155 square miles Inventory: $39,039.40 M
Contact:

Denver Office of Emergency Management
1437 Bannock Street, Room 3
Denver, CO
(720)865-7600

Faults within County: None
Historical Earthquakes: Dec. 29, 1901 Denver (#21); Jan. 27, 1923 Denver (#49); Jan. 4, 1924 Denver (#50); June 5, 1963 RM Arsenal (#140); Numerous 1960's RM Arsenal shocks NE of Denver
Faults analyzed for County: Anton Scarp, Chase Gulch (LQ), Cheraw (H), Frontal (LQ), Golden (Q), Mosquito (LQ), Rampart (MLQ), Rocky Mountain Arsenal Epicenter, N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H), Ute Pass (MLQ), Valmont (MLQ), Walnut Creek (Q), Williams Fork (H), 1882 Historical Epicenter
HAZUS Loss Estimates:

Anton Scarp: M6.7 – 172 fatal, $3.05 Billion (-7.8%)
Chase Gulch: M6.75 – 13 fatal, $1.01 Billion (-2.6%)
Cheraw: M7.0 – 0 fatal, $8.02 Million (-0.0%)

Frontal: M7.0 – 30 fatal, $1.48 Billion (-3.8%)
Golden: M6.5 – 416 fatal, $7.51 Billion (-19.2%)
Mosquito: M7.0 – 25 fatal, $1.32 Billion (-3.4%)
Rampart: M7.0 – 203 fatal, $4.65 Billion (-11.9%)
RM Arsenal: M6.25 – 262 fatal, $5.56 Billion (-14.2%)
M6.0 – 126 fatal, $3.89 Billion (-10.0%)
M5.5 – 10 fatal, $1.41 Billion (-3.6%)
M5.0 – 1 fatal, $544 Million (-1.4%)
N Sangre de Cristo: M7.5 WUS – 0 fatal, $69.9 Million (-0.2%)
M7.5 CEUS – 48 fatal, $1.47 Billion (-3.8%)
N Sawatch: M7.0 – 7 fatal, $652 Million (-1.7%)
S Sawatch: M7.25 – 12 fatal, $866 Million (-2.2%)
Ute Pass: M7.0 – 84 fatal, $2.75 Billion (-7.0%)
Valmont: M5.0 – 0 fatal, $98.4 Million (-0.3%)
Walnut Creek: M6.0 – 75 fatal, $3.15 Billion (-8.1%)
Williams Fork: M6.75 – 10 fatal, $850 Million (-2.2%)
1882 Earthquake: M6.6 RMNP – 5 fatal, $527 Million (-1.4%)

Dolores County

Population: 1,848 Growth since 1990: 22.6%
County Size: 1,077 square miles Inventory: $515.70 M
Contact:
Dolores County Courthouse
409 N. Main St. or PO Box 608
Dove Creek, CO 81324
(970)677-2383
Faults within County: None
Historical Earthquakes: Feb. 12, 1967 Rico (#248); Sept. 9, 1987 Rico (#436)
Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ)
HAZUS Loss Estimates:
Busted Boiler: M6.5 – 0 fatal, $0.85 Million (-0.2%)
Cannibal: M7.0 – 0 fatal, $0.90 Million (-0.2%)

Douglas County

Population: 175,766 Growth since 1990: 191%
County Size: 843 square miles Inventory: $13,697.50 M
Contact:

Douglas County Office of Emergency Management
4000 Justice Way
Castle Rock, CO 80109
(303)660-7589

Faults within County: Kennedy Gulch (LC), Oil Creek (LC), Perry Park-Jarre Canyon (LC), Rampart Range (MLQ), Ute Pass (MLQ)
Historical Earthquakes: Sept. 14, 1965 S of Denver (#189); Dec. 25, 1994 Palmer Lake (#482)
Faults analyzed for County: Chase Gulch (LQ), Cheraw (H), Frontal (LQ), Golden (Q), Mosquito (LQ), Rampart (MLQ), N Sawatch (LQ), Ute Pass (MLQ)
HAZUS Loss Estimates:

Chase Gulch: M6.75 – 1 fatal, $117 Million (-0.9%)
Cheraw: M7.0 – 0 fatal, $19.2 Million (-0.1%)
Frontal: M7.0 – 1 fatal, $114 Million (-0.8%)
Golden: M6.5 – 7 fatal, $578 Million (-4.2%)
Mosquito: M7.0 – 1 fatal, $111 Million (-0.8%)
Rampart: M7.0 – 79 fatal, $1.85 Billion (-13.5%)
N Sawatch: M7.0 – 0 fatal, $64.1 Million (-0.5%)
Ute Pass: M7.0 – 15 fatal, $652 Million (-4.8%)

Eagle County

Population: 47,990 Growth since 1990: 90.0%
County Size: 1,694 square miles Inventory: $5,014.90 M
Contact:

Eagle County Emergency Management
PO Box 850
Eagle, CO 81631
(970)328-8603

Faults within County: Basalt Mountain (LC), Burns Faults (MLQ), Dotsero Faults (LC), Frontal (LQ), Gore (LC), Greenhorn Mountain (Q), Gypsum Faults (LC), Leadville (Q), Red Hill Faults (Q)
Historical Earthquakes: Apr. 3, 1946 Riland (#80); May 30, 1965 Tennessee Pass (#161); Apr. 3, 1966 South Park Blast (#221-border); Sept. 12, 1990 Vail (#449)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Mosquito (LQ), N Sawatch (LQ), S Sawatch (H), Williams Fork (H)
HAZUS Loss Estimates:

Chase Gulch: M6.75 – 0 fatal, $33.9 Million (-0.7%)
Frontal: M7.0 – 26 fatal, $572 Million (-11.4%)
Mosquito: M7.0 – 15 fatal, $417 Million (-8.3%)
N Sawatch: M7.0 – 9 fatal, $387 Million (-7.7%)
S Sawatch: M7.25 – 2 fatal, $146 Million (-2.9%)
Williams Fork: M6.75 – 5 fatal, $207 Million (-4.1%)

El Paso County

Population: 543,818 Growth since 1990: 30.2%
County Size: 2,158 square miles Inventory: $32,570.60 M
Contact:
El Paso Board of County Commissioners
27 E. Vermijo Ave.
Colorado Springs, CO 80903
(719)520-7276
Faults within County: Colorado Springs Faults (LC), Rampart Range (MLQ), Ute Pass (MLQ)
Historical Earthquakes: Dec. 23 and 31, 1995 Manitou Springs (#492, 493); Jan. 1997 Woodland Park (#497-499); Apr. 18, 1998 Woodland Park (#503); July 22, 2001 Woodland Park (#515); Feb. 19, 2003 Woodland Park (#556)
Faults analyzed for County: Chase Gulch (LQ), Cheraw (H), Goodpasture (Q), Rampart (MLQ), N Sangre de Cristo (H), S Sawatch (H), Ute Pass (MLQ)
HAZUS Loss Estimates:
Chase Gulch: M6.75 – 8 fatal, $636 Million (-2.0%)
Cheraw: M7.0 – 4 fatal, $353 Million (-1.1%)
Goodpasture: M6.0 – 0 fatal, $103 Million (-0.3%)
Rampart: M7.0 – 545 fatal, $9.01 Billion (-27.7%)
M6.0 – 20 fatal, $1.67 Billion (-5.1%)
N Sangre de Cristo: M7.5 WUS – 1 fatal, $90.8 Million (-0.3%)
M7.5 CEUS – 125 fatal, $2.12 Billion (-6.5%)
S Sawatch: M7.25 – 11 fatal, $659 Million (-2.0%)
Ute Pass: M7.0 – 477 fatal, $8.22 Billion (-25.2%)
M6.0 – 27 fatal, $1.91 Billion (-5.9%)

Elbert County

Population: 19,872 Growth since 1990: 106.0%

County Size: 1,865 square miles Inventory: $2,431.60 M
Contact:
Elbert County Emergency Management
(303)621-2027
Faults within County: None
Historical Earthquakes: Oct. 13, 1966 E of Castle Rock (#236)
Faults analyzed for County: Cheraw (H), Golden (Q), Rampart (MLQ), Ute Pass (MLQ)
HAZUS Loss Estimates:
Cheraw: M7.0 – 0 fatal, $5.3 Million (-0.2%)
Golden: M6.5 – 0 fatal, $15.6 Million (-0.6%)
Rampart: M7.0 – 3 fatal, $98.9 Million (-4.1%)
Ute Pass: M7.0 – 1 fatal, $44.3 Million (-1.8%)

Fremont County
Population: 46,145 Growth since 1990: 43.0%
County Size: 1,502 square miles Inventory: $3,759.70 M
Contact:
Fremont County Emergency Services
615 Macon Ave., Rm. #204
Cañon City, CO 81212
Faults within County: Alvarado (LC), Bare Hills (LC), Box Canyon and Quarry Faults (LC), Coaldale-Wellsville (LC), Currant Creek (LC), Dead Mule Gulch (LC), Fourmile Creek (LC), High Park (LC), Iron Mountain (LC), Isle (LC), Parkdale Faults (LC), Pleasant Valley (LC), Rice Mountain (LC), Salida South (LC), Tanner Peak (LC), Texas Creek (LC), Thompson Mountain (LC), Westcliffe (LC), Wet Mountain (LC)
Historical Earthquakes: Mar. 16, 1985 Salida (#402); Apr. 16, 1987 Howard (#434)
Faults analyzed for County: Chase Gulch (LQ), Goodpasture (Q), Rampart (MLQ), N Sangre de Cristo (H), S Sawatch (H), Ute Pass (MLQ)
HAZUS Loss Estimates:
Chase Gulch: M6.75 – 1 fatal, $79.5 Million (-2.1%)
Goodpasture: M6.0 – 0 fatal, $56.1 Million (-1.5%)
Rampart: M7.0 – 2 fatal, $127 Million (-3.4%)
N Sangre de Cristo: M7.5 WUS – 3 fatal, $89.6 Million (-2.4%)
M7.5 CEUS – 19 fatal, $394 Million (-10.5%)
S Sawatch: M7.25 – 2 fatal, $121 Million (-3.2%)
Ute Pass: M7.0 – 3 fatal, $184 Million (-4.9%)

Garfield County
Population: 48,503 Growth since 1990: 46.1%
County Size: 2,958 square miles Inventory: $4,735.50 M
Contact:

Garfield County Department of Emergency Management
109 8th St. #307
Glenwood Springs, CO 81601
(970)945-9789

Faults within County: Canyon Creek (LC), Causeway (LC), Consolidated Reservoir (LC), Grand Hogback Faults-Freeman Creek (Q), Grand Hogback-Fourmile Creek (H), Grand Hogback-SW Glenwood (LQ), Grand Hogback Faults-SW Glenwood (LC), Heuschkel Park Faults (LC), Lookout Mountain Faults (LC), Missouri Heights Faults (LC), Possum Creek (LC), Red Canyon (LC), Spring Valley Faults (LC), West Coal Creek (LC)
Historical Earthquakes: Jan. 15, 1889 Glenwood Springs (#13); Dec. 21, 1906 New Castle (#24); Dec. 29-30, 1920 New Castle (#30-33); Jan. 31, 1946 Glenwood Springs (#79); Sept. 10, 1969 Rulison AEC Test (#329); Jan. 7, 1971 Glenwood Springs (#341); Nov. 22, 1982 Rifle (#376); Apr.-May 1984 Carbondale Earthquakes (#381-399); Oct. 19, 1990 New Castle (#450-451); Dec. 12, 1990 New Castle (#453); Mar. 8, 1994 Douglas Pass (#472); Dec. 5, 2000 Carbondale (#514); Aug. 2001 Glenwood Springs Earthquakes (#516-519); Mar. 19, 2002 Douglas Pass (#536); Feb. 8, 2006 Glenwood Springs (#578)
Faults analyzed for County: Frontal (LQ), Mosquito (LQ), N Sawatch (LQ)
HAZUS Loss Estimates:

Frontal: M7.0 – 0 fatal, $35.3 Million (-0.8%)
Mosquito: M7.0 – 0 fatal, $35.3 Million (-0.8%)
N Sawatch: M7.0 – 1 fatal, $76.6 Million (-1.6%)

Gilpin County
Population: 4,757 Growth since 1990: 55.0%
County Size: 149 square miles Inventory: $725.30 M
Contact:

Gilpin County Commissioners
203 Eureka St., 2nd Floor or PO Box 366
Central City, CO 80427
(303)582-5214

Faults within County: Floyd Hill Fault Zone (LC)
Historical Earthquakes: None
Faults analyzed for County: Frontal (LQ), Golden (Q), Williams Fork (H)

HAZUS Loss Estimates:

- Frontal: M7.0 – 0 fatal, $10.8 Million (-1.5%)
- Golden: M6.5 – 0 fatal, $40.1 Million (-5.5%)
- Williams Fork: M6.75 – 0 fatal, $9.96 Million (-1.4%)

Grand County

Population: 12,442 Growth since 1990: 56.2%

County Size: 1,840 square miles Inventory: $3,131.50 M

Contact:

Grand County Courthouse
308 Byers Ave. or PO Box 264
Hot Sulphur Springs, CO 80451
(970)725-3347

Faults within County: Antelope Pass (LC), Barger Gulch (LC), Gore (LC), Granby Basin Faults (LC), Granby Faults West (LC), Kremmling Faults West (LC), Laramie River (LC), Parshall (LC), Rabbit Ears Pass Faults (LC), Rabbit Ears Range (LC), Sheephorn Mountain Faults (LC), Trail Ridge (LC), Troublesome Creek (LC), Williams Fork Mountains (H), Williams Fork Valley Faults (MLQ), Williams Fork Valley Faults East (LC)

Historical Earthquakes: Aug. 4, 1964 Dillon (#149)

Faults analyzed for County: Frontal (LQ), Mosquito (LQ), N Sawatch (LQ), Williams Fork (H), 1882 Historical Epicenter

HAZUS Loss Estimates:

- Frontal: M7.0 – 2 fatal, $157 Million (-5.0%)
- Mosquito: M7.0 – 0 fatal, $47.2 Million (-1.5%)
- N Sawatch: M7.0 – 0 fatal, $24.1 Million (-0.8%)
- Williams Fork: M6.75 – 2 fatal, $184 Million (-5.9%)
- 1882 RMNP: M6.6 – 0 fatal, $110 Million (-3.5%)

Gunnison County

Population: 14,012 Growth since 1990: 35.9%

County Size: 3,238 square miles Inventory: $2,681.30 M

Contact:

Gunnison County Commissioners
200 East Virginia Ave.
Gunnison, CO 81230
(970)641-0248

Faults within County: Cimarron (Q, LQ, LC), Red Rocks (Q), Treasure Mountain (LC)
Historical Earthquakes: July 1886 Cimarron (#11); Sept. 9, 1944 Montrose-Basalt (#75); Oct. 12, 1960 Montrose-Ridgway (#93); Sept. 4, 1966 Cimarron Ridge (#234); Jan. 12, 1967 Somerset (#243); Aug. 14, 1983 Cimarron (#377); Apr.-Oct. 1986 Crested Butte Earthquakes (#404-430, 432-433); Dec. 26, 1991 Powderhorn (#460-461); Sept. 26, 1994 Somerset Coal Bump (#479); Nov. 2, 1994 Somerset Coal Bump (#480); Jan. 1, 1995 Somerset Coal Bump (#483); Mar. 14, 1995 Somerset Coal Bump (#485); Nov. 5, 2001 Paonia-Somerset (#533); Dec. 4, 2001 Paonia-Somerset (#534); Mar.-Apr. 2002 Paonia-Somerset (#538-540); June-Dec. 2002 Paonia-Somerset (#543, 546-549, 551-552); Jan.-Aug. 2003 Paonia-Somerset (#555, 557-558); Apr.-Nov. 2004 Paonia-Somerset (#564-567, 569)
Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ), Cimarron (LQ,Q), Roubideau Creek (H), N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H)
HAZUS Loss Estimates:

- Busted Boiler: M6.5 – 0 fatal, $13.1 Million (-0.5%)
- Cannibal: M7.0 – 2 fatal, $70.1 Million (-2.6%)
- Cimarron: M6.75 – 1 fatal, $67.6 Million (-2.5%)
- Mosquito: M7.0 – 0 fatal, $32.4 Million (-1.2%)
- Roubideau Cr.: M5.5 – 0 fatal, $0.5 Million (-0.0%)
- N Sangre de Cristo: M7.5 WUS – 0 fatal, $4.2 Million (-0.2%)
  M7.5 CEUS – 4 fatal, $100 Million (-3.7%)
- N Sawatch: M7.0 – 1 fatal, $46.2 Million (-1.7%)
- S Sawatch: M7.25 – 2 fatal, $88.3 Million (-3.3%)

Hinsdale County

Population: 790 Growth since 1990: 69.2%
County Size: 1,124 square miles Inventory: $347.30 M
Contact:

Hinsdale County Courthouse
PO Box 277
Lake City, CO 81235
(970)944-2225

Faults within County: Cannibal (LQ), Lake City Caldera Faults (LC)
Historical Earthquakes: Aug. 3, 1955 Lake City (#85-87)
Faults analyzed for County: Busted Boiler (H), Cannibal (LQ), Cimarron (LQ)
HAZUS Loss Estimates:

- Busted Boiler: M6.5 – 0 fatal, $1.1 Million (-0.3%)
- Cannibal: M7.0 – 0 fatal, $35.2 Million (-10.1%)
- Cimarron: M6.75 – 0 fatal, $1.9 Million (-0.6%)

Huerfano County
Population: 7,960 Growth since 1990: 30.8%
County Size: 1,592 square miles Inventory: $1,939.50 M
Contact:
Huerfano County Courthouse
401 Main St.
Walsenburg, CO 81089
(719)738-2370
Faults within County: Alvarado (LC), Bear Creek (LC), Farista Faults (LC), Greenhorn (LC), Ilse (LC), La Veta Faults West (LC), Westcliffe (LC), Wet Mountains South (LC)
Historical Earthquakes: None
Faults analyzed for County: Cheraw (H), Goodpasture (Q), N Sangre de Cristo (H)
HAZUS Loss Estimates:
Cheraw: M7.0 – 0 fatal, $4.6 Million (-0.2%)
Goodpasture: M6.0 – 0 fatal, $10.1 Million (-0.5%)
N Sangre de Cristo: M7.5 WUS – 0 fatal, $19.0 Million (-1.0%)
M7.5 CEUS – 1 fatal, $84.0 Million (-4.3%)

Jackson County
Population: 1,557 Growth since 1990: -1.7%
County Size: 1,620 square miles Inventory: $949.70 M
Contact:
Jackson County Courthouse
404 4th St. or PO Box 1019
Walden, CO 80480
(970)723-4660
Faults within County: Arapahoe Ridge Faults (LC), East Independence Mountain (LC), North Park Faults NW and W (LC), Park Range Faults (LC), Rabbit Ears Range (LC), Sierra Madre Range Faults (LC), Spring Creek (LC), Trail Ridge (LC), Walden Faults (LC), West Independence Mountain (LC)
Historical Earthquakes: Oct. 3, 1948 Walden (#81)
Faults analyzed for County: Frontal (LQ), Williams Fork (H), 1882 Historical Epicenter
HAZUS Loss Estimates:
Frontal: M7.0 – 0 fatal, $3.0 Million (-0.3%)

Williams Fork: M6.75 – 0 fatal, $2.3 Million (-0.2%)
1882 RMNP: M6.6 – 0 fatal, $3.7 Million (-0.4%)

Jefferson County

Population: 527,056 Growth since 1990: 20.2%
County Size: 774 square miles Inventory: $35,828.60 M
Contact:

Jefferson County Department of Emergency Management
800 Jefferson County Parkway
Golden, CO 80419
(303)271-4900

Faults within County: Floyd Hill (LC), Golden (Q), Ken Caryl (LC), Kennedy Gulch (LC), Rock Creek (Q), Walnut Creek (Q)
Historical Earthquakes: Jan. 5, 1965 Rocky Flats (#153); Feb. 16, 1965 N of Denver (#155); Sept. 29, 1965 N of Denver (#192); 1960's-70's RM Arsenal Earthquakes; Nov.-Dec. 1981 Conifer (#372-373); Sept. 21, 1986 Conifer (#431)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Golden (Q), Mosquito (LQ), Rampart (MLQ), Rocky Mountain Arsenal Epicenter, N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H), Ute Pass (MLQ), Valmont (MLQ), Walnut Creek (Q), Williams Fork (H)
HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 2 fatal, $307 Million (-0.9%)
Frontal:	M7.0 – 5 fatal, $460 Million (-1.3%)
Golden:	M6.5 – 174 fatal, $5.88 Billion (-16.4%)
	M5.5 – 3 fatal, $1.03 Billion (-2.9%)
Mosquito:	M7.0 – 4 fatal, $402 Million (-1.1%)
Rampart:	M7.0 – 25 fatal, $1.30 Billion (-3.6%)
RM Arsenal:	M6.25 – 23 fatal, $1.42 Billion (-4.0%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $15.6 Million (-0.0%)
	M7.5 CEUS – 5 fatal, $285 Million (-0.8%)
N Sawatch:	M7.0 – 1 fatal, $206 Million (-0.6%)
S Sawatch:	M7.25 – 2 fatal, $253 Million (-0.7%)
Ute Pass:	M7.0 – 11 fatal, $770 Million (-2.2%)
Valmont:	M5.0 – 0 fatal, $50.4 Million (-0.1%)
Walnut Creek:	M6.0 – 43 fatal, $2.31 Billion (-6.4%)
Williams Fork:	M6.75 – 2 fatal, $274 Million (-0.8%)

Kiowa County
Population: 1,622 Growth since 1990: -3.9%
County Size: 1,872 square miles Inventory: $1,141.60 M
Contact:

Kiowa County Commissioners Office
PO Box 100
Eads, CO 81036
(719)438-5810

Faults within County: Cheraw (H)
Historical Earthquakes: Oct. 15, 1921 Eads (#48); Jan. 10, 2003 Lamar (#554)
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:

Cheraw: M7.0 – 0 fatal, $11.4 Million (-1.0%)

Kit Carson County
Population: 7,987 Growth since 1990: 12.2%
County Size: 2,162 square miles Inventory: $2,252.00 M
Contact:

Kit Carson County Courthouse
PO Box 160
Burlington, CO 80807
(719)346-8139

Faults within County: High Plains Grabens (Anton Scarp) under investigation
Historical Earthquakes: May 27, 1984 Burlington (#400)
Faults analyzed for County: Anton Scarp, Cheraw (H)
HAZUS Loss Estimates:

Anton Scarp: M7.6 – 17 fatal, $285 Million (-12.7%)
Cheraw: M7.0 – 0 fatal, $11.25 Million (-0.5%)

La Plata County
Population: 47,494 Growth since 1990: 36.1%
County Size: 1,690 square miles Inventory: $4,309.40 M
Contact:

La Plata County Office of Emergency Management
1060 E. 2nd Ave.
Durango, CO 81301
(970)382-6274

Faults within County: None
Historical Earthquakes: Aug. 29, 1941 Durango-Bayfield (#72)
Faults analyzed for County: Busted Boiler (H), Cannibal (LQ), Cimarron (LQ,Q)
HAZUS Loss Estimates:

Busted Boiler: M6.5 – 0 fatal, $14.4 Million (-0.3%)
Cannibal: M7.0 – 0 fatal, $53.1 Million (-1.2%)
Cimarron: M6.75 – 0 fatal, $12.3 Million (-0.3%)

Lake County

Population: 7,917 Growth since 1990: 30.0%
County Size: 384 square miles Inventory: $1,098.70 M
Contact:

Lake County Courthouse
505 Harrison Ave. or PO Box 964
Leadville, CO 80461
(719)486-0993

Faults within County: Leadville-NW and S (Q), Mosquito (LQ), North Sawatch (LQ), Northeastern Boundary Faults (MLQ), Sawatch Range Faults (LC), Twin Lakes Reservoir Faults (Q)
Historical Earthquakes: May 23, 1964 Blast at Climax (#148); May 30, 1965 Tennessee Pass (#161)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Mosquito (LQ), N Sawatch (LQ), S Sawatch (H), Williams Fork (H)
HAZUS Loss Estimates:

Chase Gulch: M6.75 – 0 fatal, $27.3 Million (-2.5%)
Frontal: M7.0 – 1 fatal, $69.5 Million (-6.3%)
Mosquito: M7.0 – 10 fatal, $299 Million (-27.2%)
N Sawatch: M7.0 – 10 fatal, $303 Million (-27.5%)
S Sawatch: M7.25 – 6 fatal, $183 Million (-16.7%)
Williams Fork: M6.75 – 0 fatal, $17.2 Million (-1.6%)

Larimer County

Population: 283,000 Growth since 1990: 35.1%

County Size: 2,640 square miles Inventory: $18,896.00 M
Contact:

Larimer County Emergency Management Office
200 W. Oak St.
Fort Collins, CO 80521
(970)498-5310

Faults within County: Larimer River (LC), Larimer River Valley (LC), Trail Ridge (LC)
Historical Earthquakes: Nov. 8, 1882 North-Central Colorado (#8); Sept. 9, 1903 Estes Park (#22); Oct. 3, 1948 Walden (#81); Nov. 3, 1977 Poudre Canyon (#361)
Faults analyzed for County: Golden (Q), Valmont (MLQ), Williams Fork (H)
HAZUS Loss Estimates:

Golden: M6.5 – 3 fatal, $237 Million (-1.3%)
Valmont: M5.0 – 0 fatal, $11.4 Million (-0.0%)
Williams Fork: M6.75 – 2 fatal, $178 Million (-0.9%)
1882 Historical: M6.6 – 18 fatal, $887 Million (-4.7%)

Las Animas County
Population: 15,967 Growth since 1990: 10.5%
County Size: 4,773 square miles Inventory: $3,705.50 M
Contact:

Las Animas County Courthouse
200 E. 1st Street, Rm. 207
Trinidad, CO 81082
(719)845-2568

Faults within County: La Veta Faults West (LC)
Historical Earthquakes: Oct. 3, 1966 NE of Trinidad (#235); Sept. 1973 Valdez-Boncarbo (#352-356); May 30, 1976 Pinon Canyon Area (#359); Aug. 17, 1983 NE of Trinidad (#378); Mar. 24, 1989 Mesa de Maya (#442); Apr. 15, 1992 Aguilar (#462); May 2, 1992 Gulnare (#463); Aug. 1, 1996 Tyrone (#494-495); Nov. 1, 1996 Tyrone (#496); Aug.-Sept. 2001 Trinidad Earthquakes (#520-532); Sept. 8, 2003 Aguilar (#559); Jan. 14, 2004 Walsenberg (#562); Mar. 30, 2004 Weston (#563)
Faults analyzed for County: Cheraw (H), N Sangre de Cristo (H)
HAZUS Loss Estimates:

Cheraw: M7.0 – 0 fatal, $3.97 Million (-0.1%)
N Sangre de Cristo: M7.5 WUS – 0 fatal, $3.40 Million (-0.0%)
M7.5 CEUS – 0 fatal, $31.6 Million (-0.9%)

Lincoln County

Population: 6,099 Growth since 1990: 34.4%

County Size: 2,585 square miles Inventory: $1,866.40 M

Contact:

Lincoln County Courthouse
103 3rd Avenue or PO Box 39
Hugo, CO 80821
(719)743-2810

Faults within County: None

Historical Earthquakes: None

Faults analyzed for County: Anton Scarp, Cheraw (H)

HAZUS Loss Estimates:

Anton Scarp: M7.6 – 2 fatal, $59.2 Million (-3.2%)
Cheraw: M7.0 – 0 fatal, $22.5 Million (-1.2%)

Logan County

Population: 21,889 Growth since 1990: 16.7%

County Size: 1,845 square miles Inventory: $3,057.30 M

Contact:

Logan County Courthouse
315 Main St.
Sterling, CO 80751
((970)522-0888

Faults within County: None

Historical Earthquakes: None

Faults analyzed for County: Anton Scarp, Rocky Mountain Arsenal Epicenter

HAZUS Loss Estimates:

Anton Scarp: M7.6 – 20 fatal, $300 Million (-9.8%)
RM Arsenal: 6.25 – 0 fatal, $2.12 Million (-0.0%)

Mesa County

Population: 116,255 Growth since 1990: 24.8%

County Size: 3,309 square miles Inventory: $9,044.60 M

Contact:

Mesa County Emergency Management
544 Rood Avenue or PO Box 20000
Grand Junction, CO 81502
(970)244-1763

Faults within County: Atkinson Mesa (Q), Bangs Canyon (Q), Big Dominguez Creek (Q), Bridgeport (Q), Cactus Park (Q), Glade Park (Q), Granite Creek (Q), Ladder Creek (Q), Little Dolores River (Q), Little Dominguez Creek (Q), Lost Horse Basin (Q), Monitor Creek (Q), Pine Mountain (Q), Redlands Fault Complex (Q), Ryan Creek (Q), Sinbad Valley Graben (Q), Whitewater (Q), Wolf Hill (Q)

Historical Earthquakes: Feb. 28, 1915 Grand Junction (#28); June 24, 1962 Uncompahgre Plateau (#106); Nov. 12, 1971 Grand Junction (#347); Jan. 30, 1975 N of Grand Junction (#358); Dec. 6, 1985 Gateway (#403); Oct. 21, 1990 Palisade (#452); Apr. 23, 1995 Grand Mesa (#491)

Faults analyzed for County: Cimarron (LQ,Q), Roubideau Creek (H)

HAZUS Loss Estimates:

Cimarron: M6.75 – 0 fatal, $55.4 Million (-0.6%)
Roubideau: M5.5 – 0 fatal, $4.71 Million (-0.0%)

Mineral County

Population: 891 Growth since 1990: 48.9%
County Size: 878 square miles Inventory: $667.40 M

Contact:

Mineral County Courthouse
PO Box 70
Creede, CO 81130
(719)658-2331

Faults within County: Cannibal (LQ)

Historical Earthquakes: Apr.-May 1928 Creede Earthquakes (#53-66); May 3, 1957 Creede Area (#91); Jan. 23, 1966 Creede (#211)

Faults analyzed for County: Cannibal (LQ), Cimarron (LQ,Q), N Sangre de Cristo (H)

HAZUS Loss Estimates:

Cannibal: M7.0 – 1 fatal, $43.1 Million (-6.5%)
Cimarron: M6.75 – 0 fatal, $2.75 Million (-0.4%)
N Sangre de Cristo: M7.5 CEUS – 0 fatal, $9.52 Million (-1.4%)

Moffat County

Population: 13,184 Growth since 1990: 16.1%

County Size: 4,754 square miles   Inventory: $2,778.00 M
Contact:
Moffat County Courthouse
221 W. Victory Way, Suite 130
Craig, CO 81625
Faults within County: Bakers Peak (LC), Beaver Creek (LC), Browns Park Faults (LC), Craig Faults (LC), Cross Mountain (LC), East (LC), Elk Springs Faults (LC), Elkhead Mountains Faults (LC), Lay Faults (LC), Maybell Faults (LC), Mitten Park (LC), Sawmill Canyon (LC), Sparks Ranch-Uinta (LC), Teepee (LC), Wapiti Peak (LC), Yampa (LC)
Historical Earthquakes: Oct. 1871 Lily Park-Moffat (#2); Dec. 1891 Axial Basin (#14); 1899 Lay (#19); Apr. 1906 Maybell (#23); Summer 1924 Craig (#51); Jul.-Aug. 1942 W Moffat County (#73-74); Jan. 18, 1968 Dinosaur National Monument (#304); Nov. 30, 1978 Craig (#364); Jan. 20, 1979 NW of Craig (#366); Sept. 24, 1983 Browns Park (#379); Feb. 14, 1988 Maybell (#439); Aug. 31, 1988 Cold Spring Mountain (#440); Nov. 15, 1991 Hamilton (#459); Feb. 14, 1994 Craig (#471); Jan. 31, 2002 Axial Basin (#535)
Faults analyzed for County: Frontal (LQ)
HAZUS Loss Estimates:
Frontal: M7.0 – 0 fatal, $5.11 Million (-0.2%)

Montezuma County
Population: 23,830   Growth since 1990: 27.6%
County Size: 2,094 square miles   Inventory: $3,074.20 M
Contact:
Montezuma County Courthouse
109 West Main St.
Cortez, CO 81321
(970)565-8317
Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Cannibal (LQ)
HAZUS Loss Estimates:
Cannibal: M7.0 – 0 fatal, $9.8 Million (-0.3%)

Montrose County
Population: 35,971   Growth since 1990: 36.9%
County Size: 2,246 square miles   Inventory: $3,773.90 M
Contact:

Montrose County Courthouse
161 S. Townsend Ave.
Montrose, CO 81401
(970)249-7755

Faults within County: Atkinson Mesa Faults (Q), Big Gypsum Valley Graben Faults (Q), Cimarron (Q, LQ), Clay Creek (Q), Cottonwood Creek Faults (Q), Ellison Gulch Scarp (H), Hanks Creek (Q), Horsefly Creek (Q), Johnson Spring (Q), Love Mesa (Q), Monitor Creek (Q), Montrose Faults SW (Q), Paradox Valley Graben Faults (Q), Pinto Mesa Faults (Q), Red Canyon (Q), Red Rocks (Q), Roubideau Creek (H), Roubideau Creek Faults East (Q), San Miguel Canyon Faults (Q), Sinbad Valley Graben (Q)

Historical Earthquakes: Jan. 13, 1962 Montrose (#97); May 13, 1989 Uravan (#443); May 15, 1992 Olathe (#464); Sept. 13-15, 1994 Norwood (#475-478); Apr. 10, 1998 Paradox Valley (#502); June-Nov. 1999 Paradox Valley (#504-508); Mar.-May 2000 Paradox Valley (#511-512); June 6, 2002 Paradox Valley (#544); Nov. 6, 2004 Naturita (#568)

Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ), Cimarron (LQ,Q), Roubideau Creek (H)

HAZUS Loss Estimates:

Busted Boiler: ______M6.5 – 21 fatal, $432 Million (-11.5%)
Cannibal: __________M7.0 – 4 fatal, $174 Million (-4.6%)
Cimarron: __________M6.75 – 28 fatal, $497 Million (-13.2%)
Roubideau: _________M5.5 – 0 fatal, $78.2 Million (-2.1%)

Morgan County

Population: 28,183 Growth since 1990: 23.8%
County Size: 1,294 square miles Inventory: $5,404.70 M
Contact:

Morgan County Courthouse
PO Box 596
Fort Morgan, CO 80701
(970)542-3500

Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Anton Scarp, Rocky Mountain Arsenal Epicenter
HAZUS Loss Estimates:

Anton Scarp: ________M7.6 – 48 fatal, $2.44 Billion (-45.2%)
RM Arsenal: ________M6.25 – 0 fatal, $21.8 Million (-0.4%)

Otero County

Population: 19,681 Growth since 1990: 0.6%
County Size: 1,268 square miles Inventory: $2,935.40 M
Contact:
Otero County Courthouse
PO Box 511
La Junta, CO 81050
(719)383-3000
Faults within County: Cheraw (H)
Historical Earthquakes: None
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:
Cheraw: M7.0 – 15 fatal, $416 Million (-14.2%)

Ouray County
Population: 4,030 Growth since 1990: 63.1%
County Size: 542 square miles Inventory: $781.70 M
Contact:
Ouray County Courthouse
PO Bin C
Ouray, CO 81427
(970)325-7320
Faults within County: Busted Boiler (LQ), Cow Creek (LC), Log Hill Mesa Graben Faults (LQ), Montrose Faults SW (Q), Ridgway (Q), Ridgway Quarry Faults (LC)
Historical Earthquakes: Aug. 3, 1897 Ridgway (#18); Nov. 11, 1913 Ridgway Area (#25-27); Oct. 11, 1960 Montrose-Ridway (#92); Feb. 5, 1962 Ridgway-Montrose (#100); Apr. 4, 1967 Montrose (#252); Nov. 19, 1989 Ridgway (#447); Nov. 22, 1989 Ouray (#448); Jan. 17, 1994 Ridgway (#470)
Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ), Cimarron (LQ,Q), Roubideau Creek (H)
HAZUS Loss Estimates:
Busted Boiler: M6.5 – 1 fatal, $104 Million (-13.3%)
Cannibal: M7.0 – 0 fatal, $36.5 Million (-4.7%)
Cimarron: M6.75 – 0 fatal, $32.7 Million (-4.2%)
Roubideau: M5.5 – 0 fatal, $2.8 Million (-0.4%)

Park County

Population: 14,523 Growth since 1990: 102.4%
County Size: 2,166 square miles Inventory: $2,806.30 M
Contact:

Park County Commissioners Office
501 Main St. or PO Box 1373
Fairplay, CO 80440
(719)836-4201

Faults within County: Bare Hills (LC), Chase Gulch-East Side (LQ), Chase Gulch-West Side (LQ), Currant Creek Fault Zone (LC), Eleven Mile (LQ), Elevenmile Canyon Reservoir Faults (LC), Frontal (LQ), Hartsel Faults W (LC), High Park Fault Zone (LC), Ilse (LC), Kaufman Ridge (LC), Northeastern Boundary Faults (MLQ), Pulver Gulch-Rocky Gulch (LC), Schoolmarm Mountain (LC), Tarryall (LC), Thirty-nine Mile Mountain (LC),
Historical Earthquakes: Nov. 27, 1961 South Park (#95-96); Apr. 3, 1966 Blast in South Park (#221)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Golden (Q), Mosquito (LQ), Rampart (MLQ), N Sangre (H), N Sawatch (LQ), S Sawatch (H), Ute Pass (MLQ), Williams Fork (H)
HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 1 fatal, $166 Million (-5.9%)
Frontal:	M7.0 – 1 fatal, $75.9 Million (-2.7%)
Golden:	M6.5 – 0 fatal, $13.0 Million (-0.5%)
Mosquito:	M7.0 – 3 fatal, $169 Million (-6.0%)
Rampart:	M7.0 – 0 fatal, $25.9 Million (-0.9%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $4.17 Million (-0.2%)
N Sawatch:	M7.0 – 1 fatal, $66.9 Million (-2.4%)
S Sawatch:	M7.25 – 1 fatal, $72.2 Million (-2.6%)
Ute Pass:	M7.0 – 0 fatal, $34.5 Million (-1.2%)
Williams Fork:	M6.75 – 0 fatal, $18.5 Million (-0.7%)

Phillips County

Population: 4,505 Growth since 1990: 6.9%
County Size: 688 square miles Inventory: $1,151.20 M
Contact:

Phillips County Courthouse
221 S. Interocean Ave.
Holyoke, CO 80734
(970)854-2454

Faults within County: None

Historical Earthquakes: None
Faults analyzed for County: Anton Scarp
HAZUS Loss Estimates:

Anton Scarp: M7.6 – 0 fatal, $17.6 Million (-1.5%)
RM Arsenal: M6.25 – 0 fatal, $0 Million (-0.0%)

Pitkin County

Population: 14,872 Growth since 1990: 17.5%
County Size: 975 square miles Inventory: $2,224.30 M
Contact:

Pitkin County Emergency Management
506 E. Main Street
Aspen, CO 81611
(970)920-5234

Faults within County: Basalt Mountain Fault (Q), Sawatch Range Faults (LC)
Historical Earthquakes: Sept. 17, 1880 Aspen (#4); Apr. 8, 1940 Aspen (#68); Feb. 1941 Aspen (#69-71); Oct. 17, 1960 Aspen (#94); Mar. 5, 1962 Aspen (#101); June 23, 1968 SW of Carbondale (#310); Sept. 24, 1977 SW of Carbondale (#360); May 29, 1978 SW of Carbondale (#362); Apr.-May 1984 Carbondale Earthquakes (#381-399); Apr. 21, 1991 Aspen (#454); July 7-8, 1993 Aspen (#466-469); Oct. 13, 2002 Aspen (#550); Jan. 1, 2003 Aspen (#553)
Faults analyzed for County: Chase Gulch (LQ), Cimarron (LQ,Q), Frontal (LQ), Mosquito (LQ), N Sawatch (LQ), S Sawatch (H), Williams Fork (H)
HAZUS Loss Estimates:

Chase Gulch: M6.75 – 0 fatal, $10.9 Million (-0.5%)
Cimarron: M6.75 – 0 fatal, $12.6 Million (-0.6%)
Frontal: M7.0 – 0 fatal, $32.5 Million (-1.5%)
Mosquito: M7.0 – 0 fatal, $61.4 Million (-2.8%)
N Sawatch: M7.0 – 3 fatal, $169 Million (-7.6%)
S Sawatch: M7.25 – 2 fatal, $115 Million (-5.2%)
Williams Fork: M6.75 – 0 fatal, $13.2 Million (-0.6%)

Prowers County

Population: 14,104 Growth since 1990: 8.5%
County Size: 1,645 square miles Inventory: $2,306.40 M
Contact:

Prowers County Courthouse
310 S. Main St., #215
Lamar, CO 81052
(719)336-8025

Faults within County: None

Historical Earthquakes: Sept. 29, 1928 Holly (#67); Jan. 14, 1956 Lamar (#89-90); Apr. 21, 1968 S of Holly (#307); Jan. 10, 2003 Lamar (#554)

Faults analyzed for County: Cheraw (H)

HAZUS Loss Estimates:

Cheraw: M7.0 – 1 fatal, $60.9 Million (-2.6%)

Pueblo County

Population: 141,472 Growth since 1990: 15.0%

County Size: 2,401 square miles Inventory: $10,530.10 M

Contact:

Pueblo County Department of Emergency Management
320 W. 10th St., B1
Pueblo, CO 81003
(719)583-6200

Faults within County: Goodpasture (Q), Greenhorn (LC), Ilse (LC), Wet Mountain (LC)

Historical Earthquakes: Dec. 4, 1870 Pueblo-Ft. Reynolds (#1); Nov. 13, 1963 Pueblo (#144)

Faults analyzed for County: Cheraw (H), Goodpasture (Q), Rampart (MLQ), N Sangre (H), Ute Pass (MLQ)

HAZUS Loss Estimates:

Cheraw: M7.0 – 2 fatal, $171 Million (-1.6%)
Goodpasture: M6.0 – 1 fatal, $243 Million (-2.3%)
Rampart: M7.0 – 3 fatal, $203 Million (-1.9%)
N Sangre de Cristo: M7.5 WUS – 0 fatal, $25.6 Million (-0.2%)
M7.5 CEUS – 26 fatal, $484 Million (-4.6%)
Ute Pass: M7.0 – 5 fatal, $288 Million (-2.7%)

Rio Blanco County

Population: 6,033 Growth since 1990: -1.1%

County Size: 3,226 square miles Inventory: $1,567.20 M

Contact:

Rio Blanco County Courthouse
PO Box I
Meeker, CO 81641
(970)878-5001

Faults within County: Blue Lake-Heart Lake Faults (LC), Fish Creek Faults (LC), Killarney Faults (Q), West Coal Creek (LC)
Historical Earthquakes: Feb. 21, 1954 Rangely-Grand Junction (#83); July 5-6, 1966 Rangely (#230-232); Feb. 15, 1967 Rangely (#249-250); Apr. 21, 1970 Rangely (#337-338); May 17, 1973 Rio Blanco AEC Test (#351); Mar. 19, 1979 Rangely (#367); Mar. 29, 1979 Rangely (#368); June 30, 1989 Meeker (#444); Nov. 3, 1994 Meeker (#481); Mar.-Apr. 1995 Dinosaur National Monument (#486-490)
Faults analyzed for County: Frontal (LQ)
HAZUS Loss Estimates:

Frontal: M7.0 – 0 fatal, $6.69 Million (-0.4%)

Rio Grande County
Population: 12,711 — Growth since 1990: 15.3%
County Size: 913 square miles — Inventory: $1,783.20 M
Contact:

Rio Grande County Courthouse
925 6th Street, Rm. 207
Del Norte, CO 81132
(719)657-2744

Faults within County: Del Norte Peak Faults (LC), Monte Vista Faults (Q), Monte Vista Faults West (LC), Summitville Faults (LC)
Historical Earthquakes: Jan. 15, 1988 Summitville (#438); May 10, 1991 Summitville (#455-458)
Faults analyzed for County: Cannibal (LQ), N Sangre de Cristo (H)
HAZUS Loss Estimates:

Cannibal: M7.0 – 0 fatal, $36.6 Million (-2.1%)
N Sangre de Cristo: M7.5 WUS – 0 fatal, $16.3 Million (-0.9%)
M7.5 CEUS – 7 fatal, $124 Million (-7.0%)

Routt County
Population: 19,690 — Growth since 1990: 39.8%
County Size: 2,331 square miles — Inventory: $3,114.00 M
Contact:

Routt County Office of Emergency Management
135 6th Street or PO Box 773598

Steamboat Springs, CO 80477
(970)870-5551

Faults within County: Blacktail Mountain Faults (LC), Brush Mountain (LC), Diamond Peak Faults (LC), Fish Creek Faults (LC), Gardner Reservoir Faults (LC), Green Ridge (LC), Grouse Mountain (LC), Hahns Peak Faults (LC), Hinman Creek (LC), King Solomon (LC), Kremmling Faults (LC), Lawson Creek (LC), Lester Creek Reservoir (LC), Little Rock Creek (LC), Lone Spring Faults (LC), Milner Faults (LC), Morrison Creek (LC), Newcomer Creek Faults (LC), Park Range Faults (LC), Rabbit Ears Pass Faults (LC), Reed Creek (LC), Sand Mountain (LC), Sierra Madre Range Faults (LC), Silver City Creek (LC), Silver Creek (LC), Spillway (LC), Steamboat Lake (LC), Steamboat Springs Fault Zone (LC), Trail Creek (LC), Twentymile Park Faults (LC), Wheeler Creek (LC), Willow Creek Structural Zone (LC), Yampa (LC)

Historical Earthquakes: Mar. 22, 1895 Steamboat Springs (#17); Feb. 10, 1955 Steamboat Springs (#84); Nov. 1, 1966 Yampa (#238); Jan. 18, 1967 Flat Tops (#245); Mar. 18, 1971 Clark (#343); Mar. 31, 1974 Clark (#357); Apr. 29, 1993 Clark (#465); Feb. 2000 E of Steamboat Springs (#509-510); July 30, 2000 Steamboat Springs (#513); Mar. 23, 2002 Steamboat Springs (#537); Apr. 2002 Steamboat Springs (#541-542)

Faults analyzed for County: Frontal (LQ), Mosquito (LQ), Williams Fork (H), 1882 Rocky Mountain Park Epicenter

HAZUS Loss Estimates:

Frontal: M7.0 – 1 fatal, $56.0 Million (-1.8%)
Mosquito: M7.0 – 0 fatal, $23.2 Million (-0.7%)
Williams Fork: M6.75 – 0 fatal, $40.4 Million (-1.3%)
1882 RMNP: M6.6 – 0 fatal, $16.5 Million (-0.5%)

Saguache County

Population: 6,425 Growth since 1990: 28.1%
County Size: 3,168 square miles Inventory: $1,517.10 M
Contact:

Saguache County Courthouse
PO Box 655
Saguache, CO 81149
(719)655-2231

Faults within County: Alamosa Horst Fault Zone-East (LC), Cimarron Fault-Powderhorn Section (LC), Houselog Creek Faults (LC), Kerber Creek (LC), Lucky Boy (LQ), Mineral Hot Springs (LQ), North Sangre de Cristo (H), Poncha Pass Faults (LC), Saguache Creek Faults (LC), Squaw Creek Faults (LC), Villa Grove Fault Zone (H), Western Boundary (LQ)

Historical Earthquakes: None

Faults analyzed for County: Cannibal (LQ), N Sangre de Cristo (H), S Sawatch (H)

HAZUS Loss Estimates:

Cannibal: M7.0 – 0 fatal, $16.3 Million (-1.1%)

N Sangre de Cristo: M7.5 WUS – 0 fatal, $25.2 Million (-1.7%)
M7.5 CEUS – 4 fatal, $104 Million (-6.9%)
S Sawatch: M7.25 – 0 fatal, $28.6 Million (-1.9%)

San Juan County
Population: 570 Growth since 1990: -25.1%
County Size: 389 square miles Inventory: $369.20 M
Contact:
San Juan County Courthouse
PO Box 466
Silverton, CO 81433
(970)387-5766
Faults within County: None
Historical Earthquakes: Nov. 23, 1882 Silverton (#10); Apr. 29, 1945 Silverton (#77-78); Jan. 16, 1967 Silverton (#244); June 18, 2002 SE of Silverton (#545)
Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ)
HAZUS Loss Estimates:
Busted Boiler: M6.5 – 0 fatal, $0.89 Million (-0.2%)
Cannibal: M7.0 – 0 fatal, $2.36 Million (-0.6%)

San Miguel County
Population: 7,100 Growth since 1990: 80.5%
County Size: 1,291 square miles Inventory: $1,361.60 M
Contact:
San Miguel County
PO Box 1170
Telluride, CO 81435
(970)728-3844
Faults within County: Big Gypsum Valley Graben Faults (Q), Dolores Fault Zone (Q), San Miguel Canyon Faults (Q)
Historical Earthquakes: Jan. 1, 1894 Telluride (#15); Feb. 3, 1970 S of Norwood (#335); Sept. 13-15, 1994 Norwood (#475-478)
Faults analyzed for County: Busted Boiler (LQ), Cimarron (LQ,Q), Roubideau (H)
HAZUS Loss Estimates:
Busted Boiler: M6.5 – 0 fatal, $36.2 Million (-2.7%)
Cimarron: M6.75 – 0 fatal, $7.53 Million (-0.6%)

Roubideau: M5.5 – 0 fatal, $0.81 Million (-0.0%)

Sedgwick County

Population: 2,747 Growth since 1990: 2.1%

County Size: 544 square miles Inventory: $1,071.60 M

Contact:

Sedgwick County Courthouse
315 Cedar St. or PO Box 50
Julesburg, CO 80737
(970)474-2485

Faults within County: None

Historical Earthquakes: None

Faults analyzed for County: Anton Scarp

HAZUS Loss Estimates:

Anton Scarp: M7.6 – 0 fatal, $4.01 Million (-0.4%)
RM Arsenal: M6.25 – 0 fatal, $0 Million (-0.0%)

Summit County

Population: 23,548 Growth since 1990: 82.8%

County Size: 612 square miles Inventory: $4,184.10 M

Contact:

Summit County Commissioners Office
208 E. Lincoln Ave. or PO Box 68
Breckenridge, CO 80424
(970)453-3535

Faults within County: Blue River Graben Faults (LC), Blue River Fault West (LC), Frontal (LQ), Gore (LC), Green Mountain Reservoir Faults (LC), Mosquito (LQ), Mount Powell Faults (LC), Sheephorn Mountain Faults (LC)

Historical Earthquakes: Aug. 4, 1964 Dillon (#149); Sept. 12, 1990 Vail (#449)

Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Golden (Q), Mosquito (LQ), N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H), Ute Pass (MLQ), Williams Fork (H)

HAZUS Loss Estimates:

Chase Gulch: M6.75 – 0 fatal, $73.3 Million (-1.8%)
Frontal: M7.0 – 39 fatal, $1.35 Billion (-32.2%)
Golden: M6.5 – 0 fatal, $27.1 Million (-0.7%)

Mosquito: M7.0 – 25 fatal, $1.06 Billion (-25.3%)
N Sawatch: M7.0 – 3 fatal, $217 Million (-5.2%)
S Sawatch: M7.25 – 2 fatal, $141 Million (-3.4%)
Ute Pass: M7.0 – 0 fatal, $42.7 Million (-1.0%)
Williams Fork: M6.75 – 9 fatal, $436 Million (-10.4%)

Teller County

Population: 22,156 Growth since 1990: 64.9%
County Size: 559 square miles Inventory: $1,952.20 M
Contact:
Teller County Courthouse
PO Box 959
Cripple Creek, CO 80813
(719)689-2988

Faults within County: Bare Hills (LC), Colorado Springs Faults (LC), Fourmile Creek (LC), Hay Creek (LC), High Park Fault Zone (LC), Midland (LC), Oil Creek (LC), Raspberry Mountain (LC), Ute Pass Fault Zone (MLQ)
Historical Earthquakes: Jan. 6, 1979 Divide (#365); Dec. 23 and 31, 1995 Manitou Springs (#492-493); Jan. 1997 Woodland Park (#497-499); Apr. 18, 1998 Woodland Park (#503); July 22, 2001 Woodland Park (#515); Feb. 19, 2003 Woodland Park (#556)
Faults analyzed for County: Chase Gulch (LQ), Rampart Range (MLQ), N Sangre de Cristo (H), S Sawatch (H), Ute Pass (MLQ)
HAZUS Loss Estimates:
Chase Gulch: M6.75 – 0 fatal, $50.0 Million (-2.6%)
Rampart: M7.0 – 4 fatal, $260 Million (-13.3%)
N Sangre de Cristo: M7.5 WUS – 0 fatal, $2.44 Million (-0.1%)
S Sawatch: M7.25 – 0 fatal, $18.0 Million (-0.9%)
Ute Pass: M7.0 – 14 fatal, $524 Million (-26.8%)

Washington County

Population: 5,048 Growth since 1990: 2.4%
County Size: 2,523 square miles Inventory: $2,148.70 M
Contact:
Washington County Courthouse
150 Ash Ave.
Akron, CO 80720
(970)345-2701

Faults within County: High Plains Grabens under investigation
Historical Earthquakes: None
Faults analyzed for County: Anton Scarp
HAZUS Loss Estimates:

Anton Scarp: M7.6 – 10 fatal, $228 Million (-10.6%)
RM Arsenal: M6.25 – 0 fatal, $1.09 Million (-0.0%)

Weld County
Population: 180,936 Growth since 1990: 37.3%
County Size: 3,999 square miles Inventory: $14,295.20 M
Contact:

Weld County Commissioners
915 Tenth Street or PO Box 758
Greeley, CO 80632
(970)336-7204

Faults within County: None
Historical Earthquakes: May 26, 1969 E of Greeley (#328)
Faults analyzed for County: Golden (Q), Rocky Mountain Arsenal Epicenter, Valmont (MLQ), Walnut Creek (Q)
HAZUS Loss Estimates:

Golden: M6.5 – 3 fatal, $299 Million (-2.1%)
RM Arsenal: M6.25 – 7 fatal, $502 Million (-3.5%)
Valmont: M5.0 – 0 fatal, $40.2 Million (-0.3%)
Walnut Creek: M6.0 – 1 fatal, $212 Million (-1.5%)

Yuma County
Population: 10,018 Growth since 1990: 9.9%
County Size: 2,370 square miles Inventory: $2,633.00 M
Contact:

Yuma County Courthouse
310 Ash Suite A
Wray, CO 80758
(970)332-5796

Faults within County: High Plains Grabens under investigation
Historical Earthquakes: None

Faults analyzed for County: Anton Scarp

HAZUS Loss Estimates:

Anton Scarp: M7.6 – 12 fatal, $214 Million (-8.1%)

Cheraw: M7.0 – 0 fatal, $3.29 Million (-0.13%)

RM Arsenal: M6.25 – 0 fatal, $0.37 Million (-0.0%)

HAZUS Procedures

Fault Parameters
Soil Types
Building Types
Region Inventories

COLORADO GEOLOGICAL SURVEY

HAZUS Procedures

1. **Create or Open a Study Region**:
    a. The study region defines the Hazus boundary within which a scenario will be run. A statewide scenario will produce statewide results, so each county must be run separately to see these results. If improved inventory becomes available, scenarios can be run for individual census tracts or a combination of census tracts that make up a specific city.
    b. The first Hazus startup window will allow you to choose whether you create a new study region or use an existing region. For the current MR1 version, **state and county-level study regions have already been created**. (Regions are stored in C:\Program Files\HAZUS-MH)
    c. If you are creating a new study region and need to select more than one county or census tract, hold down the Control key.
    d. **A warning about study regions**: Hazus results are only shown for the earthquake scenario that is most recent. If more than one scenario is run for the same study region, the previous results must be saved or they will be lost!
2. **Open Hazus Window:**
    a. When region aggregation is complete, choose 'Open a region' and the ArcView window will open up containing the region. You can add shapefiles such as faults, soils, and landslide susceptibility, but they do not need to be visible for scenarios to run.
    b. You can see if there is a current scenario and set of hazard maps for the study region through 'Hazard' > 'Show Current'.
3. **Add Hazard Maps:**
    a. To add hazard maps that Hazus will recognize during a scenario, go to 'Hazard' > 'Data Maps' > 'Add Maps' and browse for the appropriate maps. These must be .mdb files with a 'type' field or else Hazus will not accept them. To date, two hazard maps have been used in every scenario: 'Geology' > 'CO_Soils' > type: cosoils.mdb in the space, and select 'cosoils_region_1' from the list (Soil map) and 'Landslide Data' > type: nat_co_ls.mdb and select nat_ls_co_II from the list (Landslide susceptibility map).
    b. Once hazard maps are added to the table, you must select them under 'Hazard' > 'Scenario' > 'Define hazard maps' and select the maps from the dropdown lists under each hazard type. Liquefaction and depth to water table have been left as default values for all scenarios to date. It takes up to 20 minutes for the hazard maps to be clipped and applied to large study regions.
4. **Defining Scenarios:**
    a. From the menu bar, choose 'Hazard' > 'Scenario', and you will be given a choice to define a new scenario or to use an already predefined scenario. There are many predefined scenarios that are "re-usable", for all of the faults, epicenters, and random epicenters analyzed through May 2006.

Click on 'Use an already pre-defined scenario' to see the dropdown list. Using these saves you the step of creating more scenarios.

b. If you are making a new scenario, choose 'Hazard' > 'Scenario' > 'Define new scenario', and the scenario wizard will open to guide you through the setup of various parameters.
c. For Seismic Hazard Type, choose 'Arbitrary Event' for a Deterministic scenario or 'Probabilistic Hazard'.
d. **Deterministic:**
    i. Choose the appropriate attenuation coefficient and type of fault motion. Most of the newer Hazus scenarios in the MR1 version have been run with the 'CEUS Event' attenuation function. This is a combination of several functions used by the USGS in their seismic hazard maps, and it produces results that are representative of a worst-case scenario. The only region in Colorado that should be run with a WUS function is the Rio Grande Rift. 'WUS Shallow Crustal Event – Ext.' is the best combination of WUS functions to use.
    ii. In the next window, enter epicenter values that approximate the midpoint of the fault under investigation. See "Hazus Fault Parameters" in the Hazus notebook for a list of epicenters used in previous scenarios. To modify these, go to 'View' > 'Data Frame Properties' and change the map coordinates to decimal degrees. Then select a point along the given fault and note the coordinates.
    iii. Enter earthquake magnitude, leave depth and width at 10. Enter average fault strike as a value between 0 and 180, 0 being directly north, 90 being due east. Enter the fault dip as a value between 0 and 90, with a positive value for NW, W, or SW dips and a negative value for NE, E, or SE dips.
    iv. In the next window, enter the scenario name. This is important in organizing and recognizing each scenario so it must be specific to the fault and magnitude of an event, along with the attenuation function being used.
    v. The final window allows you to review the entered data. Click finish when complete.
e. **Probabilistic:**
    i. Choose either a return period, from 100 to 2500 years, or annualized losses. (There appears to be an error with annualized loss scenarios – the same calculation can be done by running a specific return period then dividing the total economic losses by the number of years in the return period.)
    ii. Choose a driving magnitude. By May 2006, all probabilistic scenarios were run with a M6.5, but the USGS is now using a M7.0 for their hazard maps.
    iii. Name the scenario with specific information so it can be identified.

5. **Running Scenarios:**
   a. If you will be running contour mapping (PGA), go to 'Analysis' – 'Parameters' – 'Contour Interval' first , and change the value to 200 for a better-looking map.
   b. On the menu bar choose 'Analysis' > 'Run' and select the modules you wish to analyze. Most of the scenarios have been run with all modules selected **except** 'Military Installation', 'Advanced Engineering Building Mode' and 'User-supplied Inventory'. If you want to map ground shaking results (PGA), select 'Contour maps' – this adds time to the scenario analysis, but can be a helpful part of the presentation of results.
   c. For planning ahead, most statewide scenarios with contour mapping take between 4-5 hours and are best run overnight. Statewide scenarios without mapping take between 1-2 hours. County scenarios take from 30 minutes to 1 hour with mapping, or between 1 and 6 minutes without mapping.
6. **Handling Results:**
   a. After the Hazus windows say that a scenario is complete, the 'Results' menu is where to go.
   b. To generate a thorough PDF report, go to 'Summary Reports', choose the 'Other' tab, and view the **'Global Summary Report'**. This is a 20-25 page report that summarizes all of the modules analyzed. Page 14 and 15 are where casualties and economic loss are listed, with total economic loss in the paragraph at the top of page 15. Each global report must be exported and saved as a PDF file before another scenario is run for the same region. Only one scenario and its results are saved in a region at a time. In the upper left corner of the report, click the arrow-envelope button and save the entire report as a PDF in C:\Program Files\HAZUS-RESULTS using a name similar to the scenario.
   c. To map results, select a facility or result from the 'Results' dropdown menu. County maps created in the spring of 2006 used 'Ground Motion', 'Essential Facilities', 'Transportation Systems', 'Utility Systems', and 'Building Economic Loss'. We mapped Structural Damage, At Least Extensive, which can be found by navigating to the far right side of any facility's results table. A sample of all possible damage states to map can be found in the Hazus notebook for schools in Mesa County.
      i. To map a damage level, select the column by clicking at its top, then click 'Map'. Default colors will show up, but symbology can be changed as in any other ArcView project.
      ii. Symbology layers are saved in C:\Program Files\HAZUS-DATA\Layers and Epicenters and can be imported by right-clicking the layer in ArcMap > 'Layer Properties' > 'Symbology' > 'Quantities' > 'Graduated Colors'. Click the Import button in the upper right corner, and navigate to the above location to find facilities that already have a symbol/color layer.

iii. You can also create your own symbology manually and can determine how graduated symbols are distributed through the 'Classify' button.
iv. We found it helpful to open all of the results layers you want to map in the original Hazus window, then save the project as a normal ArcView project. Re-opening as the normal ArcView project will make final layout of maps much easier, since Hazus uses a default layout and will not save any other format.
v. When a map is complete, save it under **File** – **Export Map**, save the maps onto **D:\Hazus Result Maps** into the appropriate county folder. Format as **pdf** with the highest resolution possible (usually 300).

d. To map ground shaking such as **PGA (peak ground acceleration)**, go to Results>Ground Motion or Ground Failure> Contours or Ground Failure Maps> PGA contours. Select 'map', let the colors fill in the region, then 'cancel' (weird, but it's what you do). At this point, save the shapefile by right clicking the layer, going to 'Data' > 'Export Data' and saving in a folder so the raw data is not lost. The default colors are much too coarse, so you have to change the color scheme and classification.
    i. You can import the standardized PGA color ramp that was used for most of the statewide PGA maps. Right click the shapefile> Properties> Symbology. Click 'quantities'> 'graduated colors'. Click the 'Import' button in the upper right corner and navigate to C:\Program Files\HAZUS-DATA\PGA Shapefiles and Data, and the 'N_Sangre_MaxPGA.lyr' layer file should show up. This has the greatest PGA value and is therefore the best standard to use. Keep clicking OK, and when the symbology window shows up again, make sure that blue equals 0 ground shaking and that there are no box outlines around the cells. To change, click on the top of the 'symbol' column and flip symbols or go to properties for all symbols to get rid of the gray outline.
    ii. If you want to create your own PGA symbology, use the same process as above but do not import the N Sangre layer. Click the 'Classify' button: Method = natural breaks (Jenks), Classes = 50 for a good color distribution, Sampling = add a 0 so the max size is 100,000 and all samples are used. Apply>OK for classification. 'Symbol' button: flip colors so that blue is 0 value, 'properties for all symbols' = no outline color so boxes don't show. Apply>OK. Save this as a layer file if you want to keep this color scheme.

iii. For final map layout, it is easier to save changes in a normal ArcView project instead of the Hazus Arc window. Export the final layout as a jpeg or pdf.

Using and Creating Attenuation Functions:

1. We have experimented with the attenuation functions that are appropriate for Colorado. The USGS seismic hazard maps place most of Colorado in the CEUS zone, with only the Rio Grande Rift lying within the WUS zone. Most of our newer scenarios have used 'CEUS Event' which is a combination of four functions. CEUS results are generally 3-5 times greater than WUS results, so we are presenting worst-case scenarios by using CEUS functions and the maximum credible earthquake magnitudes.
2. If Hazus is re-installed, you must activate the CEUS functions because the program automatically assumes only WUS functions will be used. To activate/create CEUS event: Go to the START button on the desktop, select Programs and get into the Microsoft SQL Server>Enterprise Manager. (if the screen is blank when you open it, look in the bottom left corner and maximize the console)
3. Next, in the "Tree" keep clicking the +'s until you open the "Databases" folder. This folder can take a VERY long time to open, so be patient.
4. Look for a folder called "syHAZUS", then open the table eqAttenFunct.
5. Hazus MR1 should have 34 rows of different functions. The 'FltMechanism' column has letters that represent type of movement: N = normal, S = strike-slip, R = reverse, E = East coast (?), I = interslab, F = subduction interface. These control what can be selected when scenarios are being created, so make sure either N or E is present in the functions you plan on using. The 'EorW' column controls what functions will show up in the drop-down list during scenario creation. Change all values to W if you want all of them to be visible.

Other Helpful Hints:

- All shapefiles and layers need to be in the geographic coordinate system NAD_1983. Use the ArcToolbox to change projections.
- When polishing up maps that contain cities and city names, right click> properties> labels – in 'placement properties' change the buffer from 0 to 1. This keeps city names or other labels from overlapping each other.
- If map layers are not showing or if Hazus is acting sluggish, close and reopen the program.
- To backup regions, create .hpr files through the initial Hazus window options. This is also the only way to delete a region or duplicate a region. If a new version of Hazus is installed, all regions have to be re-created since they are likely to have different inventories.
- The SQL Server can be accessed to change parameters built into Hazus. Go to the Start menu > 'Microsoft SQL Server' > '(local machine)' > 'syHazus' > 'tables' and choose the table you wish to modify.

- There is a Hazus Technical Draft and a User Manual in C:\Program Files\HAZUS-DATA\Earthquake and also on the MR1 CD. These provide thorough directions and background methodology if interested.
- You can email Doug Bausch (Douglas.Bausch@dhs.gov), Pushpendra Johari (PJohari@pbsj.com), Jawhar Bouabid (jbouabid@pbsj.com), or Lauren Heerschap (laurenheerschap@hotmail.com) for help in solving problems.
- Lauren's login and password are 'heerschl' and 'Durango17' in case access is denied to certain files.

Fault Parameters for HAZUS Scenarios

--All scenarios run with 10km Depth and Width unless otherwise noted—
MCE based on Wells and Coppersmith (1994)

<u>1882 Historical EQ – Rocky Mountain National Park epicenter:</u>
Epicenter: (40.41, -105.74); Strike = 45 (N45E); Dip = +60 (60W);
Max. Magnitude = 7.2

<u>1882 Historical EQ – North Park epicenter:</u>
Epicenter: (40.79, -106.5); Strike = 161 (N19W); Dip = -60 (60E);
Max. Magnitude = 7.2; Depth = 30 km for two scenarios

<u>1882 Historical EQ – Piceance Basin epicenter:</u>
Epicenter: (40.5, -108.0); Strike = 110 (N70W); Dip = +75 (75SW);
Max. Magnitude = 7.2

<u>Anton Scarp (possible fault):</u>
Epicenter (39.6, -102.93); Strike = 140 (N40W); Dip = -60 (60E);
Max. Magnitude = 7.6

<u>Busted Boiler Fault:</u>
Epicenter (38.24, -107.86); Strike = 175 (N5W); Dip = +60 (60W);
Max. Magnitude = 6.5

<u>Cannibal Fault:</u>
Epicenter (37.94, -107.16); Strike = 160 (N20W); Dip = +60 (60W);
Max. Magnitude = 7.0

<u>Chase Gulch Fault:</u>
Epicenter (39.00, -105.62); Strike = 157 (N23W); Dip = -60 (60E);
Max. Magnitude = 6.75

<u>Cheraw Fault:</u>
Epicenter (38.28, -103.42); Strike = 44 (N44E); Dip = +66 (66 NW);
Max. Magnitude = 7.0

<u>Cimarron Fault:</u>
Epicenter (38.41, -107.48); Strike = 122 (N58W); Dip = -70 (70NE);
Max. Magnitude = 6.75

<u>Frontal (Gore) Fault:</u>
Epicenter (39.68, -106.16); Strike = 156 (N24W); Dip = -75 (75 NE);
Max. Magnitude = 7.0

<u>Golden Fault:</u>
Epicenter (39.74, -105.22); Strike = 157 (N23W); Dip = +60 (60 SW);

Max. Magnitude = 6.5

Goodpasture Fault:
Epicenter (38.05, -104.91); Strike = 148 (N32W); Dip = -60 (60NE);
Max. Magnitude = 6.0

Mosquito Fault:
Epicenter (39.38, -106.16); Strike = 9 (N9E); Dip = +70 (70W);
Max. Magnitude = 7.0

Rampart Range Fault:
Epicenter (39.06, -104.92); Strike = 171(N9W); Dip = +60 (60W);
Max. Magnitude = 7.0

Rocky Mountain Arsenal Fault:
Epicenter (39.90, -104.90); Strike = 130 (N50W); Dip = +60 (60SW);
Max. Magnitude = 6.25

Roubideau Creek Fault:
Epicenter (38.41, -108.19); Strike = 106 (N74W); Dip = -65 (65NE);
Max. Magnitude = 5.5

N Sangre de Cristo Fault:
Epicenter (37.90, -105.63); Strike = 161 (N19W); Dip = +60 (60W);
Max. Magnitude = 7.5

N Sawatch Fault:
Epicenter (39.15, -106.39); Strike = 147 (N33W); Dip = -72 (72E);
Max. Magnitude = 7.0

S Sawatch Fault:
Epicenter (38.75, -106.18); Strike = 148 (N32W); Dip = -70 (70E);
Max. Magnitude = 7.25

Ute Pass Fault:
Epicenter (38.92, -105.00); Strike = 152 (N28W); Dip = +50 (50SW);
Max. Magnitude = 7.0

Valmont Fault:
Epicenter (40.03, -105.20); Strike = 75 (N75E); Dip = -80 (80SE);
Max. Magnitude = 5.0

Walnut Creek Fault:
Epicenter (39.88, -105.15); Strike = 31 (N31E); Dip = +80 (80NW);
Max. Magnitude = 6.5

Williams Fork Fault:
Epicenter (39.87, -106.15); Strike = 140 (N40W); Dip = -60 (60NE);
Max. Magnitude = 6.75

SOIL TYPES

Table 1

Comparison between the 1997 UBC Provisions and the simplified site classification working scheme used in this study.

TYPE	Site class	Site class description of 1997 UBC Provisions	Site class description of simplified working scheme used in this study
1	A	Hard rock, eastern United States sites only, $\overline{V}_S$ >1500 (m/s).	(not used)
2	B	Rock, $\overline{V}_S$ is 760 to 1500 (m/s).	Miocene and older strata, and limestone, igneous rocks, and metamorphic rocks, etc..
3	C	Very dense soil and soft rock, $\overline{V}_S$ is 360 to 760 (m/s), Undrained shear strength $u_s \geqq$ 2000 psf ($u_s \geqq 100$ kPa) or N≧50 blows/ft.	Pliocene and Pleistocene strata, and conglomerates, pyroclastic rocks, etc., and geomorphologic lateritic terraces.
4	D	Stiff soils, $\overline{V}_S$ is 180 to 360 (m/s), Stiff soil with undrained shear strength 1000 psf $\leqq u_s \leqq$ 2000 psf (50 kpa $\leqq u_s \leqq$ 100 kPa), or 15≦N≦50 blows/ft.	Late Pleistocene and Holocene strata, geomorphologic fluvial terrace, and, stiff clays and sandy soils with average SPT N≧15 in the upper 30m.
5	E	Soft soils, Profile with more than 10ft (3m) of soft clay defined as soil with plasticity index PI>20, moisture content w > 40% and undarined shear strength u_s < 1000 psf (50kPa), or N<15 blows/ft.	Holocene deposits and fills, etc., with average SPT N<15 in the upper 30m.
?	F	Soils requiring site specific evaluations. 1. Soil vulnerable to potential failure or collapse under seismic loading: e.g. liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays (10ft (3m) or thicker layer). 3. Very high plasticity clays: (25ft (8m) or thicker layer with plasticity index>75). 4. Very thick soft/medium stiff clays: (120ft (36m) or thicker layer).	(This is not classified in the present study and will be studied in the future.)

Note: The Provisions of 1997 NEHRP and 1997 UBC are similar.

Table 5.1 Model Building Types

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1	W1	**Wood, Light Frame (≤ 5,000 sq. ft.)**		1 - 2	1	14
2	W2	**Wood, Commercial and Industrial (> 5,000 sq. ft.)**		All	2	24
3	S1L	**Steel Moment Frame**	Low-Rise	1 - 3	2	24
4	S1M		Mid-Rise	4 - 7	5	60
5	S1H		High-Rise	8+	13	156
6	S2L	**Steel Braced Frame**	Low-Rise	1 - 3	2	24
7	S2M		Mid-Rise	4 - 7	5	60
8	S2H		High-Rise	8+	13	156
9	S3	**Steel Light Frame**		All	1	15
10	S4L	**Steel Frame with Cast-in-Place Concrete Shear Walls**	Low-Rise	1 - 3	2	24
11	S4M		Mid-Rise	4 - 7	5	60
12	S4H		High-Rise	8+	13	156
13	S5L	**Steel Frame with Unreinforced Masonry Infill Walls**	Low-Rise	1 - 3	2	24
14	S5M		Mid-Rise	4 - 7	5	60
15	S5H		High-Rise	8+	13	156
16	C1L	**Concrete Moment Frame**	Low-Rise	1 – 3	2	20
17	C1M		Mid-Rise	4 - 7	5	50
18	C1H		High-Rise	8+	12	120
19	C2L	**Concrete Shear Walls**	Low-Rise	1 - 3	2	20
20	C2M		Mid-Rise	4 - 7	5	50
21	C2H		High-Rise	8+	12	120
22	C3L	**Concrete Frame with Unreinforced Masonry Infill Walls**	Low-Rise	1 - 3	2	20
23	C3M		Mid-Rise	4 - 7	5	50
24	C3H		High-Rise	8+	12	120
25	PC1	**Precast Concrete Tilt-Up Walls**		All	1	15
26	PC2L	**Precast Concrete Frames with Concrete Shear Walls**	Low-Rise	1 - 3	2	20
27	PC2M		Mid-Rise	4 - 7	5	50
28	PC2H		High-Rise	8+	12	120
29	RM1L	**Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms**	Low-Rise	1-3	2	20
30	RM1M		Mid-Rise	4+	5	50
31	RM2L	**Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms**	Low-Rise	1 - 3	2	20
32	RM2M		Mid-Rise	4 - 7	5	50
33	RM2H		High-Rise	8+	12	120
34	URML	**Unreinforced Masonry Bearing Walls**	Low-Rise	1 - 2	1	15
35	URMM		Mid-Rise	3+	3	35
36	MH	**Mobile Homes**		All	1	10

Default Region Inventories

County	Buildings	Transportation	Utilities	Total (Millions)
Adams	16,869.00	2,964.50	1,191.50	**21,025.00**
Alamosa	878.00	665.70	295.80	**1,839.50**
Arapahoe	29,919.00	1,736.00	577.30	**32,232.30**
Archuleta	700.00	791.00	457.70	**1,948.70**
Baca	251.00	1,347.90	232.80	**1,831.70**
Bent	262.00	711.00	108.00	**1,081.00**
Boulder	17,762.00	1,418.40	1,557.00	**20,737.40**
Chaffee	1,011.00	1,002.70	340.40	**2,354.10**
Cheyenne	131.00	1,142.80	177.00	**1,450.80**
Clear Creek	708.00	747.70	177.20	**1,632.90**
Conejos	353.00	650.90	158.50	**1,162.40**
Costilla	174.00	605.20	234.20	**1,013.40**
Crowley	182.00	370.10	114.80	**666.90**
Custer	323.00	420.70	133.90	**877.60**
Delta	1,359.00	1,232.80	249.50	**2,841.30**
Denver	36,233.00	2,247.50	558.90	**39,039.40**
Dolores	120.00	309.90	85.80	**515.70**
Douglas	11,792.00	1,342.70	562.80	**13,697.50**
Eagle	3,003.00	1,581.40	430.50	**5,014.90**
El Paso	28,105.00	2,910.40	1,555.20	**32,570.60**
Elbert	1,029.00	1,106.10	296.50	**2,431.60**
Fremont	1,948.00	1,265.40	546.30	**3,759.70**
Garfield	2,260.00	1,564.10	911.40	**4,735.50**
Gilpin	426.00	210.20	89.10	**725.30**
Grand	1,371.00	1,281.50	479.00	**3,131.50**
Gunnison	1,122.00	1,275.90	283.40	**2,681.30**
Hinsdale	146.00	171.60	29.70	**347.30**
Huerfano	496.00	1,130.20	313.30	**1,939.50**
Jackson	124.00	610.60	215.10	**949.70**
Jefferson	32,456.00	2,033.60	1,339.00	**35,828.60**
Kiowa	83.00	953.40	105.20	**1,141.60**
Kit Carson	399.00	1,588.20	264.80	**2,252.00**
La Plata	2,563.00	950.80	795.60	**4,309.40**
Lake	411.00	456.80	230.90	**1,098.70**
Larimer	15,215.00	2,424.20	1,256.80	**18,896.00**
Las Animas	863.00	2,392.40	450.10	**3,705.50**
Lincoln	290.00	1,329.90	246.50	**1,866.40**
Logan	999.00	1,814.60	243.70	**3,057.30**
Mesa	5,816.00	2,375.30	853.30	**9,044.60**
Mineral	125.00	442.80	99.60	**667.40**
Moffat	631.00	1,570.60	576.40	**2,778.00**
Montezuma	1,148.00	1,405.00	521.20	**3,074.20**
Montrose	1,626.00	1,305.10	842.80	**3,773.90**
Morgan	3,450.00	1,467.40	487.30	**5,404.70**
Otero	1,009.00	1,575.40	351.00	**2,935.40**
Ouray	292.00	237.80	251.90	**781.70**
Park	1,238.00	1,268.60	299.70	**2,806.30**
Phillips	243.00	764.80	143.40	**1,151.20**
Pitkin	1,499.00	313.40	411.90	**2,224.30**
Prowers	669.00	1,327.30	310.10	**2,306.40**
Pueblo	7,100.00	2,448.90	981.20	**10,530.10**

Rio Blanco	379.00	764.40	423.80	**1,567.20**
Rio Grande	666.00	912.40	204.80	**1,783.20**
Routt	1,515.00	1,027.10	571.90	**3,114.00**
Saguache	265.00	992.60	259.50	**1,517.10**
San Juan	82.00	271.40	15.80	**369.20**
San Miguel	646.00	542.00	173.60	**1,361.60**
Sedgwick	162.00	854.10	55.50	**1,071.60**
Summit	2,805.00	746.00	633.10	**4,184.10**
Teller	1,345.00	331.70	275.50	**1,952.20**
Washington	243.00	1,652.20	253.50	**2,148.70**
Weld	7,704.00	4,690.10	1,901.10	**14,295.20**
Yuma	500.00	1,834.20	298.80	**2,633.00**
State	253,527.00	77,869.80	28,492.00	**359,888.80**

Statewide Scenarios

Fault Maps
PGA Maps for all Statewide Scenarios

Statewide Scenarios Ranked by Severity

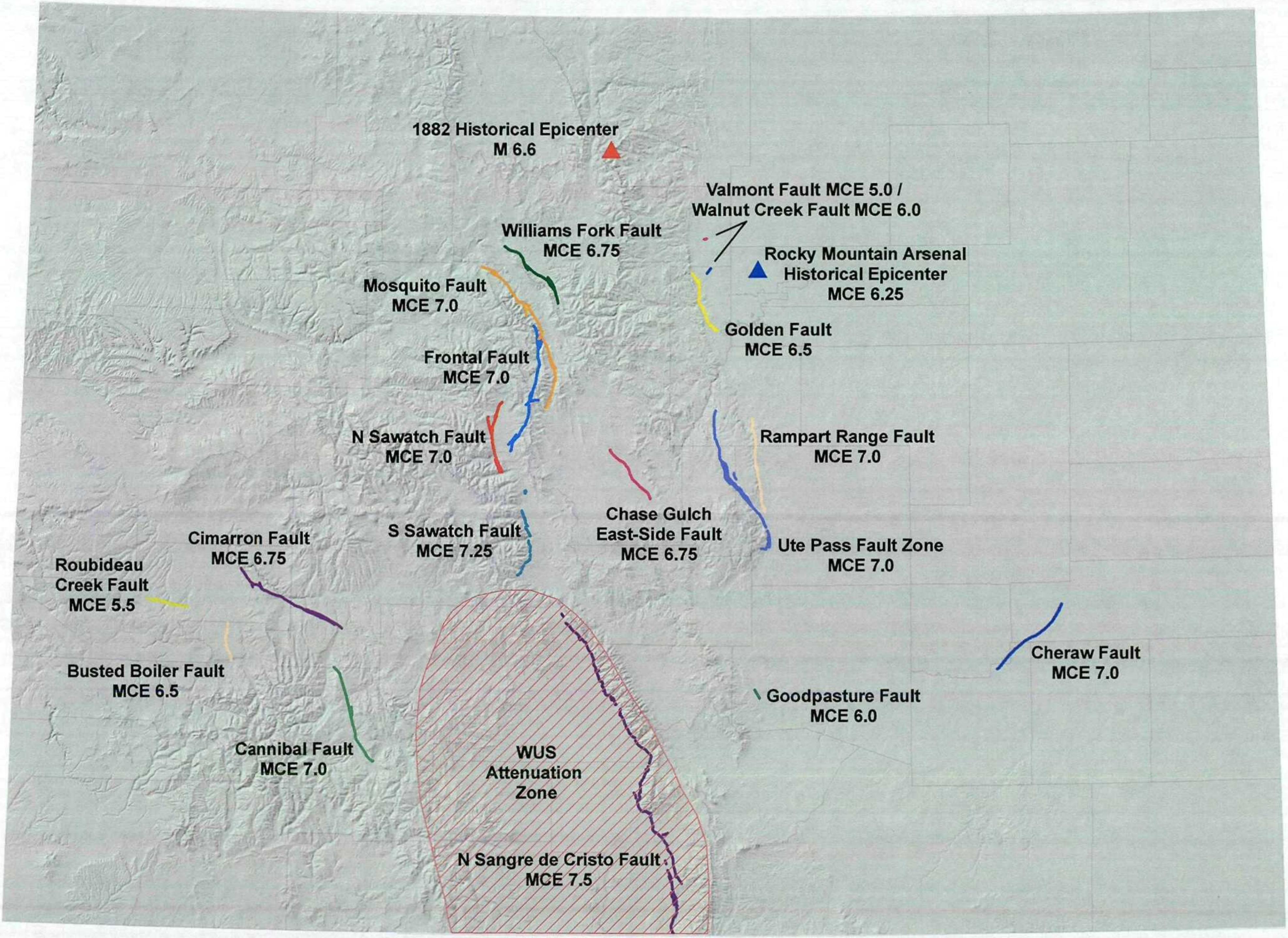
Rank	Fault	Earthquake Magnitude	Economic Loss in State
1	Rampart Range	7	$23.1 Billion
2	Golden	6.5	$21.9 Billion
3	Ute Pass	7	$16.8 Billion
4	Rocky Mountain Arsenal	6.25	$14.9 Billion
5	Anton Scarp (suspect)	7.6	$12.1 Billion
6	Walnut Creek	6	$9.70 Billion
7	N Sangre de Cristo	7.5 CEUS	$8.02 Billion
8	Frontal	7	$6.73 Billion
9	Mosquito	7	$6.19 Billion
10	South Sawatch	7.25	$4.74 Billion
11	Chase Gulch (East-Side)	6.75	$3.76 Billion
12	North Sawatch	7	$3.62 Billion
13	Williams Fork	6.75	$3.48 Billion
14	1882 Rocky Mtn National Park	6.6	$2.76 Billion
15	Cheraw	7	$1.26 Billion
16	Cimarron	6.75	$808 Million
17	N Sangre de Cristo	7.5 WUS	$767 Million
18	Valmont	5	$712 Million
19	Busted Boiler	6.5	$694 Million
20	Cannibal	7	$675 Million
21	Goodpasture	6	$479 Million
22	Roubideau Creek East	5.5	$94.2 Million

CEUS = Central-Eastern U.S. Attenuation Function
WUS = Western U.S. Attenuation Function

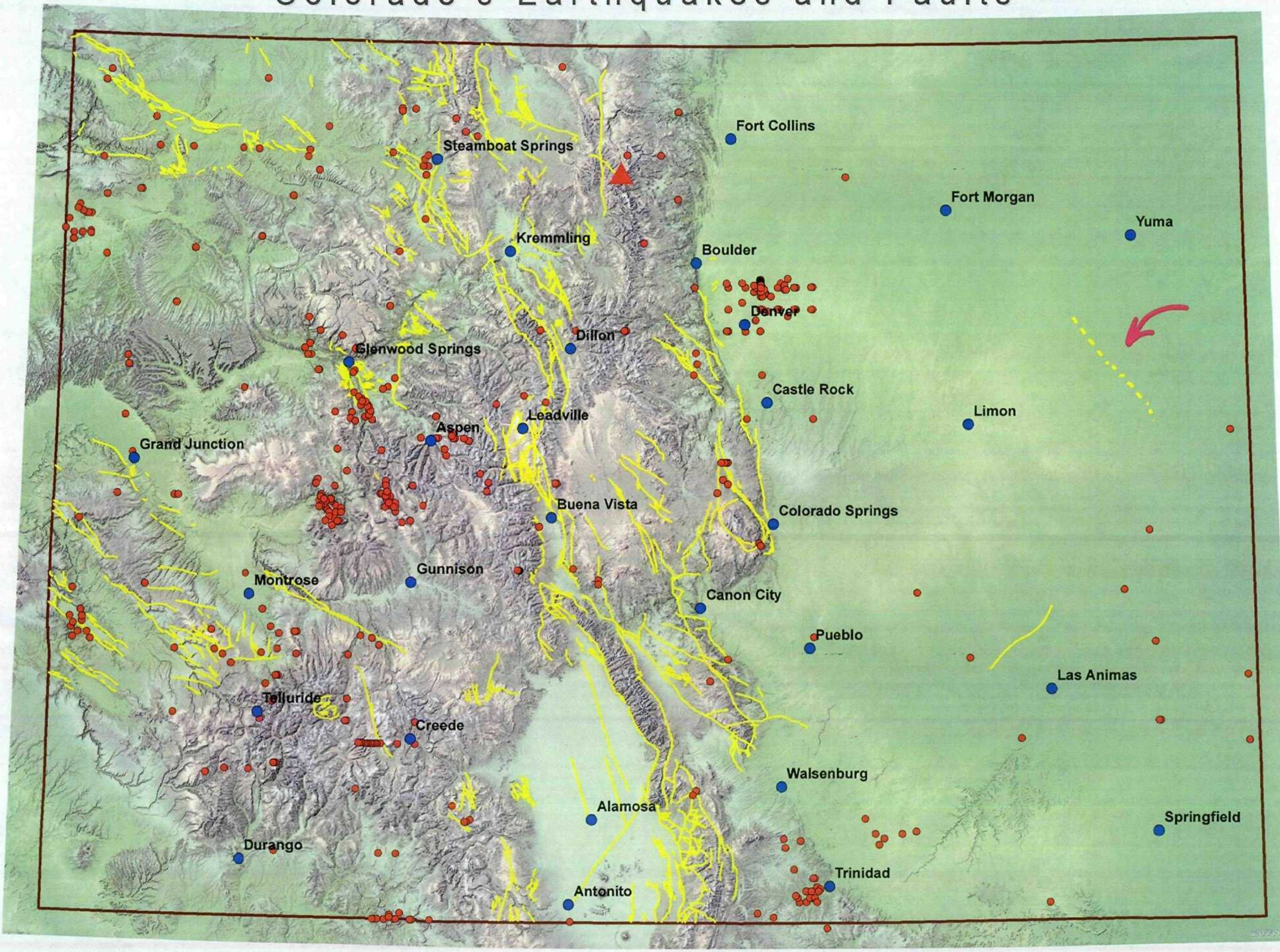
These results show how important attenuation is for accurate ground shaking models. Colorado is in the boundary zone between the two functions, with only the San Luis Valley placed in the WUS zone by the USGS. The rest of Colorado lies in the CEUS zone and was analyzed in HAZUS based on this assumption.

Statewide Scenario Summary

Fault	Earthquake Magnitude	Economic Loss in State ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Anton Scarp	7.6	12,145.18	3.37%	110,531 (8%)	2,617	23,354	5,909	7,434	4,473
Busted Boiler	6.5	694.02	0.19%	8,239 (1%)	107	693	179	12	3,295
Cannibal	7	674.66	0.19%	10,762 (1%)	46	458	117	1	561
Chase Gulch	6.75	3,760.43	1.04%	50,498 (4%)	263	4,373	1,111	304	1,198
Cheraw	7	1,260.53	0.35%	17,472 (1%)	141	1,317	354	3,055	6,291
Cimarron	6.75	807.50	0.22%	10,070 (1%)	142	1,037	262	708	1,863
Frontal	7	6,733.82	1.87%	73,922 (5%)	737	8,765	2,111	1,569	10,100
Golden	6.5	21,890.05	6.08%	213,115 (16%)	4,134	42,952	10,769	6,421	232,559
Goodpasture	6	478.59	0.13%	5,842 (<1%)	16	203	56	0	1,521
Mosquito	7	6,189.80	1.72%	70,083 (5%)	609	7,785	1,901	411	11,782
Rampart Range	7	23,046.35	6.40%	237,595 (17%)	5,058	46,717	11,343	22,364	157,654
Rocky Mountain Arsenal	6.25	14,867.04	4.13%	151,902 (11%)	2,507	28,461	7,416	1,702	112,994
Roubideau Creek East	5.5	94.23	<0.01%	665 (<1%)	1	10	2	0	0
N Sangre de Cristo	7.5 WUS	767.07	0.21%	11,639 (1%)	91	721	190	239	476
N Sangre de Cristo	7.5 CEUS	8,020.95	2.23%	93,178 (7%)	1,655	15,918	4,105	1,397	5,132
North Sawatch	7	3,617.52	1.01%	46,739 (3%)	287	4,086	1,002	695	5,880
South Sawatch	7.25	4,742.32	1.32%	62,251 (5%)	463	6,127	1,551	2,146	7,841
Ute Pass	7	16,774.21	4.66%	179,782 (13%)	3,314	31,676	7,757	19,057	126,754
Valmont	5	711.46	0.20%	1,853 (<1%)	4	77	19	0	0
Walnut Creek	6	9,704.00	2.70%	94,660 (7%)	894	12,483	3,219	0	106,167
Williams Fork	6.75	3,482.99	0.97%	42,225 (3%)	254	3,807	936	125	2,865
1882 Rocky Mtn National Park	6.6	2,761.30	0.77%	35,024 (3%)	193	2,656	658	0	2,844

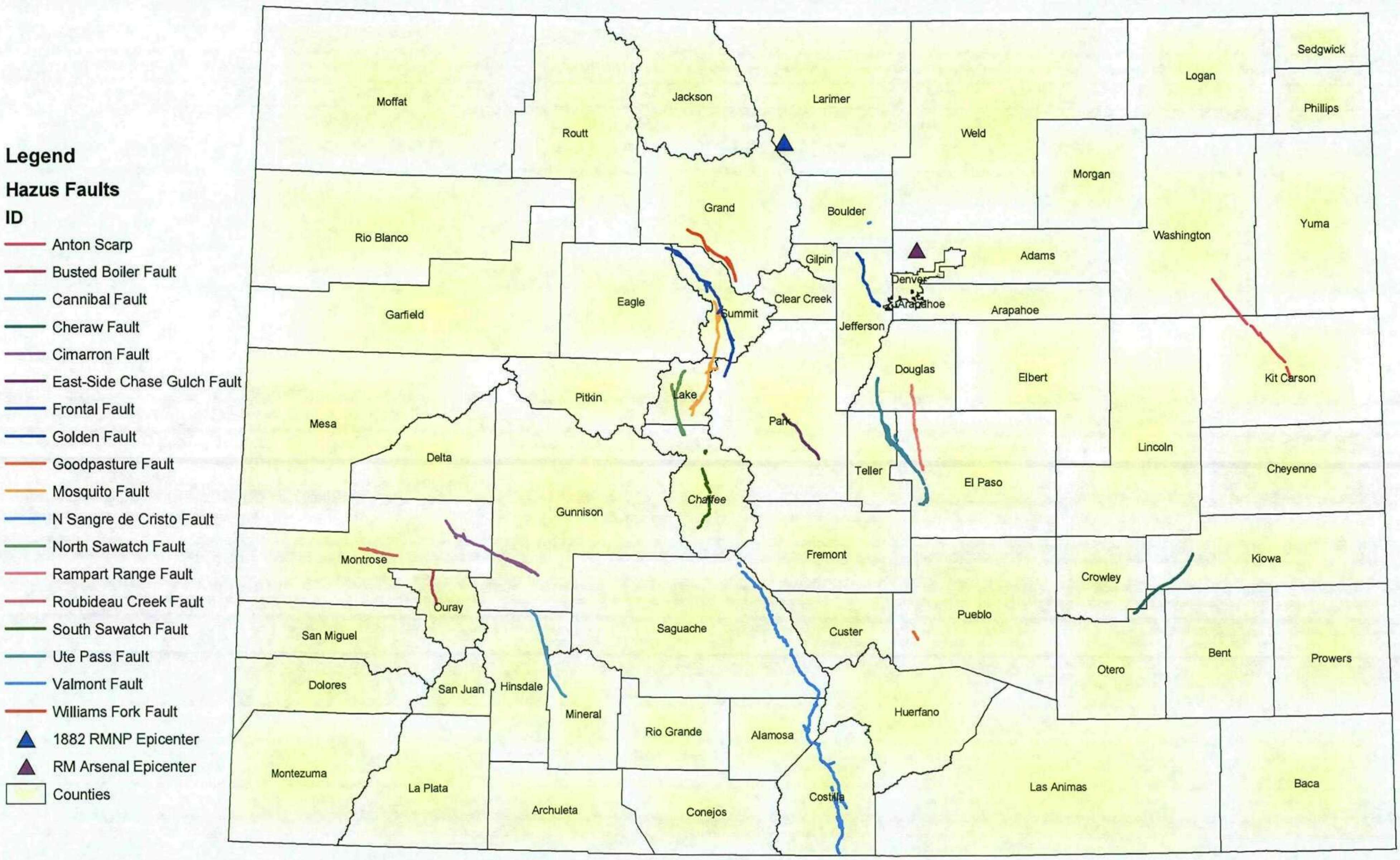

1882 Historical Epicenter
M 6.6
Valmont Fault MCE 5.0 /
Walnut Creek Fault MCE 6.0
Williams Fork Fault
MCE 6.75
Rocky Mountain Arsenal
Historical Epicenter
MCE 6.25
Mosquito Fault
MCE 7.0
Golden Fault
MCE 6.5
Frontal Fault
MCE 7.0
N Sawatch Fault
MCE 7.0
Rampart Range Fault
MCE 7.0
Chase Gulch
East-Side Fault
MCE 6.75
S Sawatch Fault
MCE 7.25
Ute Pass Fault Zone
MCE 7.0
Cimarron Fault
MCE 6.75
Roubideau
Creek Fault
MCE 5.5
Busted Boiler Fault
MCE 6.5
Cheraw Fault
MCE 7.0
Goodpasture Fault
MCE 6.0
Cannibal Fault
MCE 7.0
WUS
Attenuation
Zone
N Sangre de Cristo Fault
MCE 7.5

Colorado's Earthquakes and Faults

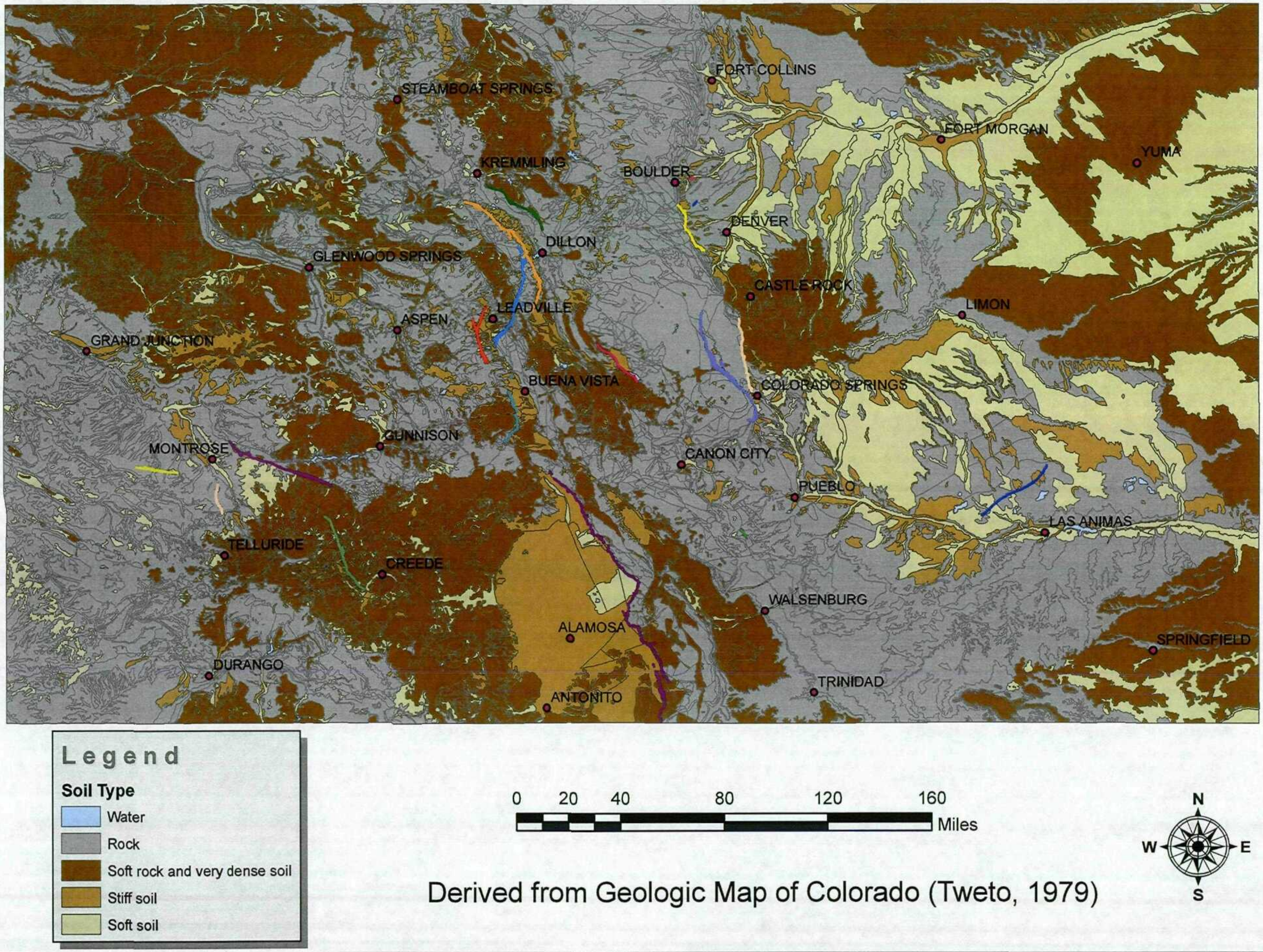


Red Dots = Historical Earthquake Locations Yellow Lines = Known Faults Dashed Yellow Line = Anton Suspect Scarp

Selected Faults for Hazus Scenarios

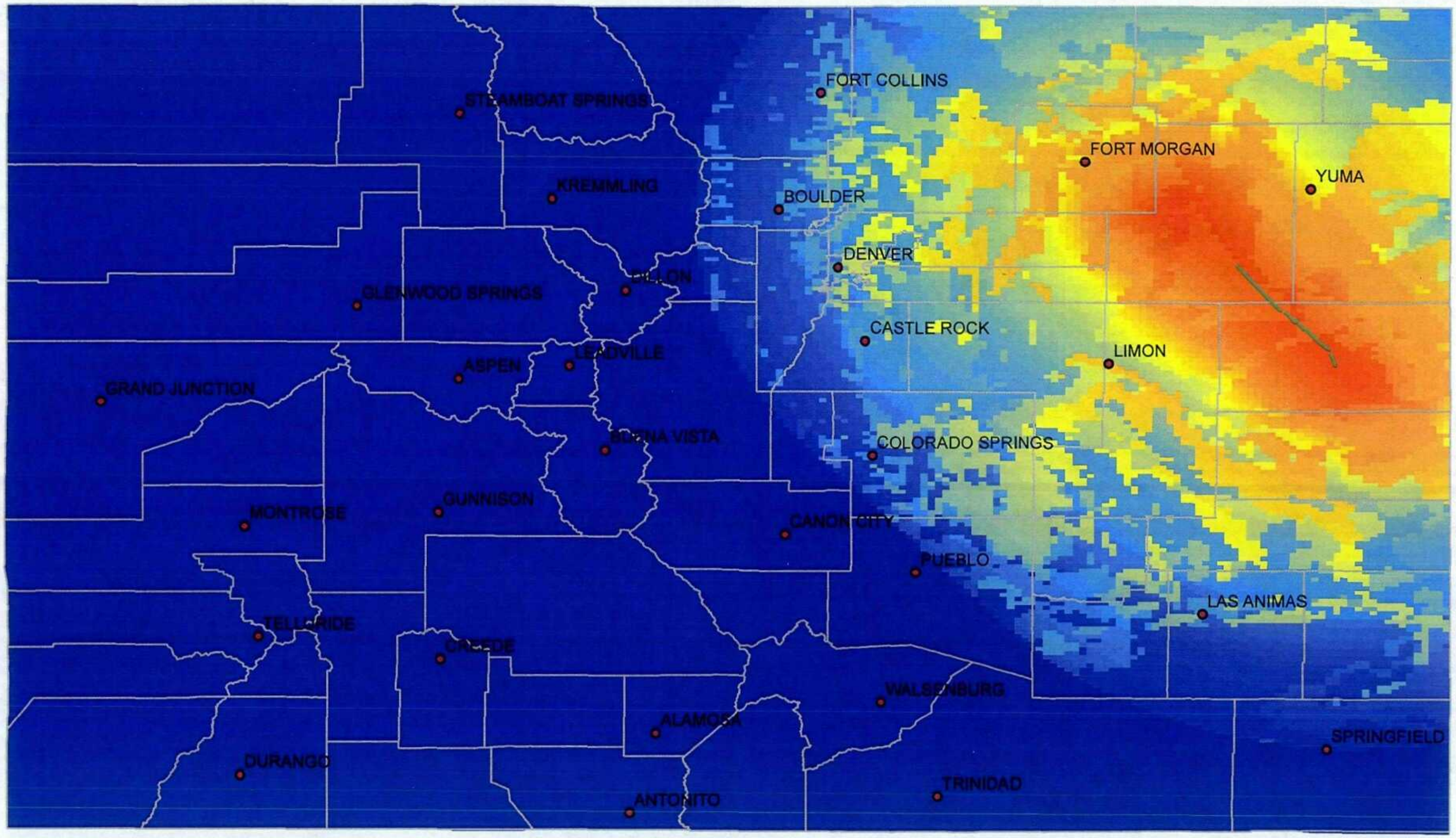


Soil Map Used in Colorado HAZUS Scenarios



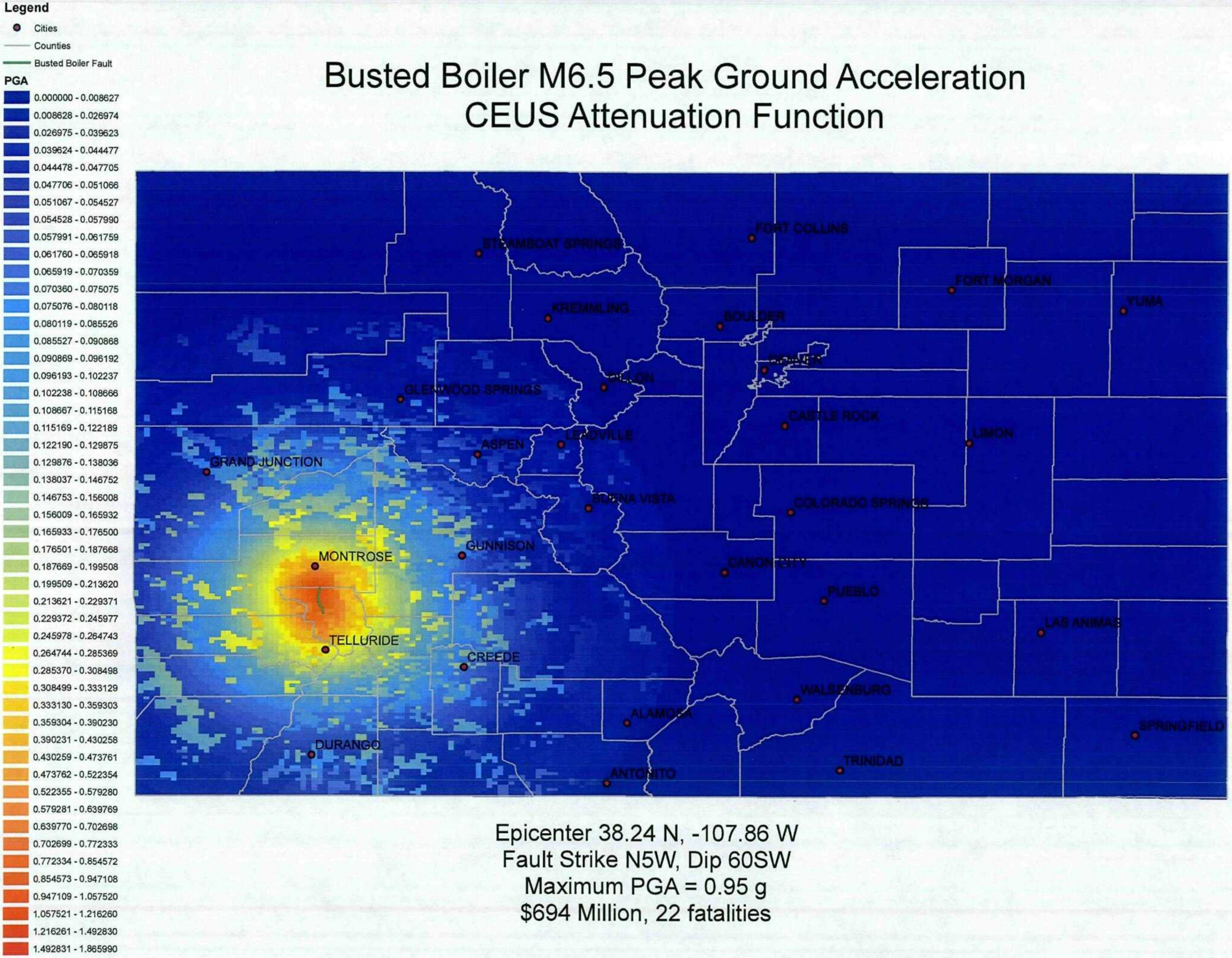
Derived from Geologic Map of Colorado (Tweto, 1979)

Anton Scarp M7.6 Peak Ground Acceleration
CEUS Attenuation Function



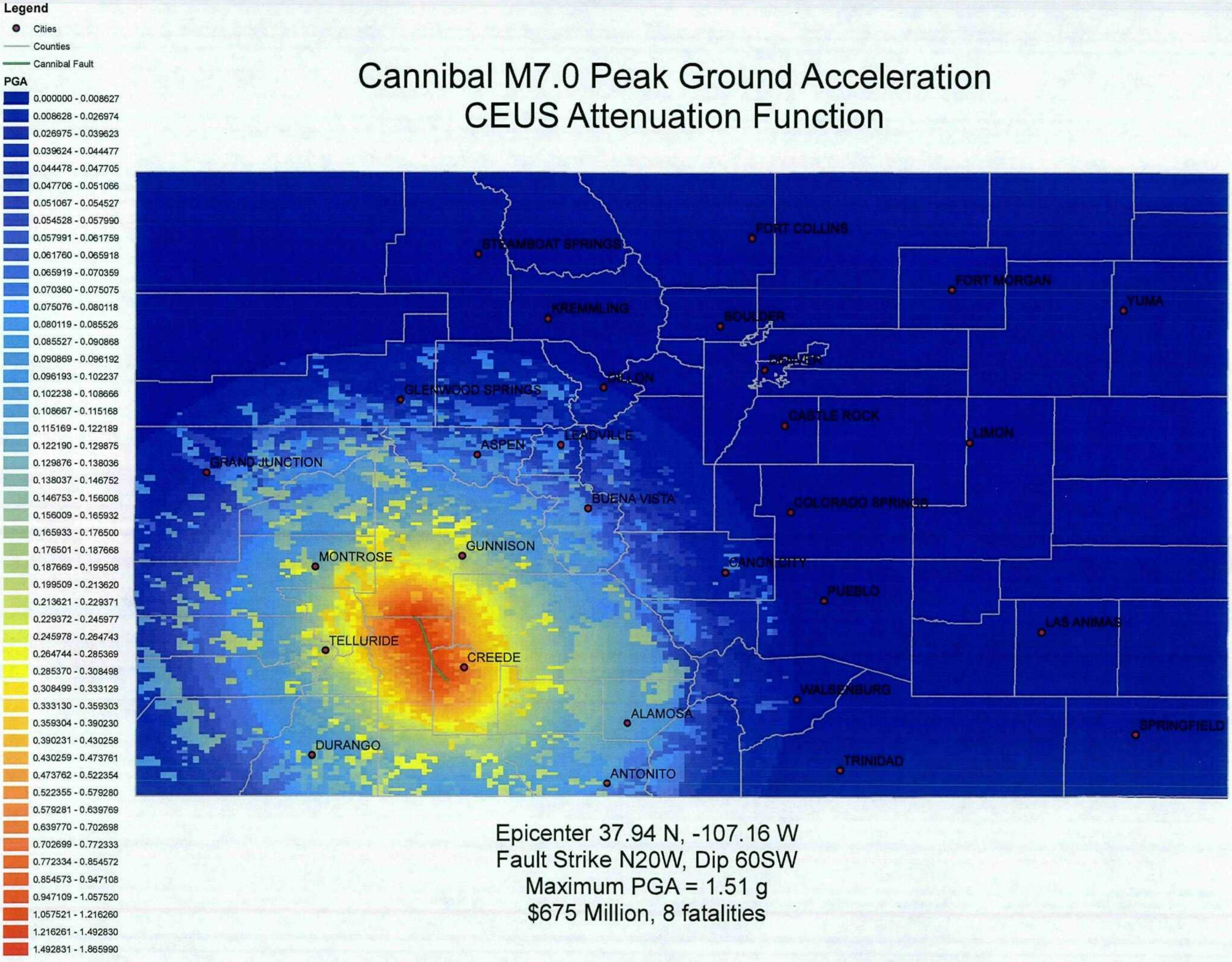
Epicenter 39.60 N, -102.93 W
Fault Strike N40W, Dip 60NE
Maximum PGA = 1.85 g
$12.15 Billion, 542 fatalities

Busted Boiler M6.5 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 38.24 N, -107.86 W
Fault Strike N5W, Dip 60SW
Maximum PGA = 0.95 g
$694 Million, 22 fatalities

Cannibal M7.0 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 37.94 N, -107.16 W
Fault Strike N20W, Dip 60SW
Maximum PGA = 1.51 g
$675 Million, 8 fatalities

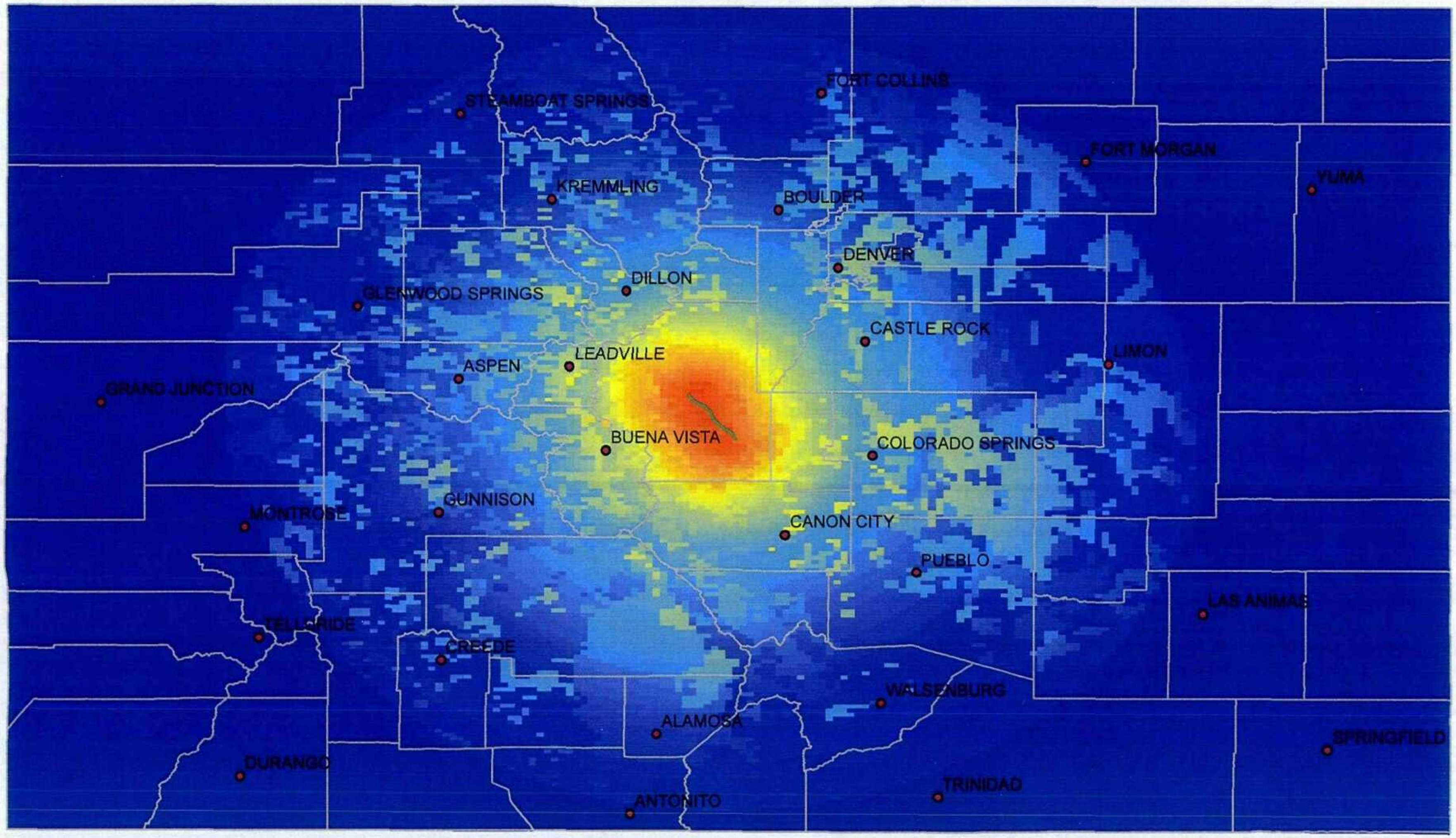
Legend

- Cities
- Counties
- Chase Gulch Fault

PGA

- 0.000000 - 0.008627
- 0.008628 - 0.026974
- 0.026975 - 0.039623
- 0.039624 - 0.044477
- 0.044478 - 0.047705
- 0.047706 - 0.051066
- 0.051067 - 0.054527
- 0.054528 - 0.057990
- 0.057991 - 0.061759
- 0.061760 - 0.065918
- 0.065919 - 0.070359
- 0.070360 - 0.075075
- 0.075076 - 0.080118
- 0.080119 - 0.085526
- 0.085527 - 0.090868
- 0.090869 - 0.096192
- 0.096193 - 0.102237
- 0.102238 - 0.108666
- 0.108667 - 0.115168
- 0.115169 - 0.122189
- 0.122190 - 0.129875
- 0.129876 - 0.138036
- 0.138037 - 0.146752
- 0.146753 - 0.156008
- 0.156009 - 0.165932
- 0.165933 - 0.176500
- 0.176501 - 0.187668
- 0.187669 - 0.199508
- 0.199509 - 0.213620
- 0.213621 - 0.229371
- 0.229372 - 0.245977
- 0.245978 - 0.264743
- 0.264744 - 0.285369
- 0.285370 - 0.308498
- 0.308499 - 0.333129
- 0.333130 - 0.359303
- 0.359304 - 0.390230
- 0.390231 - 0.430258
- 0.430259 - 0.473761
- 0.473762 - 0.522354
- 0.522355 - 0.579280
- 0.579281 - 0.639769
- 0.639770 - 0.702698
- 0.702699 - 0.772333
- 0.772334 - 0.854572
- 0.854573 - 0.947108
- 0.947109 - 1.057520
- 1.057521 - 1.216260
- 1.216261 - 1.492830
- 1.492831 - 1.865990

Chase Gulch M6.75 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 39.00 N, -105.62 W
Fault Strike N23W, Dip 60NE
Maximum PGA = 1.28 g
$3.76 Billion, 40 fatalities

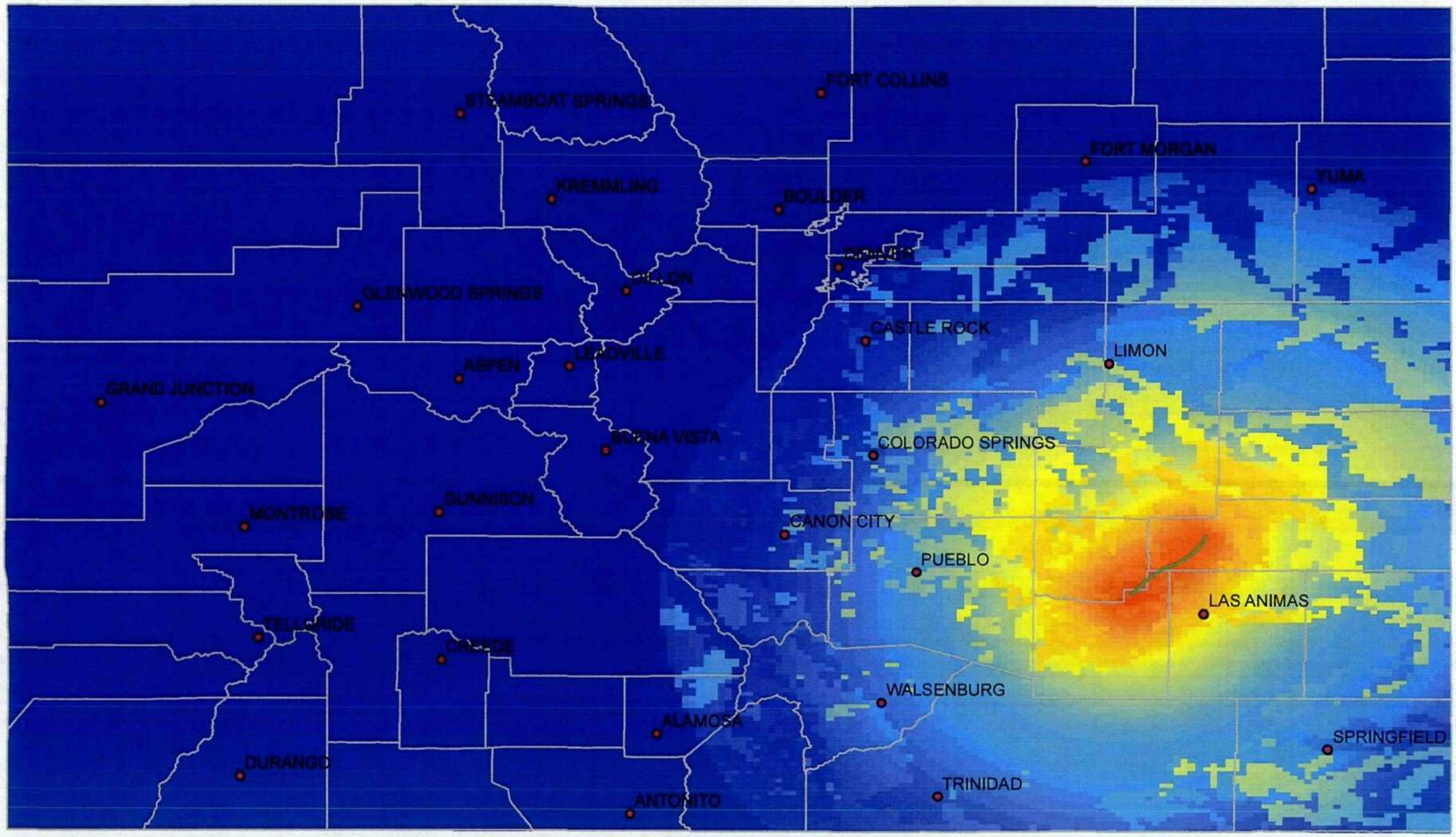
Legend

- Cities
- Counties
- Cheraw Fault

PGA

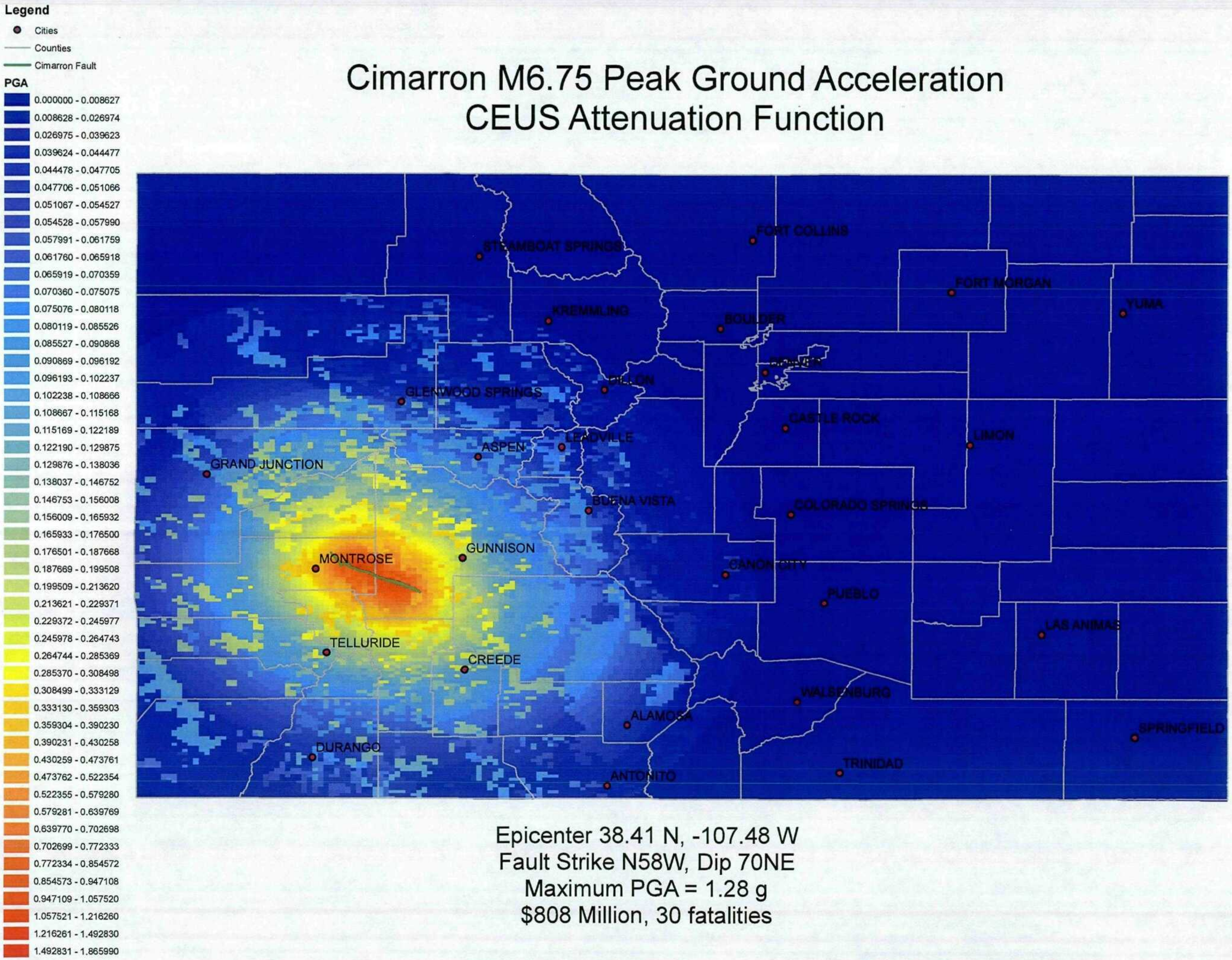
0.000000 - 0.008627
0.008628 - 0.026974
0.026975 - 0.039623
0.039624 - 0.044477
0.044478 - 0.047705
0.047706 - 0.051066
0.051067 - 0.054527
0.054528 - 0.057990
0.057991 - 0.061759
0.061760 - 0.065918
0.065919 - 0.070359
0.070360 - 0.075075
0.075076 - 0.080118
0.080119 - 0.085526
0.085527 - 0.090868
0.090869 - 0.096192
0.096193 - 0.102237
0.102238 - 0.108666
0.108667 - 0.115168
0.115169 - 0.122189
0.122190 - 0.129875
0.129876 - 0.138036
0.138037 - 0.146752
0.146753 - 0.156008
0.156009 - 0.165932
0.165933 - 0.176500
0.176501 - 0.187668
0.187669 - 0.199508
0.199509 - 0.213620
0.213621 - 0.229371
0.229372 - 0.245977
0.245978 - 0.264743
0.264744 - 0.285369
0.285370 - 0.308498
0.308499 - 0.333129
0.333130 - 0.359303
0.359304 - 0.390230
0.390231 - 0.430258
0.430259 - 0.473761
0.473762 - 0.522354
0.522355 - 0.579280
0.579281 - 0.639769
0.639770 - 0.702698
0.702699 - 0.772333
0.772334 - 0.854572
0.854573 - 0.947108
0.947109 - 1.057520
1.057521 - 1.216260
1.216261 - 1.492830
1.492831 - 1.865990

Cheraw M7.0 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 38.28 N, -103.42 W
Fault Strike N44E, Dip 66NW
Maximum PGA = 1.25 g
$1.26 Billion, 25 fatalities

Cimarron M6.75 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 38.41 N, -107.48 W
Fault Strike N58W, Dip 70NE
Maximum PGA = 1.28 g
$808 Million, 30 fatalities

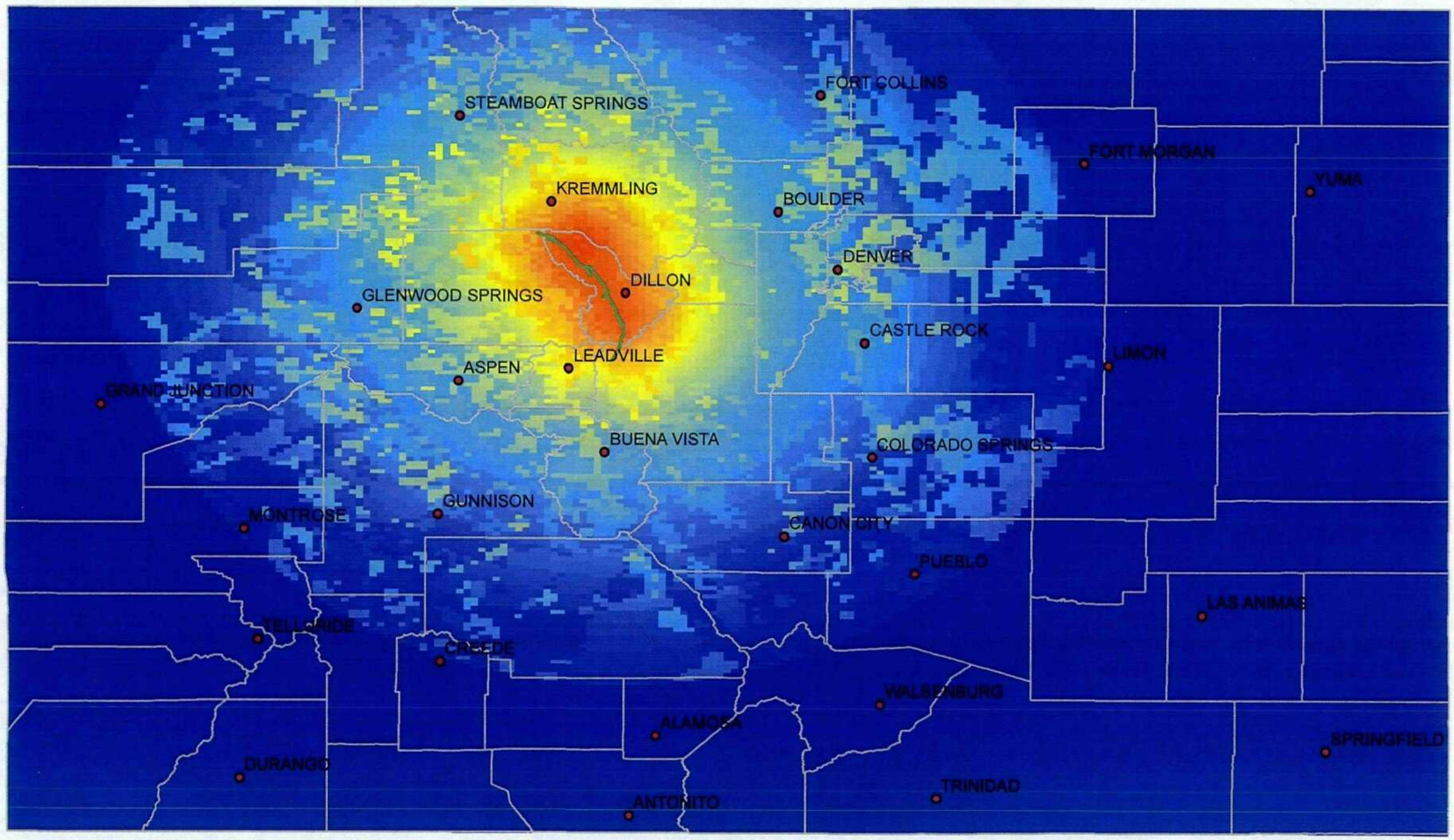
Legend

- Cities
- Counties
- Frontal Fault

PGA

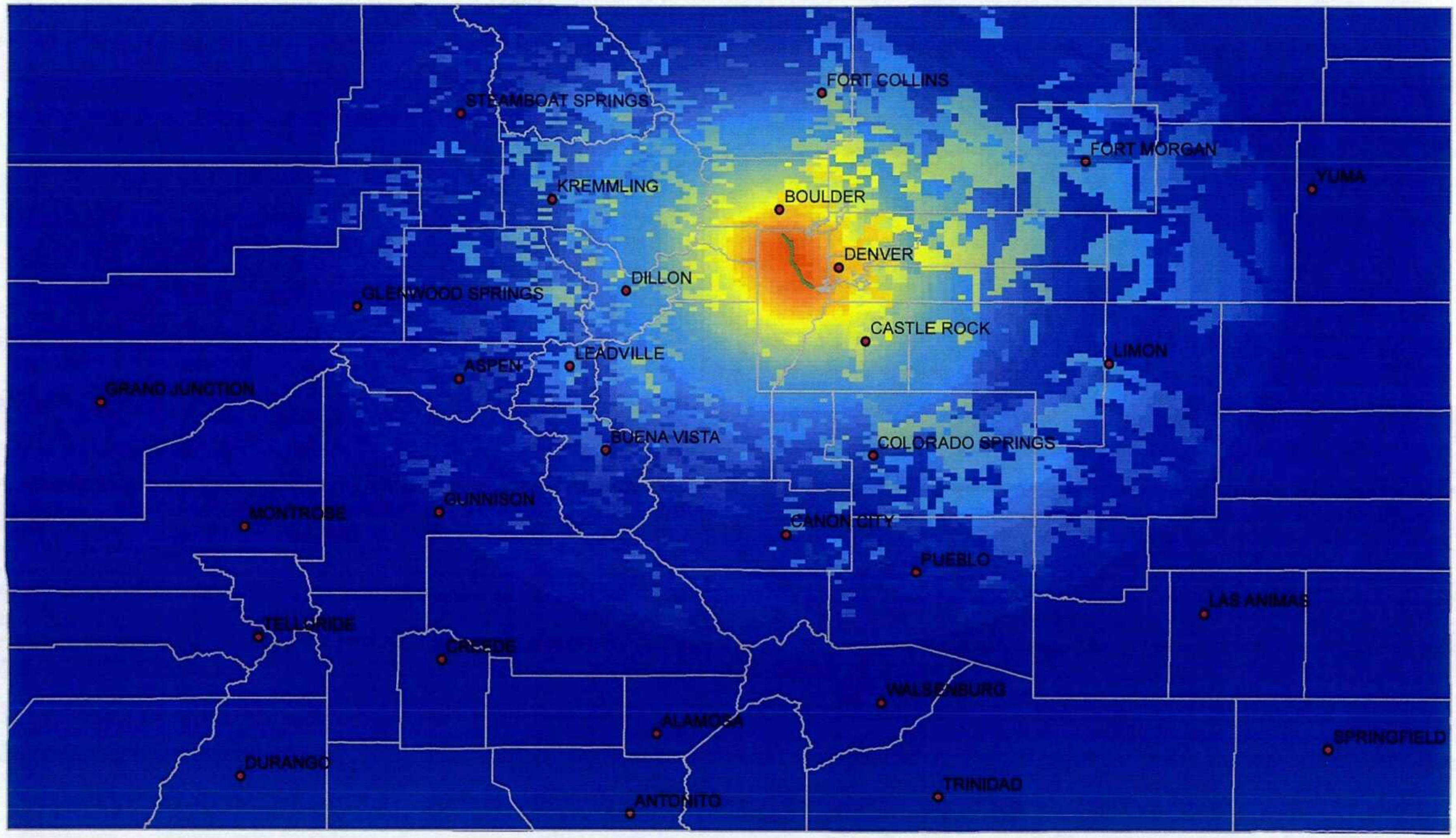
- 0.000000 - 0.008627
- 0.008628 - 0.026974
- 0.026975 - 0.039623
- 0.039624 - 0.044477
- 0.044478 - 0.047705
- 0.047706 - 0.051066
- 0.051067 - 0.054527
- 0.054528 - 0.057990
- 0.057991 - 0.061759
- 0.061760 - 0.065918
- 0.065919 - 0.070359
- 0.070360 - 0.075075
- 0.075076 - 0.080118
- 0.080119 - 0.085526
- 0.085527 - 0.090868
- 0.090869 - 0.096192
- 0.096193 - 0.102237
- 0.102238 - 0.108666
- 0.108667 - 0.115168
- 0.115169 - 0.122189
- 0.122190 - 0.129875
- 0.129876 - 0.138036
- 0.138037 - 0.146752
- 0.146753 - 0.156008
- 0.156009 - 0.165932
- 0.165933 - 0.176500
- 0.176501 - 0.187668
- 0.187669 - 0.199508
- 0.199509 - 0.213620
- 0.213621 - 0.229371
- 0.229372 - 0.245977
- 0.245978 - 0.264743
- 0.264744 - 0.285369
- 0.285370 - 0.308498
- 0.308499 - 0.333129
- 0.333130 - 0.359303
- 0.359304 - 0.390230
- 0.390231 - 0.430258
- 0.430259 - 0.473761
- 0.473762 - 0.522354
- 0.522355 - 0.579280
- 0.579281 - 0.639769
- 0.639770 - 0.702698
- 0.702699 - 0.772333
- 0.772334 - 0.854572
- 0.854573 - 0.947108
- 0.947109 - 1.057520
- 1.057521 - 1.216260
- 1.216261 - 1.492830
- 1.492831 - 1.865990

Frontal M7.0 Peak Ground Acceleration
CEUS Attenuation Function



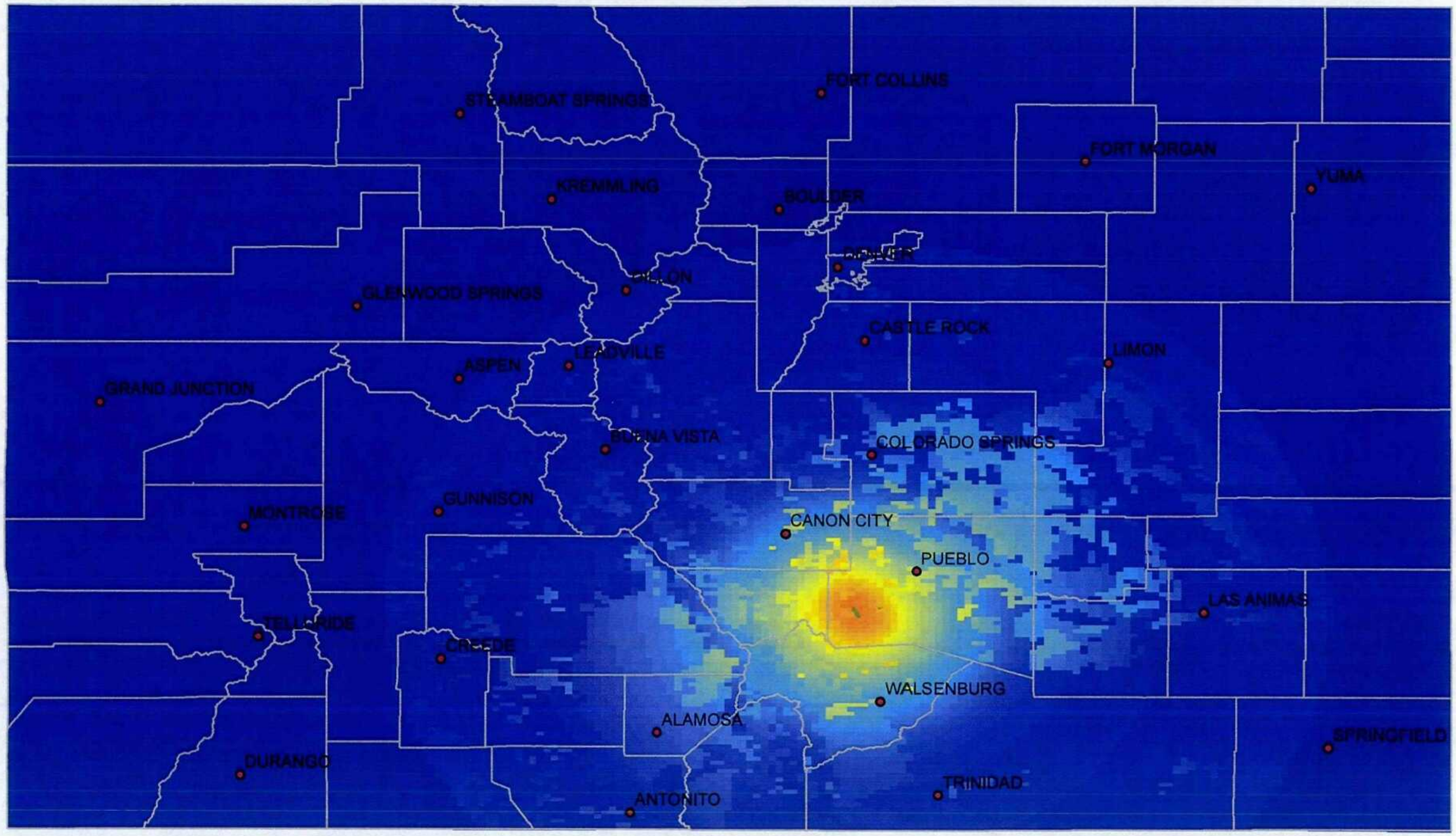
Epicenter 39.68 N, -106.16 W
Fault Strike N24W, Dip 75NE
Maximum PGA = 1.44 g
$6.73 Billion, 137 fatalities

Golden M6.5 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 39.74 N, -105.22 W
Fault Strike N23W, Dip 60SW
Maximum PGA = 1.09 g
$21.89 Billion, 862 fatalities

Goodpasture M6.0 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 38.05 N, -104.91 W
Fault Strike N32W, Dip 60NE
Maximum PGA = 0.67 g
$479 Million, 2 fatalities

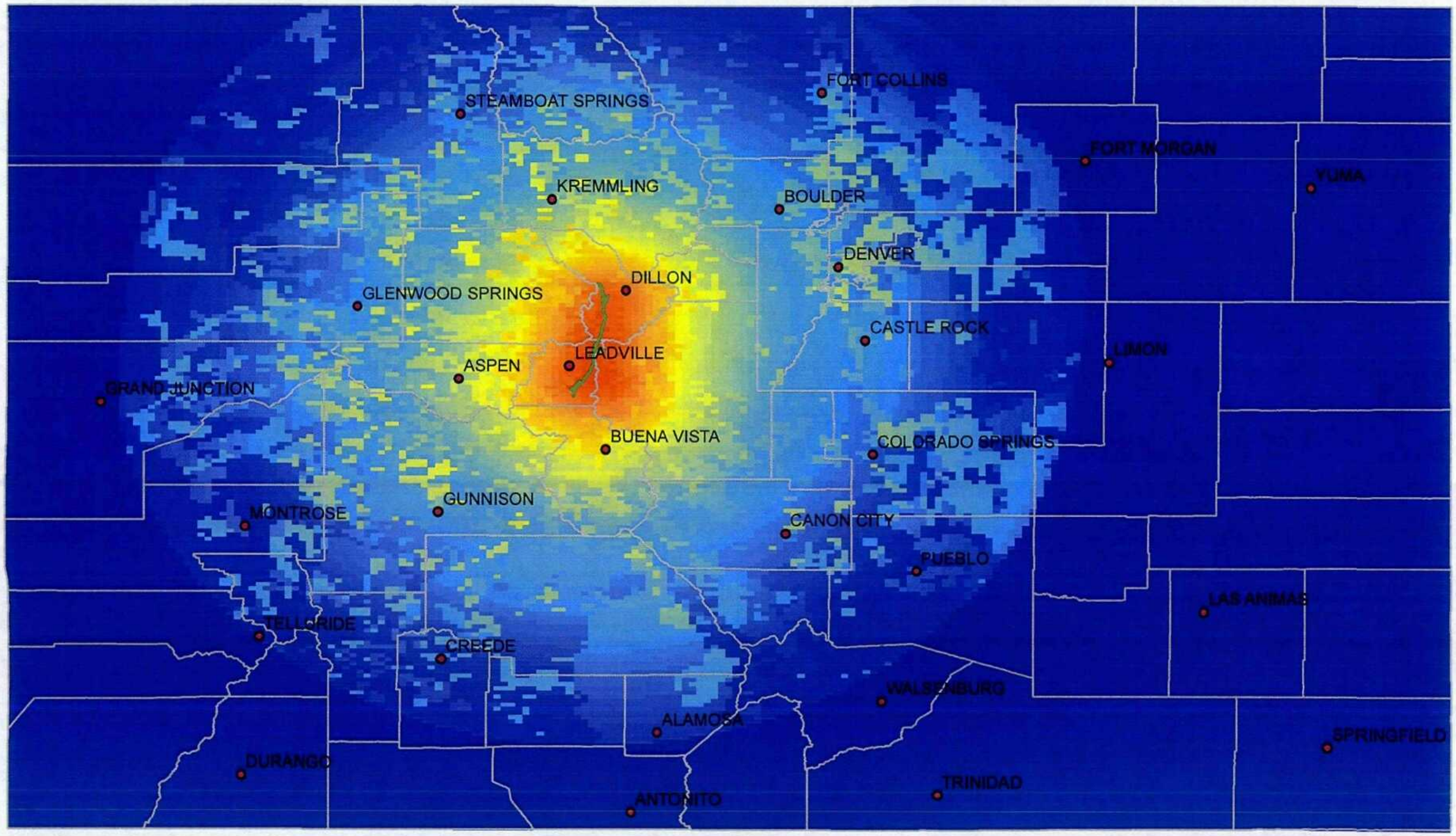
Legend

- Cities
- Counties
- Mosquito Fault

PGA

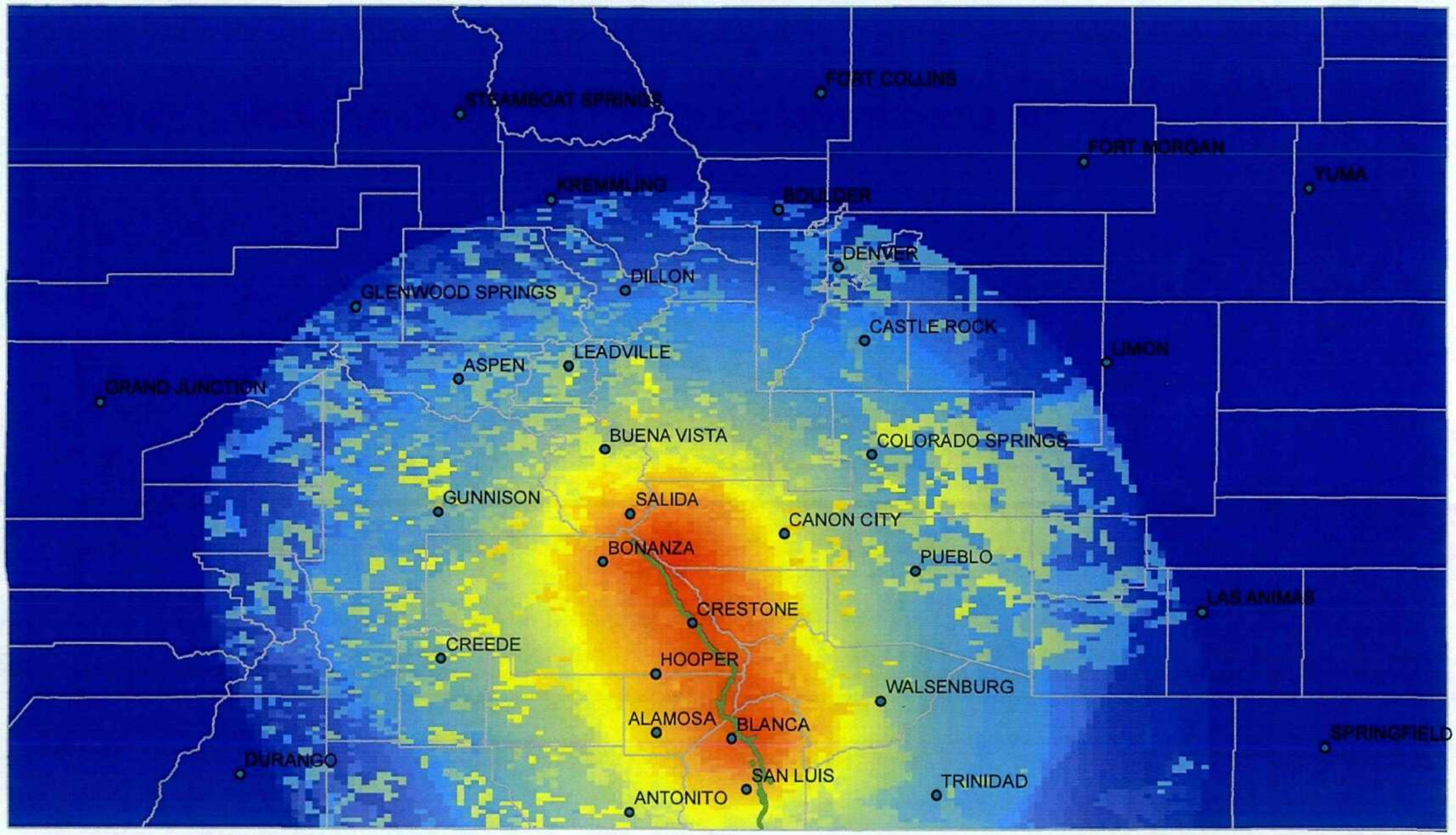
0.000000 - 0.008627
0.008628 - 0.026974
0.026975 - 0.039623
0.039624 - 0.044477
0.044478 - 0.047705
0.047706 - 0.051066
0.051067 - 0.054527
0.054528 - 0.057990
0.057991 - 0.061759
0.061760 - 0.065918
0.065919 - 0.070359
0.070360 - 0.075075
0.075076 - 0.080118
0.080119 - 0.085526
0.085527 - 0.090868
0.090869 - 0.096192
0.096193 - 0.102237
0.102238 - 0.108666
0.108667 - 0.115168
0.115169 - 0.122189
0.122190 - 0.129875
0.129876 - 0.138036
0.138037 - 0.146752
0.146753 - 0.156008
0.156009 - 0.165932
0.165933 - 0.176500
0.176501 - 0.187668
0.187669 - 0.199508
0.199509 - 0.213620
0.213621 - 0.229371
0.229372 - 0.245977
0.245978 - 0.264743
0.264744 - 0.285369
0.285370 - 0.308498
0.308499 - 0.333129
0.333130 - 0.359303
0.359304 - 0.390230
0.390231 - 0.430258
0.430259 - 0.473761
0.473762 - 0.522354
0.522355 - 0.579280
0.579281 - 0.639769
0.639770 - 0.702698
0.702699 - 0.772333
0.772334 - 0.854572
0.854573 - 0.947108
0.947109 - 1.057520
1.057521 - 1.216260
1.216261 - 1.492830
1.492831 - 1.865990

Mosquito M7.0 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 39.38 N, -106.16 W
Fault Strike N9E, Dip 70NW
Maximum PGA = 1.30 g
$6.19 Billion, 110 fatalities

N Sangre de Cristo M7.5 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 37.90 N, -105.63 W
Fault Strike N19W, Dip 60SW
Maximum PGA = 1.87g
$8.0 Billion, 335 fatalities

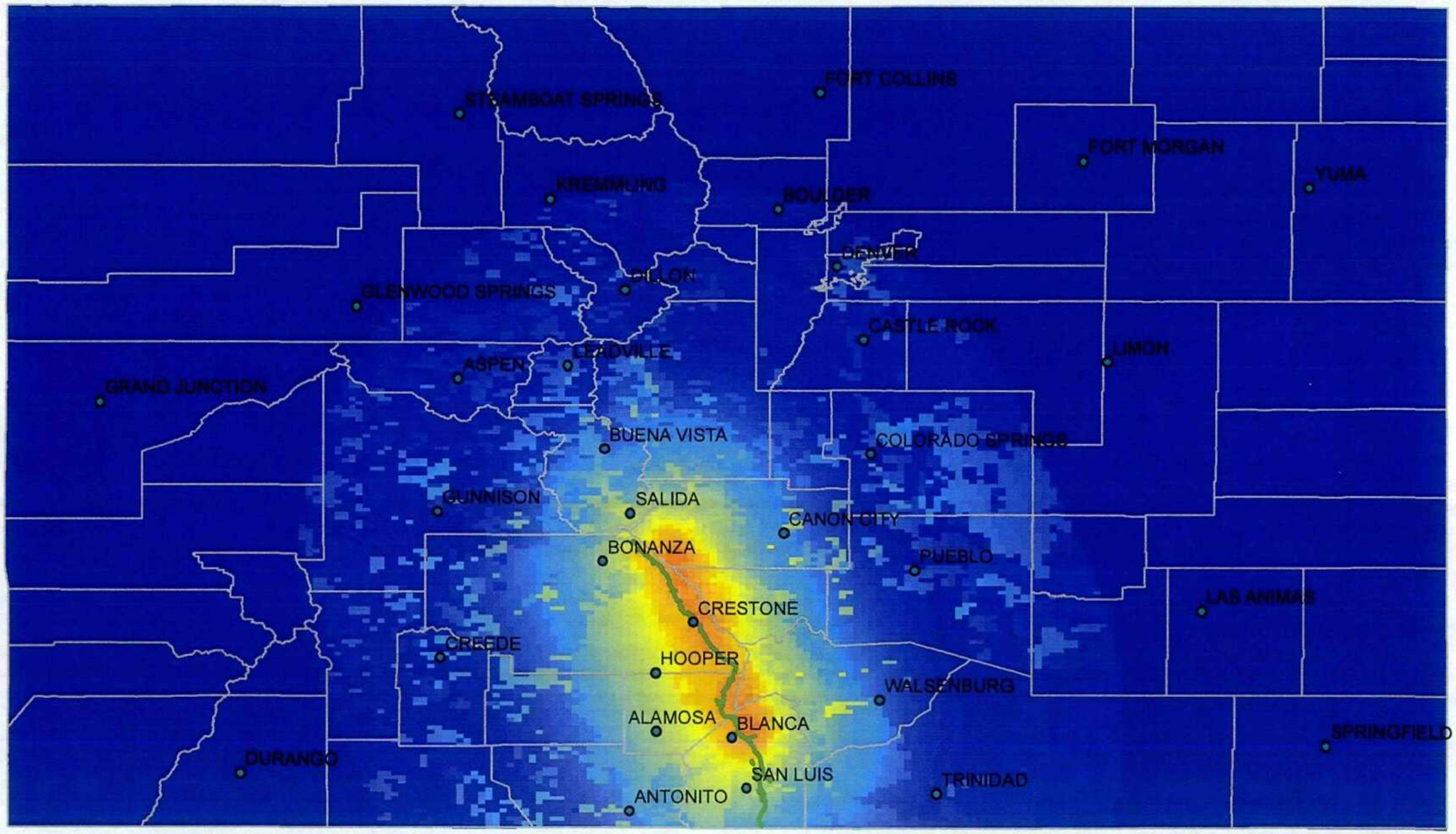
N Sangre de Cristo M7.5 Peak Ground Acceleration
WUS Attenuation Function

Legend

county_line
N_Sangre_fault
Cities

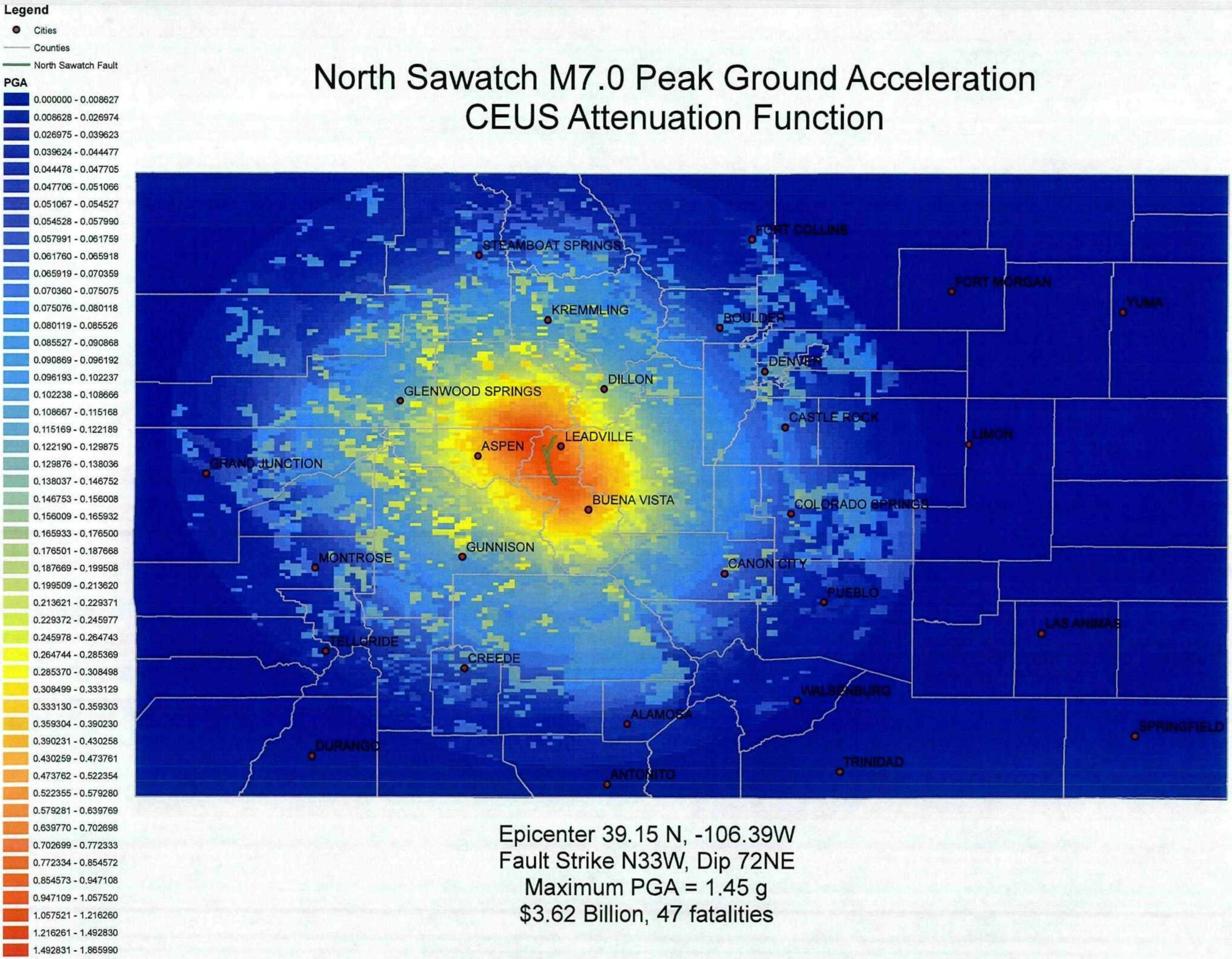
PGA

0.000000 - 0.008627
0.008628 - 0.026974
0.026975 - 0.039623
0.039624 - 0.044477
0.044478 - 0.047705
0.047706 - 0.051066
0.051067 - 0.054527
0.054528 - 0.057990
0.057991 - 0.061759
0.061760 - 0.065918
0.065919 - 0.070359
0.070360 - 0.075075
0.075076 - 0.080118
0.080119 - 0.085526
0.085527 - 0.090868
0.090869 - 0.096192
0.096193 - 0.102237
0.102238 - 0.108666
0.108667 - 0.115168
0.115169 - 0.122189
0.122190 - 0.129875
0.129876 - 0.138036
0.138037 - 0.146752
0.146753 - 0.156008
0.156009 - 0.165932
0.165933 - 0.176500
0.176501 - 0.187668
0.187669 - 0.199508
0.199509 - 0.213620
0.213621 - 0.229371
0.229372 - 0.245977
0.245978 - 0.264743
0.264744 - 0.285369
0.285370 - 0.308498
0.308499 - 0.333129
0.333130 - 0.359303
0.359304 - 0.390230
0.390231 - 0.430258
0.430259 - 0.473761
0.473762 - 0.522354
0.522355 - 0.579280
0.579281 - 0.639769
0.639770 - 0.702698
0.702699 - 0.772333
0.772334 - 0.854572
0.854573 - 0.947108
0.947109 - 1.057520
1.057521 - 1.216260
1.216261 - 1.492830
1.492831 - 1.865990



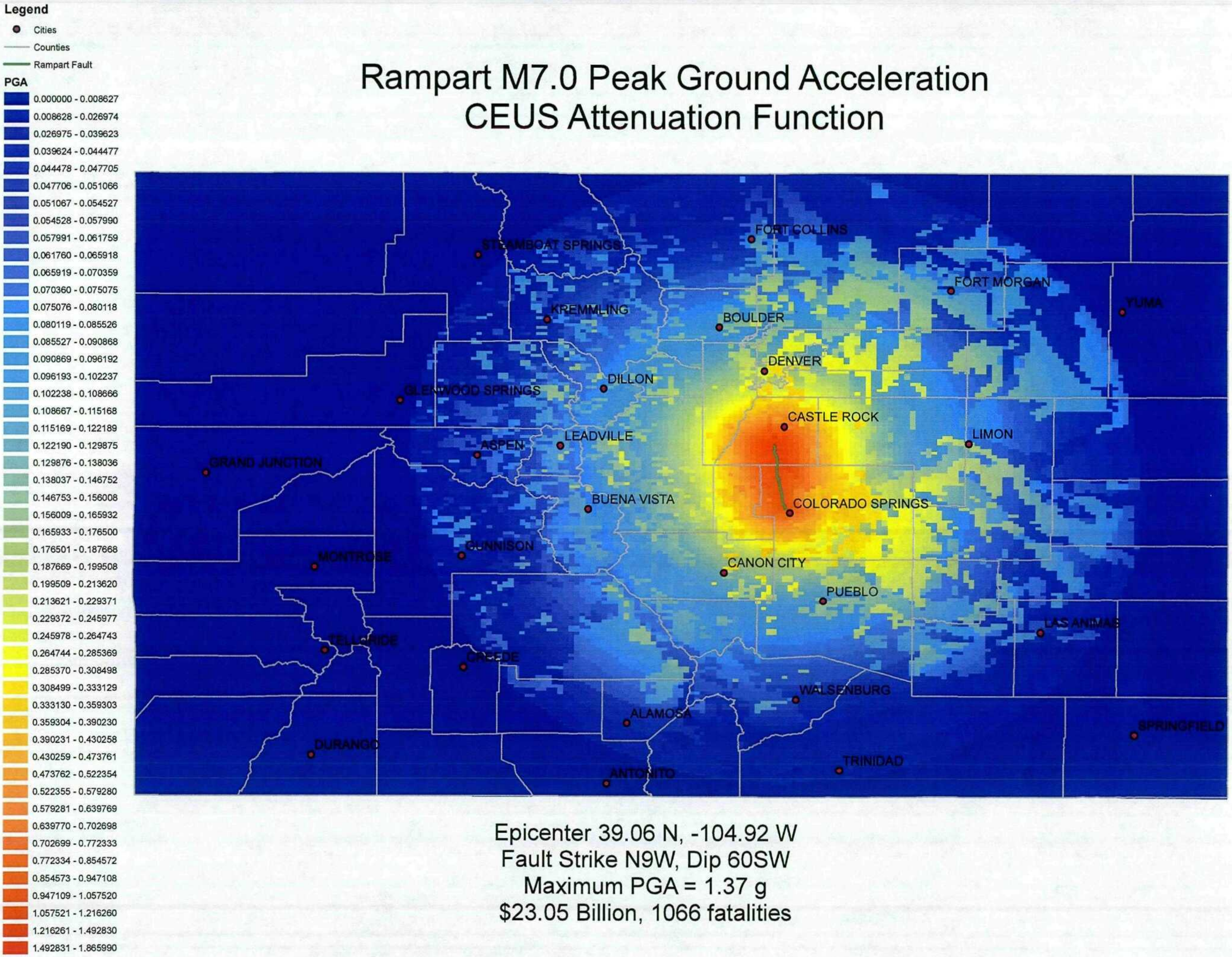
Epicenter 37.90 N, -105.63 W
Fault Strike N19W, Dip 60SW
Maximum PGA = 0.63 g
$767 Million, 17 fatalities

North Sawatch M7.0 Peak Ground Acceleration
CEUS Attenuation Function

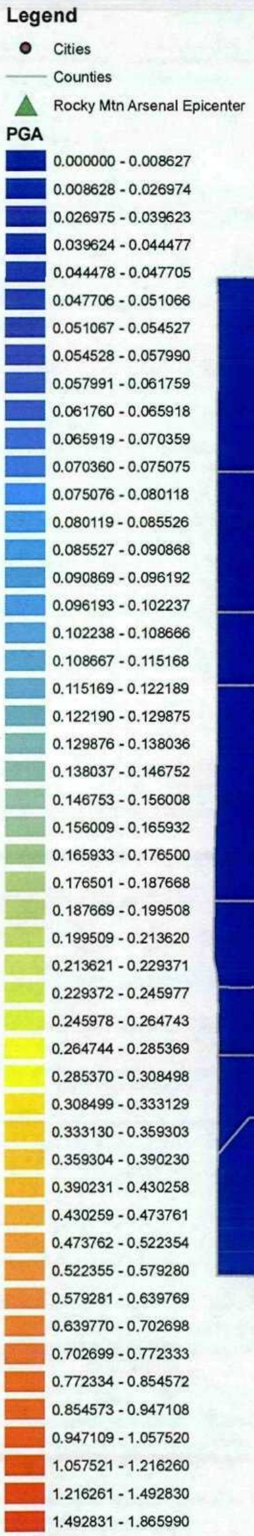


Epicenter 39.15 N, -106.39W
Fault Strike N33W, Dip 72NE
Maximum PGA = 1.45 g
$3.62 Billion, 47 fatalities

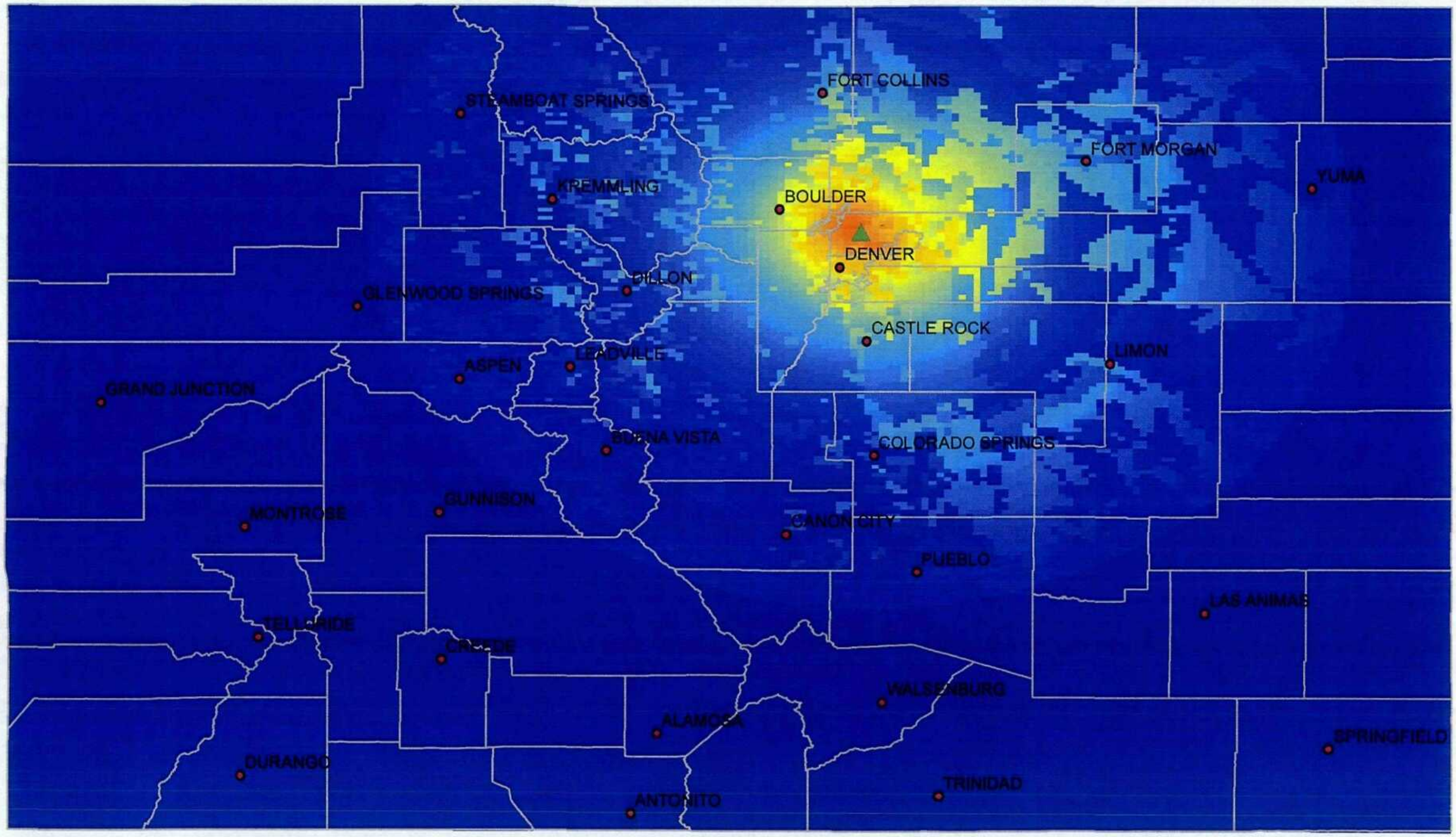
Rampart M7.0 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 39.06 N, -104.92 W
Fault Strike N9W, Dip 60SW
Maximum PGA = 1.37 g
$23.05 Billion, 1066 fatalities



Rocky Mountain Arsenal M6.25 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 39.90 N, -104.90 W
Fault Strike N50W, Dip 60SW
Maximum PGA = 0.78 g
$14.87 Billion, 511 fatalities

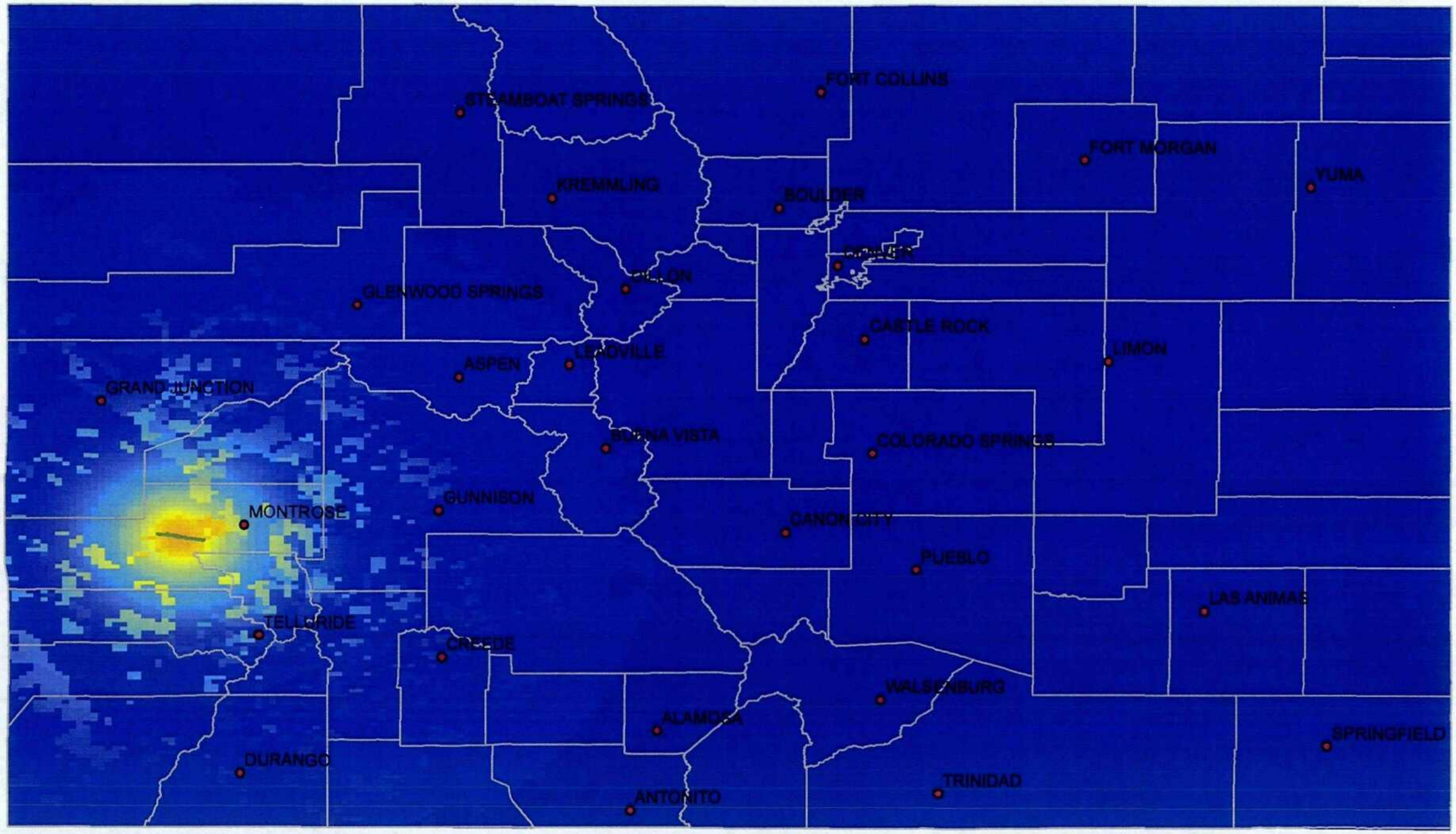
Roubideau Creek M5.5 Peak Ground Acceleration
CEUS Attenuation Function

Legend

- Cities
- Counties
- Roubideau Fault

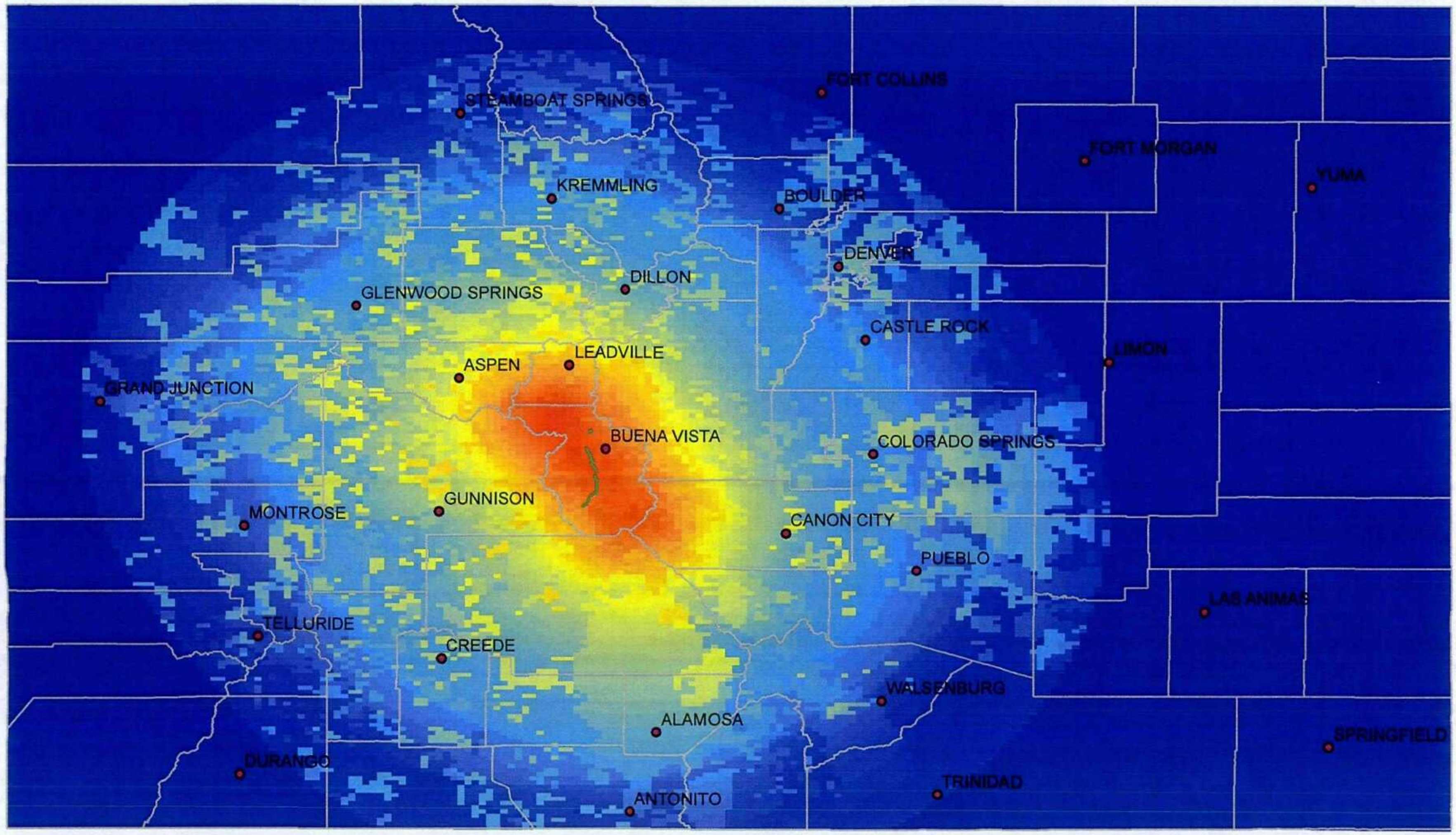
PGA

- 0.000000 - 0.008627
- 0.008628 - 0.026974
- 0.026975 - 0.039623
- 0.039624 - 0.044477
- 0.044478 - 0.047705
- 0.047706 - 0.051066
- 0.051067 - 0.054527
- 0.054528 - 0.057990
- 0.057991 - 0.061759
- 0.061760 - 0.065918
- 0.065919 - 0.070359
- 0.070360 - 0.075075
- 0.075076 - 0.080118
- 0.080119 - 0.085526
- 0.085527 - 0.090868
- 0.090869 - 0.096192
- 0.096193 - 0.102237
- 0.102238 - 0.108666
- 0.108667 - 0.115168
- 0.115169 - 0.122189
- 0.122190 - 0.129875
- 0.129876 - 0.138036
- 0.138037 - 0.146752
- 0.146753 - 0.156008
- 0.156009 - 0.165932
- 0.165933 - 0.176500
- 0.176501 - 0.187668
- 0.187669 - 0.199508
- 0.199509 - 0.213620
- 0.213621 - 0.229371
- 0.229372 - 0.245977
- 0.245978 - 0.264743
- 0.264744 - 0.285369
- 0.285370 - 0.308498
- 0.308499 - 0.333129
- 0.333130 - 0.359303
- 0.359304 - 0.390230
- 0.390231 - 0.430258
- 0.430259 - 0.473761
- 0.473762 - 0.522354
- 0.522355 - 0.579280
- 0.579281 - 0.639769
- 0.639770 - 0.702698
- 0.702699 - 0.772333
- 0.772334 - 0.854572
- 0.854573 - 0.947108
- 0.947109 - 1.057520
- 1.057521 - 1.216260
- 1.216261 - 1.492830
- 1.492831 - 1.865990



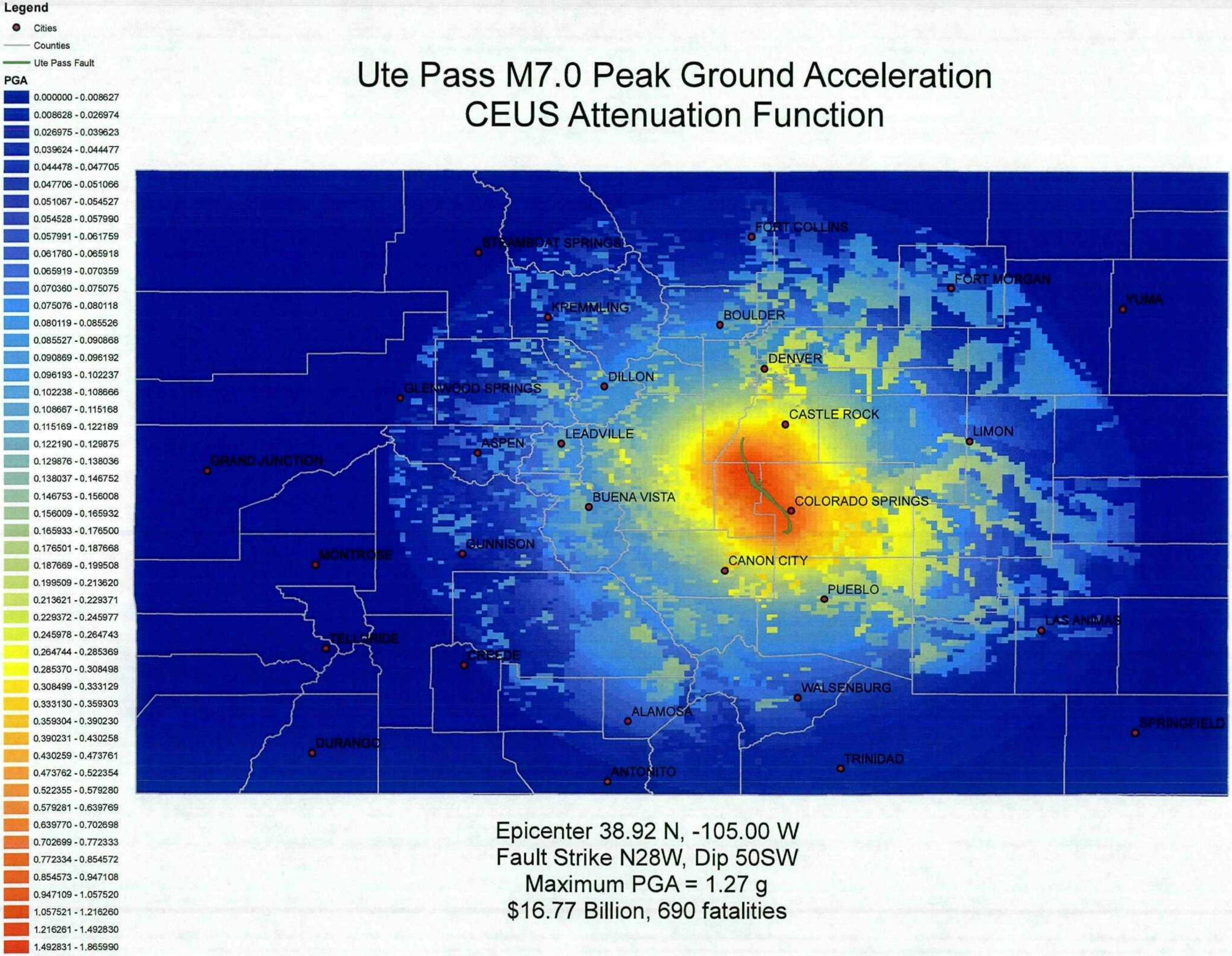
Epicenter 38.41 N, -108.19 W
Fault Strike N74W, Dip 65NE
Maximum PGA = 0.46 g
$94.2 Million, 0 fatalities

South Sawatch M7.25 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 38.75 N, -106.18 W
Fault Strike N32W, Dip 70NE
Maximum PGA = 1.44 g
$4.74 Billion, 81 fatalities

Ute Pass M7.0 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 38.92 N, -105.00 W
Fault Strike N28W, Dip 50SW
Maximum PGA = 1.27 g
$16.77 Billion, 690 fatalities

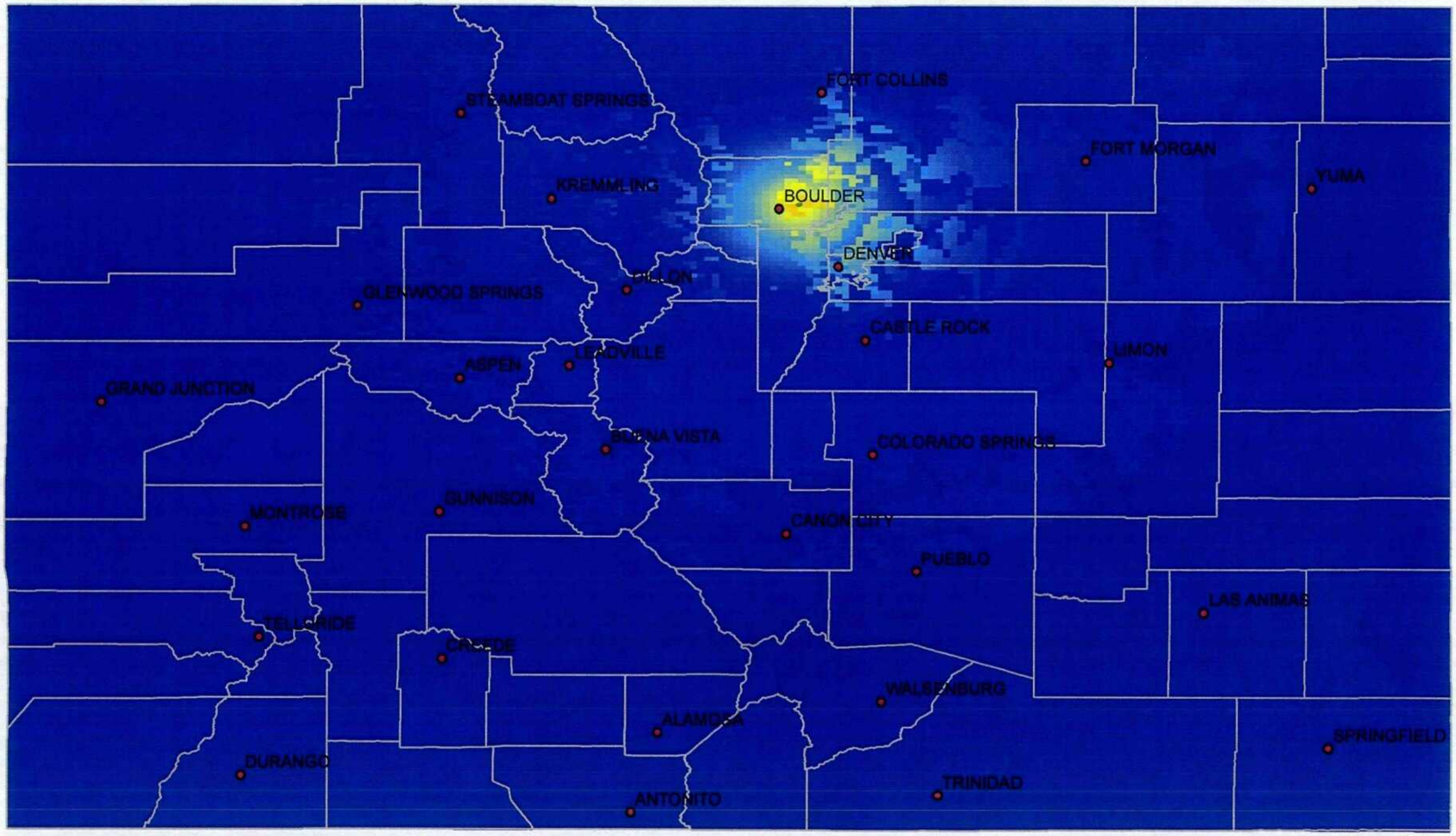
Legend

- Cities
- Counties
- Valmont Fault

PGA

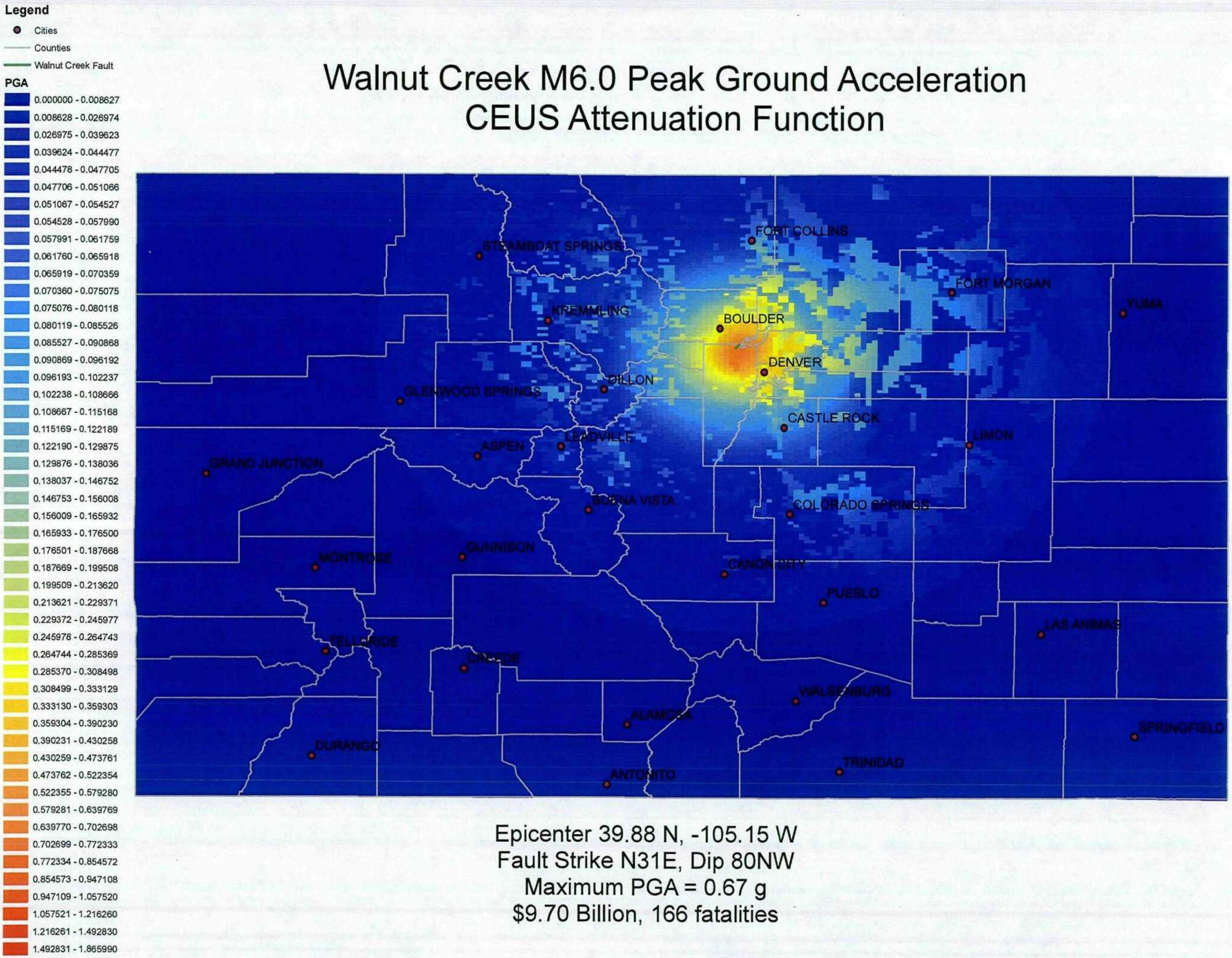
0.000000 - 0.008627
0.008628 - 0.026974
0.026975 - 0.039623
0.039624 - 0.044477
0.044478 - 0.047705
0.047706 - 0.051066
0.051067 - 0.054527
0.054528 - 0.057990
0.057991 - 0.061759
0.061760 - 0.065918
0.065919 - 0.070359
0.070360 - 0.075075
0.075076 - 0.080118
0.080119 - 0.085526
0.085527 - 0.090868
0.090869 - 0.096192
0.096193 - 0.102237
0.102238 - 0.108666
0.108667 - 0.115168
0.115169 - 0.122189
0.122190 - 0.129875
0.129876 - 0.138036
0.138037 - 0.146752
0.146753 - 0.156008
0.156009 - 0.165932
0.165933 - 0.176500
0.176501 - 0.187668
0.187669 - 0.199508
0.199509 - 0.213620
0.213621 - 0.229371
0.229372 - 0.245977
0.245978 - 0.264743
0.264744 - 0.285369
0.285370 - 0.308498
0.308499 - 0.333129
0.333130 - 0.359303
0.359304 - 0.390230
0.390231 - 0.430258
0.430259 - 0.473761
0.473762 - 0.522354
0.522355 - 0.579280
0.579281 - 0.639769
0.639770 - 0.702698
0.702699 - 0.772333
0.772334 - 0.854572
0.854573 - 0.947108
0.947109 - 1.057520
1.057521 - 1.216260
1.216261 - 1.492830
1.492831 - 1.865990

Valmont M5.0 Peak Ground Acceleration
CEUS Attenuation Function



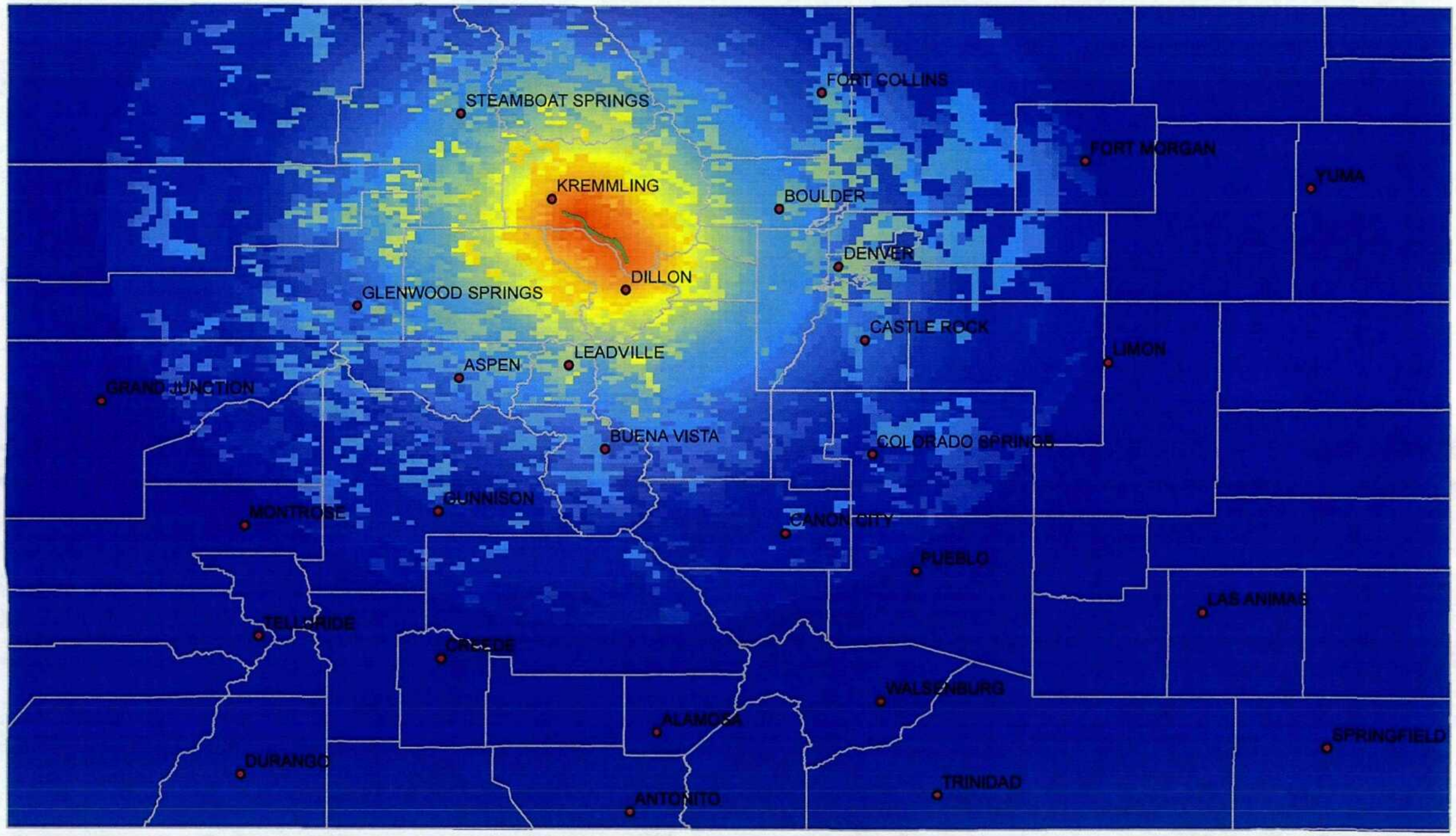
Epicenter 40.03 N, -105.20 W
Fault Strike N75E, Dip 80SE
Maximum PGA = 0.36 g
$712 Million, 0 fatalities

Walnut Creek M6.0 Peak Ground Acceleration
CEUS Attenuation Function



Epicenter 39.88 N, -105.15 W
Fault Strike N31E, Dip 80NW
Maximum PGA = 0.67 g
$9.70 Billion, 166 fatalities

Williams Fork M6.75 Peak Ground Acceleration
CEUS Attenuation Function



Legend

- Cities
- Counties
- Williams Fork Fault

PGA

0.000000 - 0.008627
0.008628 - 0.026974
0.026975 - 0.039623
0.039624 - 0.044477
0.044478 - 0.047705
0.047706 - 0.051066
0.051067 - 0.054527
0.054528 - 0.057990
0.057991 - 0.061759
0.061760 - 0.065918
0.065919 - 0.070359
0.070360 - 0.075075
0.075076 - 0.080118
0.080119 - 0.085526
0.085527 - 0.090868
0.090869 - 0.096192
0.096193 - 0.102237
0.102238 - 0.108666
0.108667 - 0.115168
0.115169 - 0.122189
0.122190 - 0.129875
0.129876 - 0.138036
0.138037 - 0.146752
0.146753 - 0.156008
0.156009 - 0.165932
0.165933 - 0.176500
0.176501 - 0.187668
0.187669 - 0.199508
0.199509 - 0.213620
0.213621 - 0.229371
0.229372 - 0.245977
0.245978 - 0.264743
0.264744 - 0.285369
0.285370 - 0.308498
0.308499 - 0.333129
0.333130 - 0.359303
0.359304 - 0.390230
0.390231 - 0.430258
0.430259 - 0.473761
0.473762 - 0.522354
0.522355 - 0.579280
0.579281 - 0.639769
0.639770 - 0.702698
0.702699 - 0.772333
0.772334 - 0.854572
0.854573 - 0.947108
0.947109 - 1.057520
1.057521 - 1.216260
1.216261 - 1.492830
1.492831 - 1.865990

Epicenter 39.87 N, -106.15 W
Fault Strike N40W, Dip 60NE
Maximum PGA = 1.28 g
$3.48 Billion, 41 fatalities

Probabilistic Scenarios

PGA Maps for Probabilistic Scenarios
USGS Hazard Maps for Colorado

COLORADO GEOLOGICAL SURVEY

Probabilistic

Date Run	Return Period (yrs)	Prob. Exc. In 50yrs	Region	Driving Magnitude	Casualties	Total Damage ($M)	AEL ($M)
24-Apr-06	2500	2%	State	6.50	3305, 641, 94, 154	$9,870	$3.95
28-Apr-06	2000	2.50%	State	6.50	2450, 443, 60, 99	$7,580	$3.79
1-May-06	1500	3.30%	State	6.50	1633, 268, 31, 53	$5,374	$3.56
2-May-06	1000	5%	State	6.50	893, 128, 12, 21	$3,054	$3.05
4-May-06	750	6.60%	State	6.50	597, 80, 6, 12	$2,043	$2.72
8-May-06	500	10%	State	6.50	310, 38, 3, 5	$1,030	$2.06
17-May-06	250	20%	State	6.50	109, 12, 1, 1	$295	$1.18
18-May-06	100	50%	State	6.50	16, 2, 0, 0	$34	$0.34

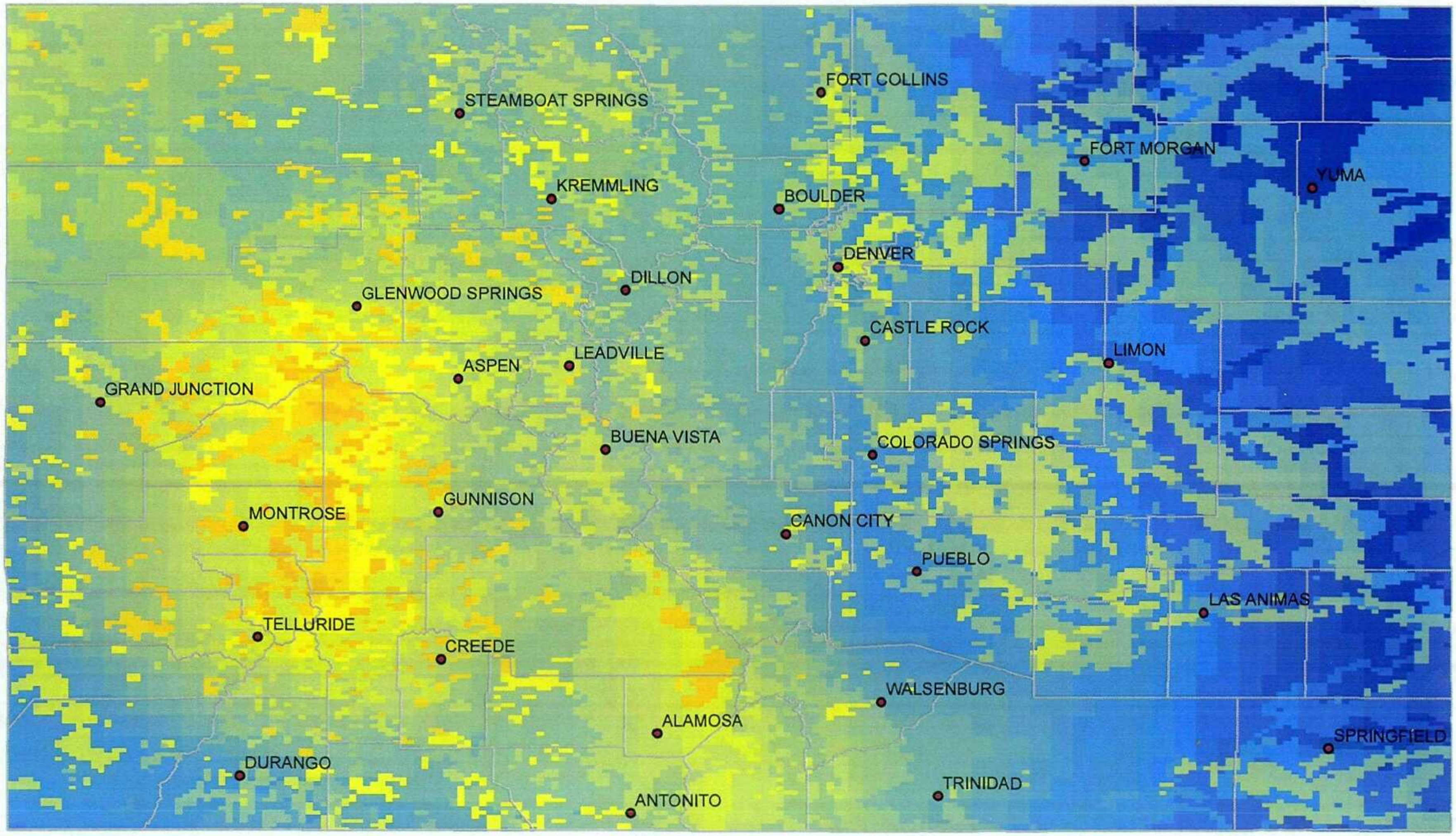
Legend

- Cities
- Counties

PGA

0.000000 - 0.008627
0.008628 - 0.026974
0.026975 - 0.039623
0.039624 - 0.044477
0.044478 - 0.047705
0.047706 - 0.051066
0.051067 - 0.054527
0.054528 - 0.057990
0.057991 - 0.061759
0.061760 - 0.065918
0.065919 - 0.070359
0.070360 - 0.075075
0.075076 - 0.080118
0.080119 - 0.085526
0.085527 - 0.090868
0.090869 - 0.096192
0.096193 - 0.102237
0.102238 - 0.108666
0.108667 - 0.115168
0.115169 - 0.122189
0.122190 - 0.129875
0.129876 - 0.138036
0.138037 - 0.146752
0.146753 - 0.156008
0.156009 - 0.165932
0.165933 - 0.176500
0.176501 - 0.187668
0.187669 - 0.199508
0.199509 - 0.213620
0.213621 - 0.229371
0.229372 - 0.245977
0.245978 - 0.264743
0.264744 - 0.285369
0.285370 - 0.308498
0.308499 - 0.333129
0.333130 - 0.359303
0.359304 - 0.390230
0.390231 - 0.430258
0.430259 - 0.473761
0.473762 - 0.522354
0.522355 - 0.579280
0.579281 - 0.639769
0.639770 - 0.702698
0.702699 - 0.772333
0.772334 - 0.854572
0.854573 - 0.947108
0.947109 - 1.057520
1.057521 - 1.216260
1.216261 - 1.492830
1.492831 - 1.865990

Probabilistic Peak Ground Acceleration
2500-year Return Period, or 2% Probability of Exceedance in 50 years



Maximum PGA = 0.36 g
\$9.87 Billion, 154 fatalities over 2500-yr period
\$3.95 Million Annualized Earthquake Loss

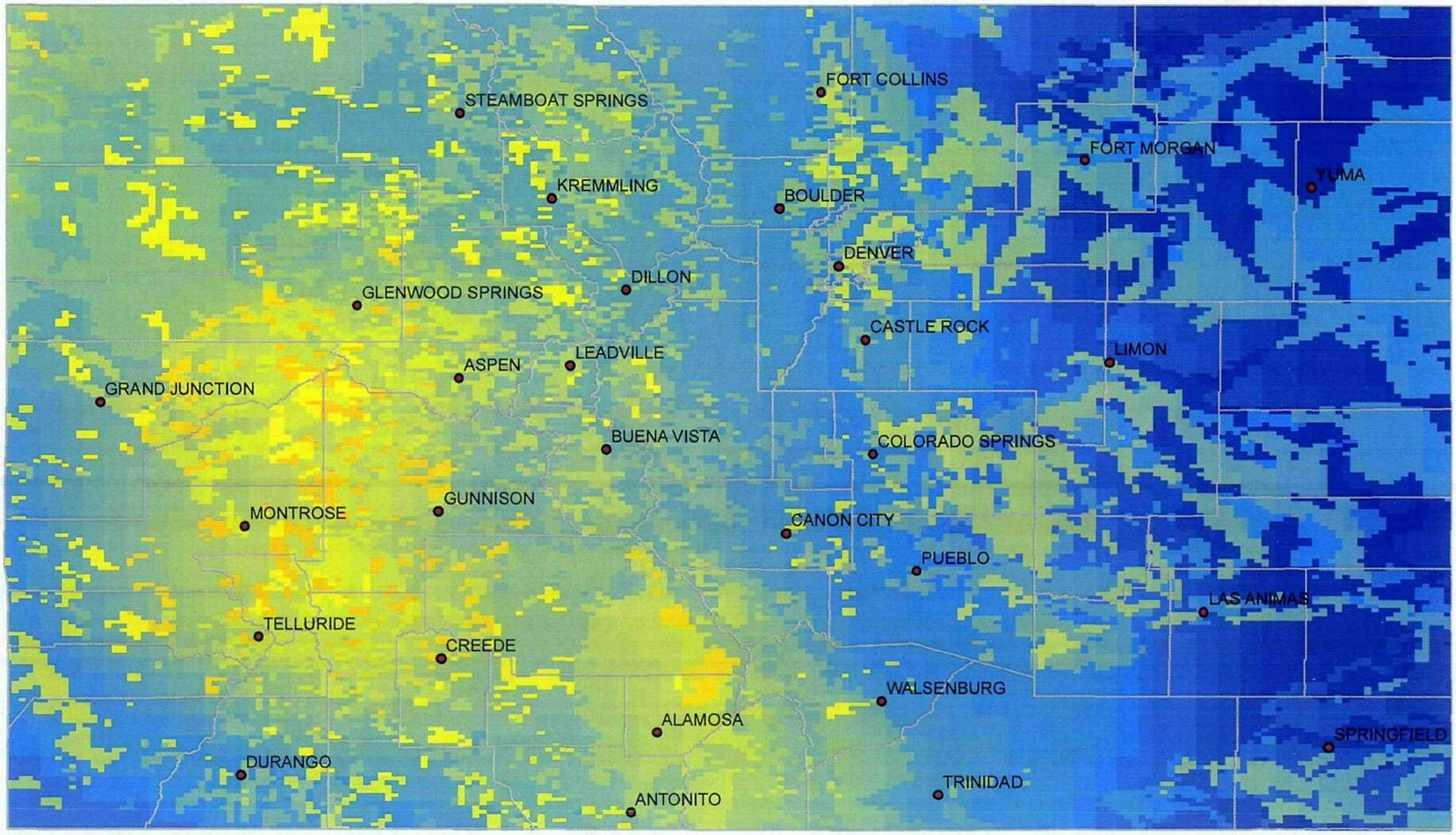
Probabilistic Peak Ground Acceleration
2000-year Return Period, or 2.5% Probability of Exceedance in 50 years

Legend

- Cities
- Counties

PGA

- 0.000000 - 0.008627
- 0.008628 - 0.026974
- 0.026975 - 0.039623
- 0.039624 - 0.044477
- 0.044478 - 0.047705
- 0.047706 - 0.051066
- 0.051067 - 0.054527
- 0.054528 - 0.057990
- 0.057991 - 0.061759
- 0.061760 - 0.065918
- 0.065919 - 0.070359
- 0.070360 - 0.075075
- 0.075076 - 0.080118
- 0.080119 - 0.085526
- 0.085527 - 0.090868
- 0.090869 - 0.096192
- 0.096193 - 0.102237
- 0.102238 - 0.108666
- 0.108667 - 0.115168
- 0.115169 - 0.122189
- 0.122190 - 0.129875
- 0.129876 - 0.138036
- 0.138037 - 0.146752
- 0.146753 - 0.156008
- 0.156009 - 0.165932
- 0.165933 - 0.176500
- 0.176501 - 0.187668
- 0.187669 - 0.199508
- 0.199509 - 0.213620
- 0.213621 - 0.229371
- 0.229372 - 0.245977
- 0.245978 - 0.264743
- 0.264744 - 0.285369
- 0.285370 - 0.308498
- 0.308499 - 0.333129
- 0.333130 - 0.359303
- 0.359304 - 0.390230
- 0.390231 - 0.430258
- 0.430259 - 0.473761
- 0.473762 - 0.522354
- 0.522355 - 0.579280
- 0.579281 - 0.639769
- 0.639770 - 0.702698
- 0.702699 - 0.772333
- 0.772334 - 0.854572
- 0.854573 - 0.947108
- 0.947109 - 1.057520
- 1.057521 - 1.216260
- 1.216261 - 1.492830
- 1.492831 - 1.865990

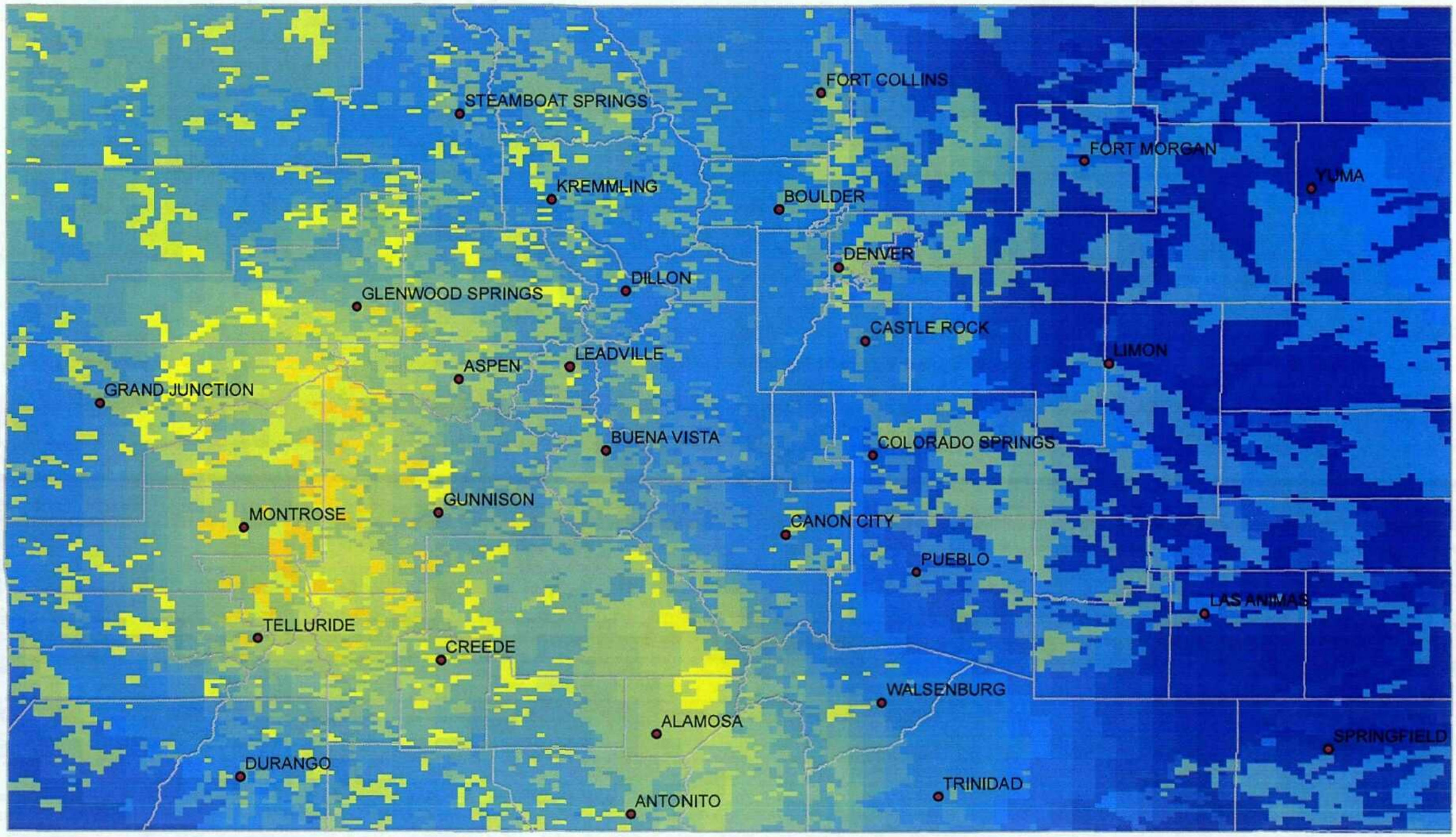


Maximum PGA = 0.355 g

$7.58 Billion, 99 fatalities over 2000-yr period

$3.79 Million Annualized Earthquake Loss

Probabilistic Peak Ground Acceleration
1500-year Return Period, or 3.3% Probability of Exceedance in 50 years

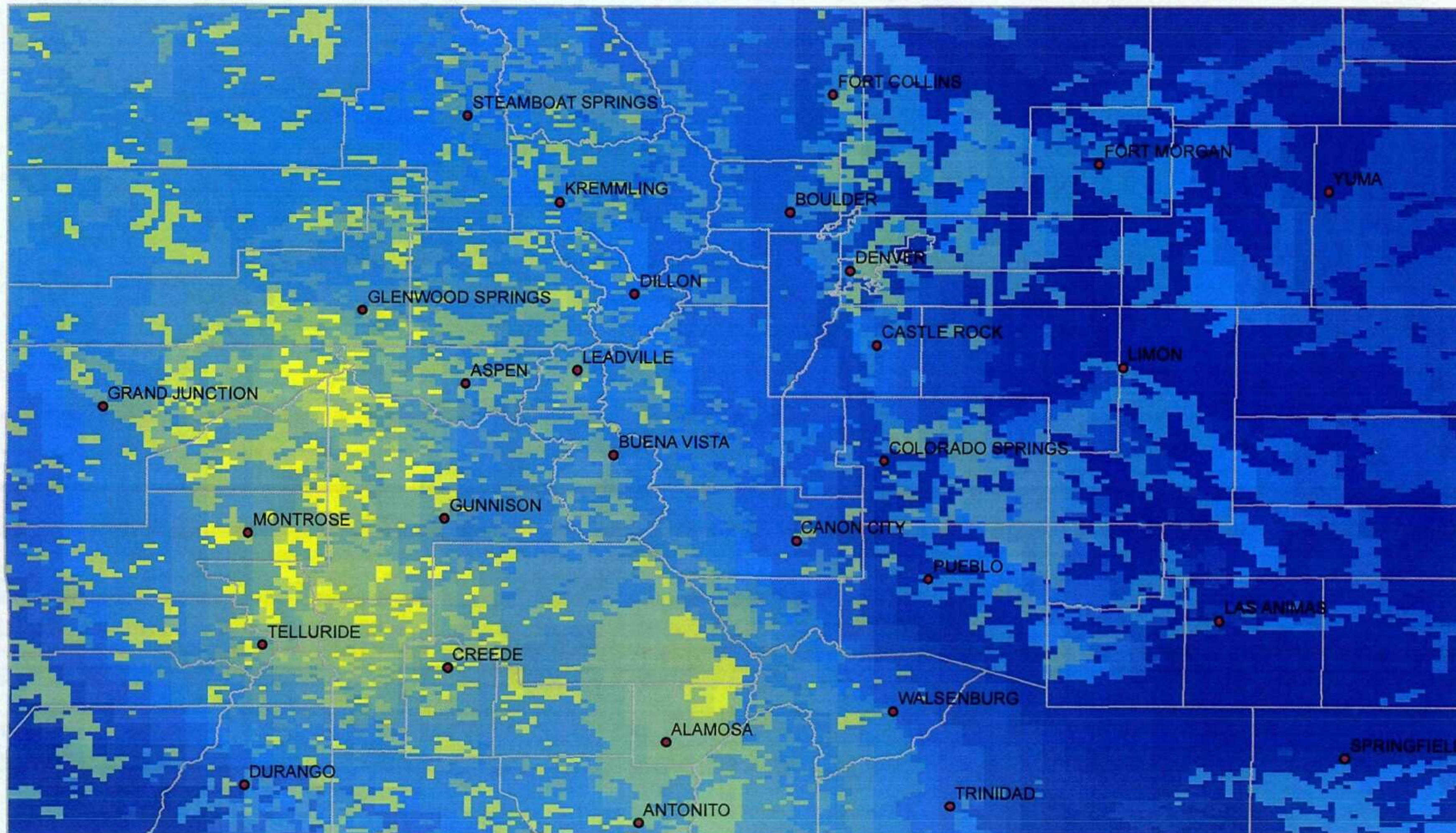


Maximum PGA = 0.34 g

$5.34 Billion, 53 fatalities over 1500-yr period

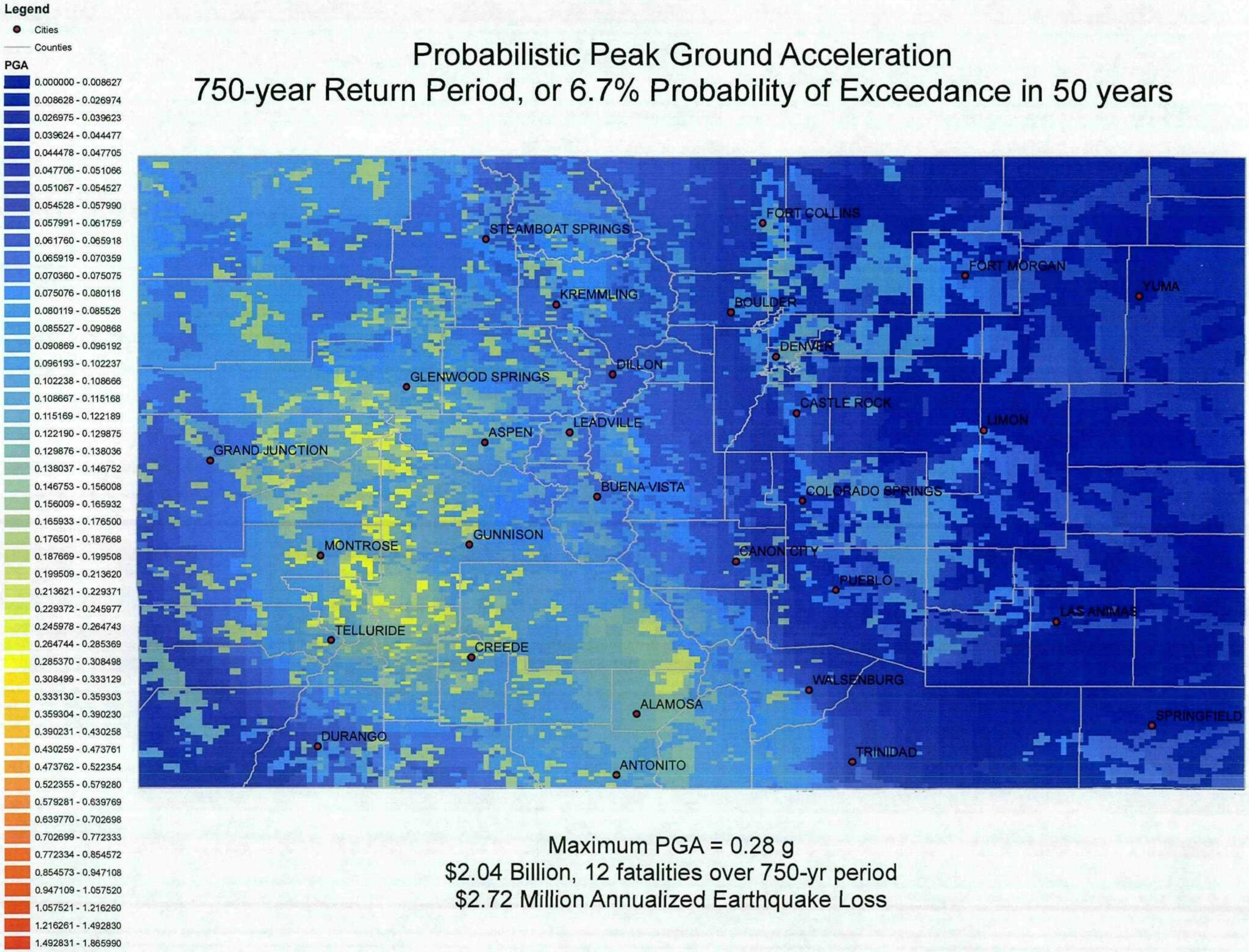
$3.56 Million Annualized Earthquake Loss

Probabilistic Peak Ground Acceleration
1000-year Return Period, or 5% Probability of Exceedance in 50 years



Maximum PGA = 0.307 g
$3.05 Billion, 21 fatalities over 1000-yr period
$3.05 Million Annualized Earthquake Loss

Probabilistic Peak Ground Acceleration
750-year Return Period, or 6.7% Probability of Exceedance in 50 years

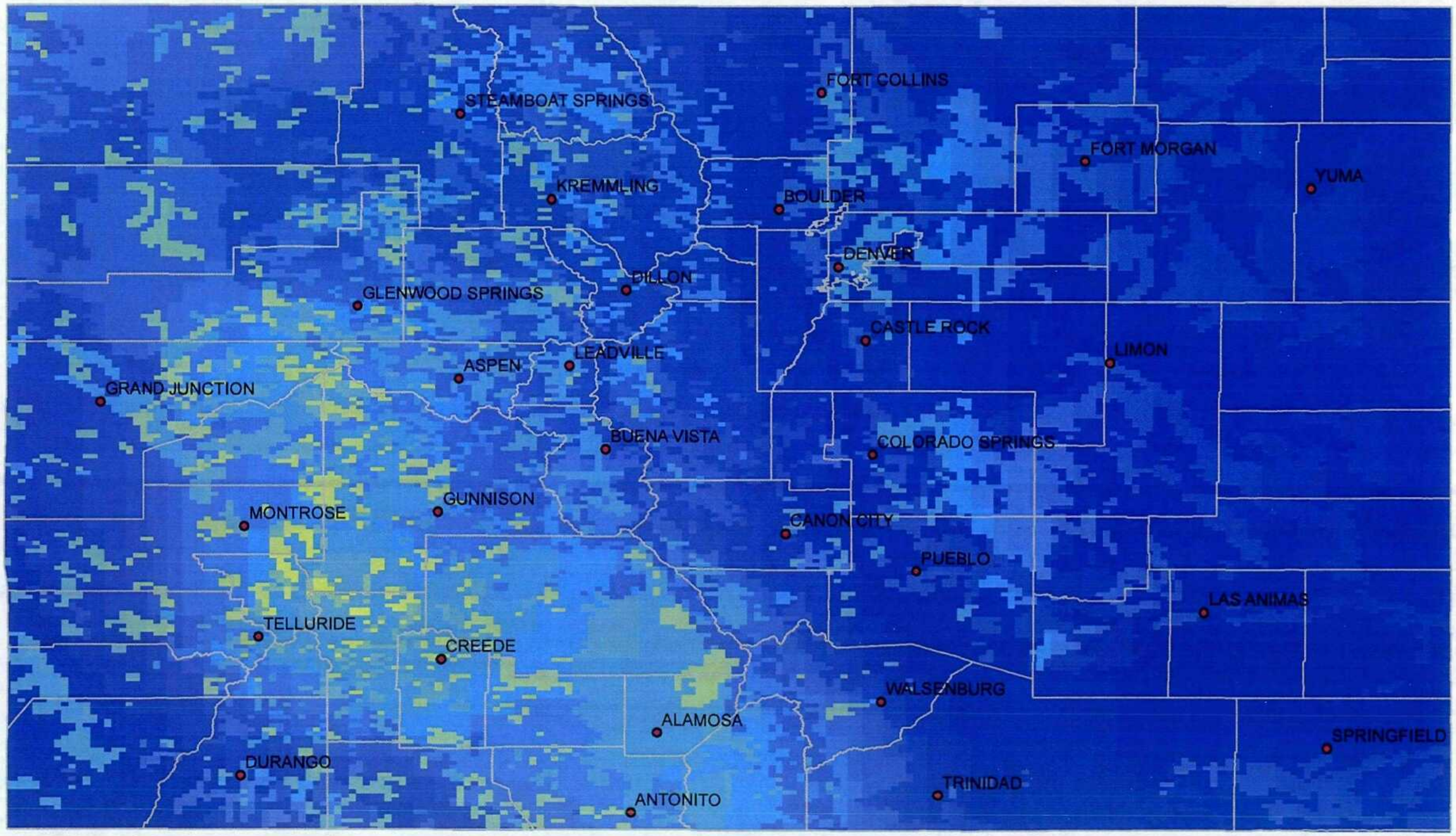


Maximum PGA = 0.28 g

$2.04 Billion, 12 fatalities over 750-yr period

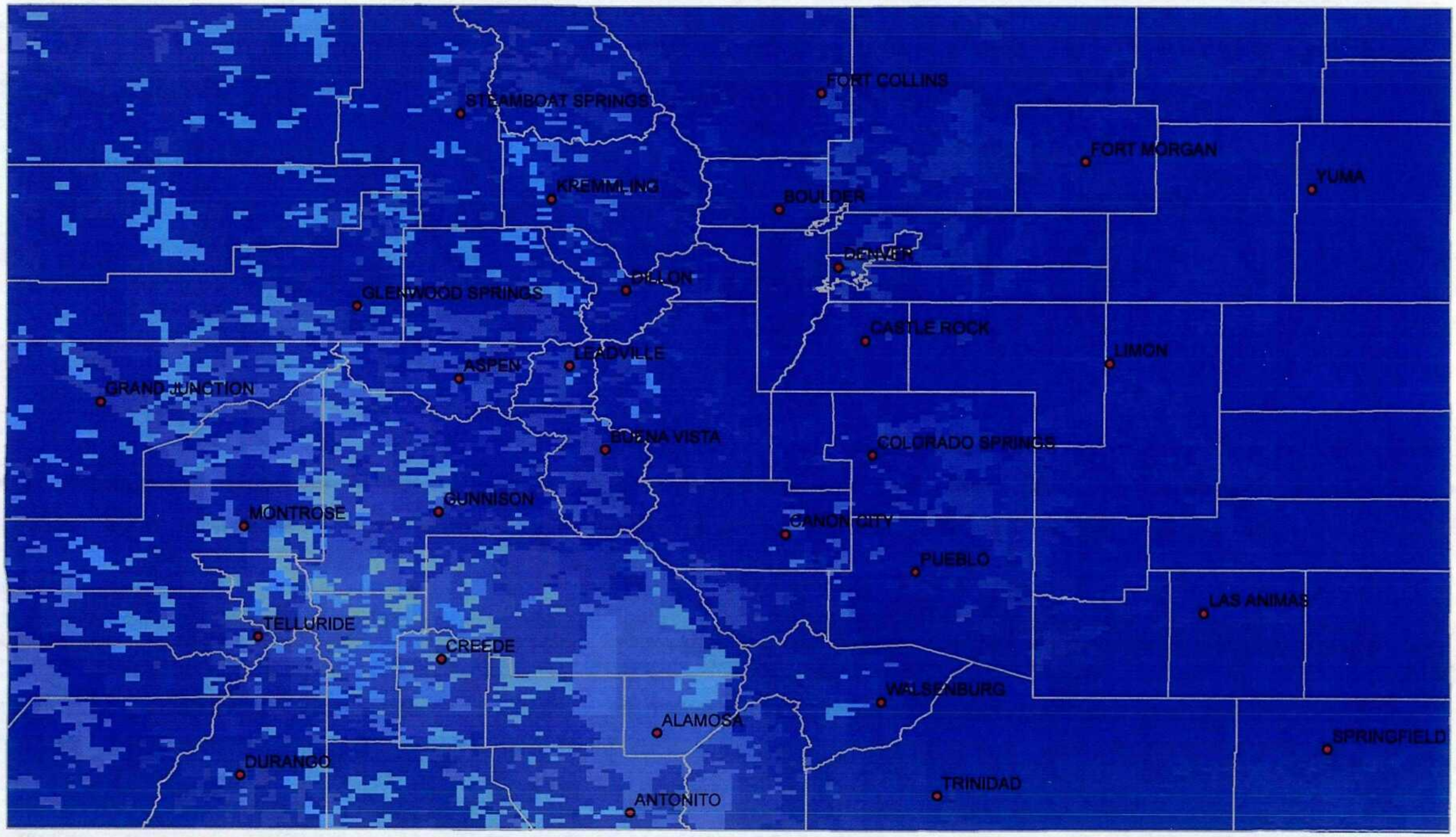
$2.72 Million Annualized Earthquake Loss

Probabilistic Peak Ground Acceleration
500-year Return Period, or 10% Probability of Exceedance in 50 years



Maximum PGA = 0.22 g
$1.03 Billion, 5 fatalities over 500-yr period
$2.06 Million Annualized Earthquake Loss

Probabilistic Peak Ground Acceleration
250-year Return Period, or 20% Probability of Exceedance in 50 years



Maximum PGA = 0.13 g
$295 Million, 1 fatality over 250-yr period
$1.18 Million Annualized Earthquake Loss

Legend

- Cities
- Counties

PGA

- 0.000000 - 0.008627
- 0.008628 - 0.026974
- 0.026975 - 0.039623
- 0.039624 - 0.044477
- 0.044478 - 0.047705
- 0.047706 - 0.051066
- 0.051067 - 0.054527
- 0.054528 - 0.057990
- 0.057991 - 0.061759
- 0.061760 - 0.065918
- 0.065919 - 0.070359
- 0.070360 - 0.075075
- 0.075076 - 0.080118
- 0.080119 - 0.085526
- 0.085527 - 0.090868
- 0.090869 - 0.096192
- 0.096193 - 0.102237
- 0.102238 - 0.108666
- 0.108667 - 0.115168
- 0.115169 - 0.122189
- 0.122190 - 0.129875
- 0.129876 - 0.138036
- 0.138037 - 0.146752
- 0.146753 - 0.156008
- 0.156009 - 0.165932
- 0.165933 - 0.176500
- 0.176501 - 0.187668
- 0.187669 - 0.199508
- 0.199509 - 0.213620
- 0.213621 - 0.229371
- 0.229372 - 0.245977
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- 0.285370 - 0.308498
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- 0.430259 - 0.473761
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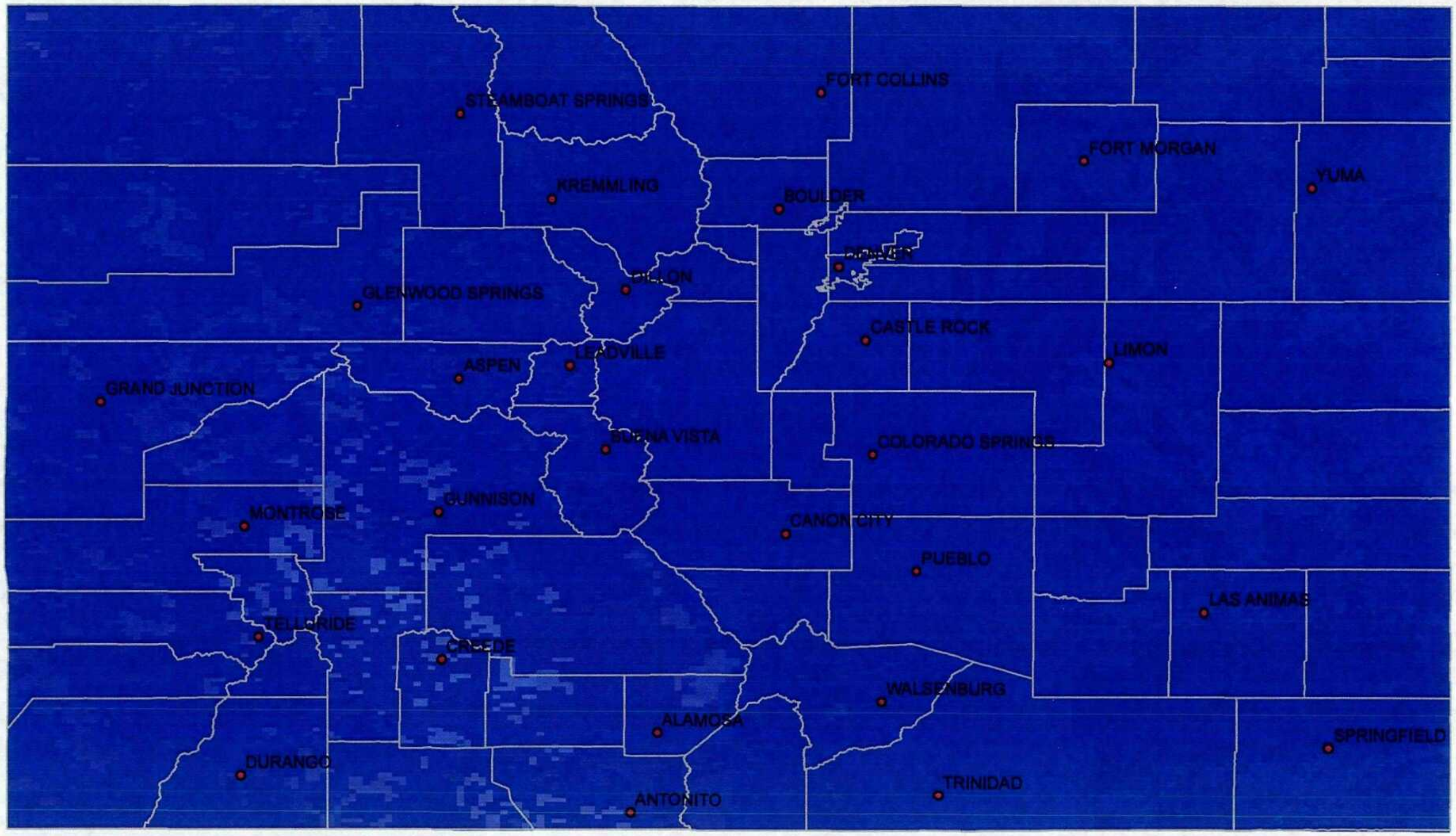
- 0.579281 - 0.639769
- 0.639770 - 0.702698
- 0.702699 - 0.772333
- 0.772334 - 0.854572
- 0.854573 - 0.947108
- 0.947109 - 1.057520
- 1.057521 - 1.216260
- 1.216261 - 1.492830
- 1.492831 - 1.865990

Probabilistic Peak Ground Acceleration
100-year Return Period, or 50% Probability of Exceedance in 50 years

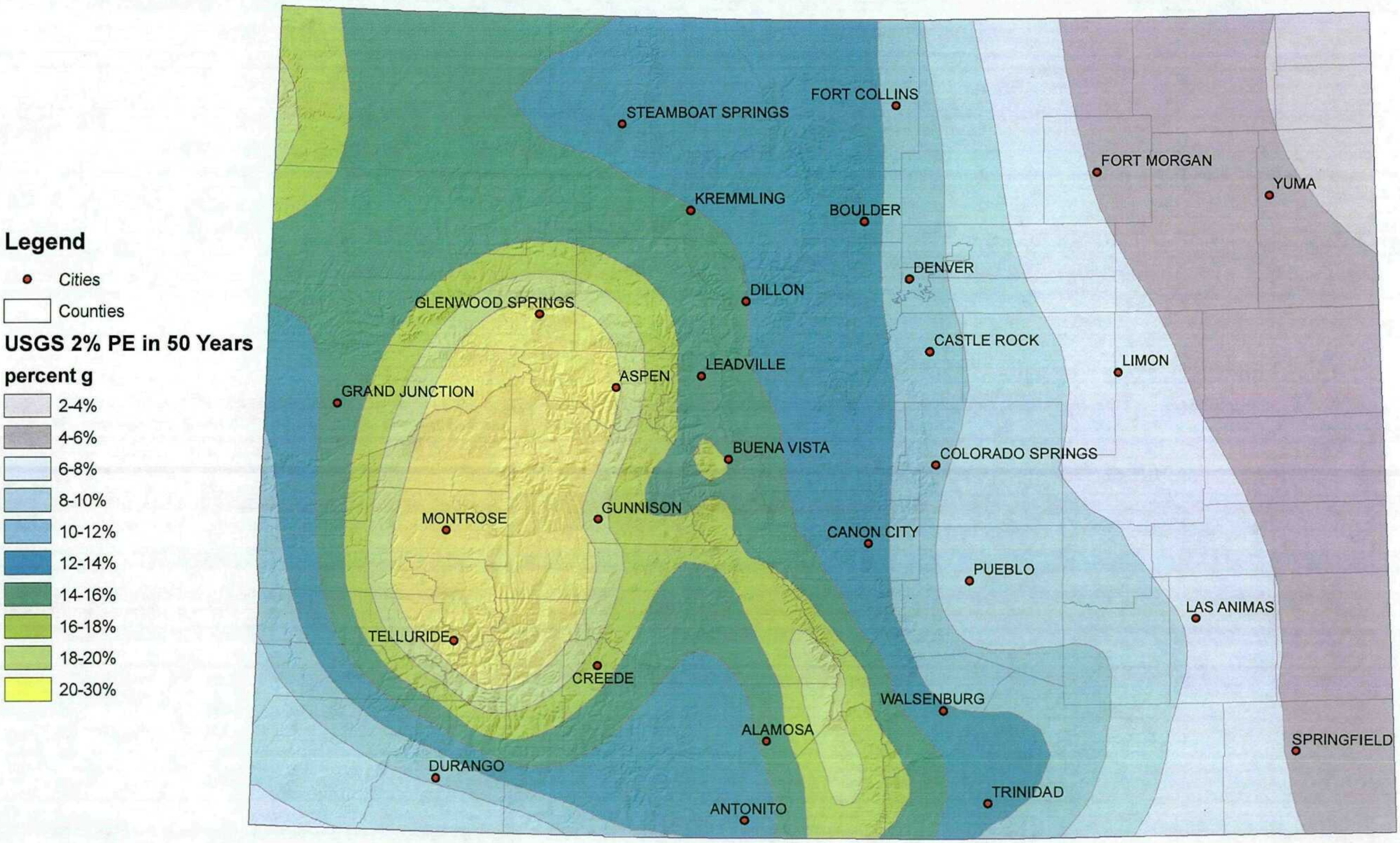


Maximum PGA = 0.06 g

$33.6 Million, 0 fatalities over 100-yr period

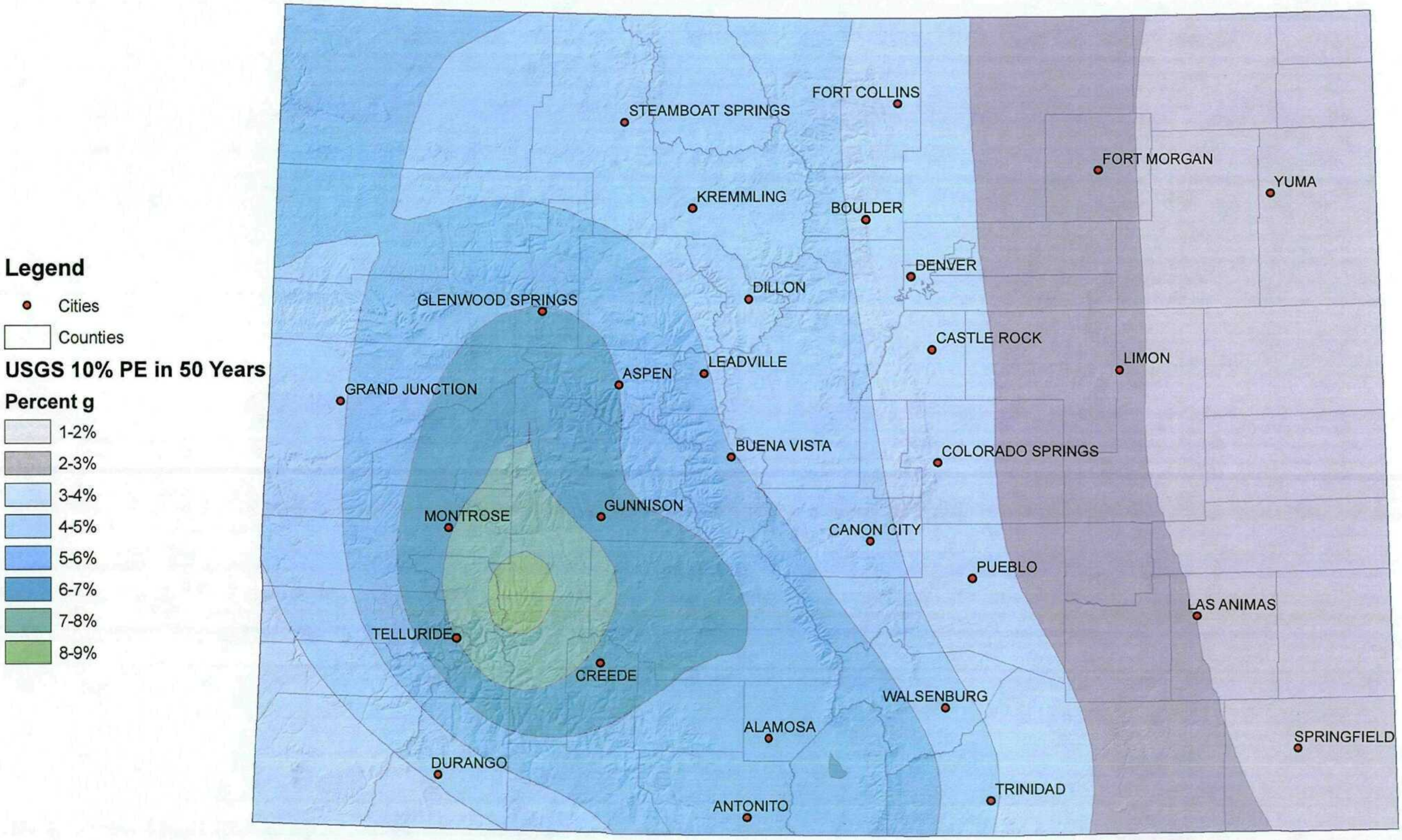
$0.34 Million Annualized Earthquake Loss

Seismic Hazard Map of Colorado
Peak Horizontal Acceleration (%g) with 2% Probability of Exceedance in 50 Years



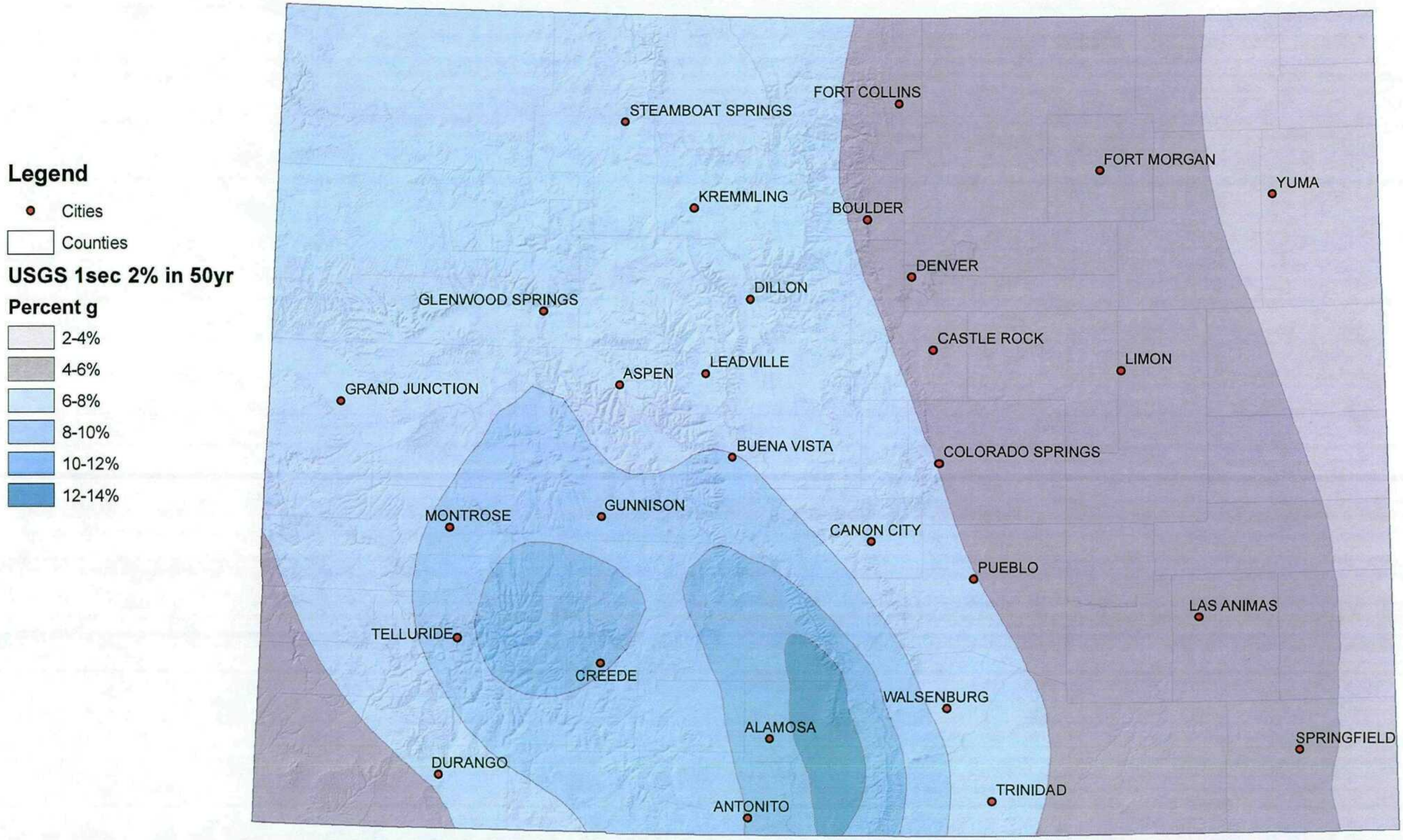
Derived from USGS National Seismic Hazard Interactive Map, 2002

Seismic Hazard Map of Colorado
Peak Horizontal Acceleration (%g) with 10% Probability of Exceedance in 50 Years



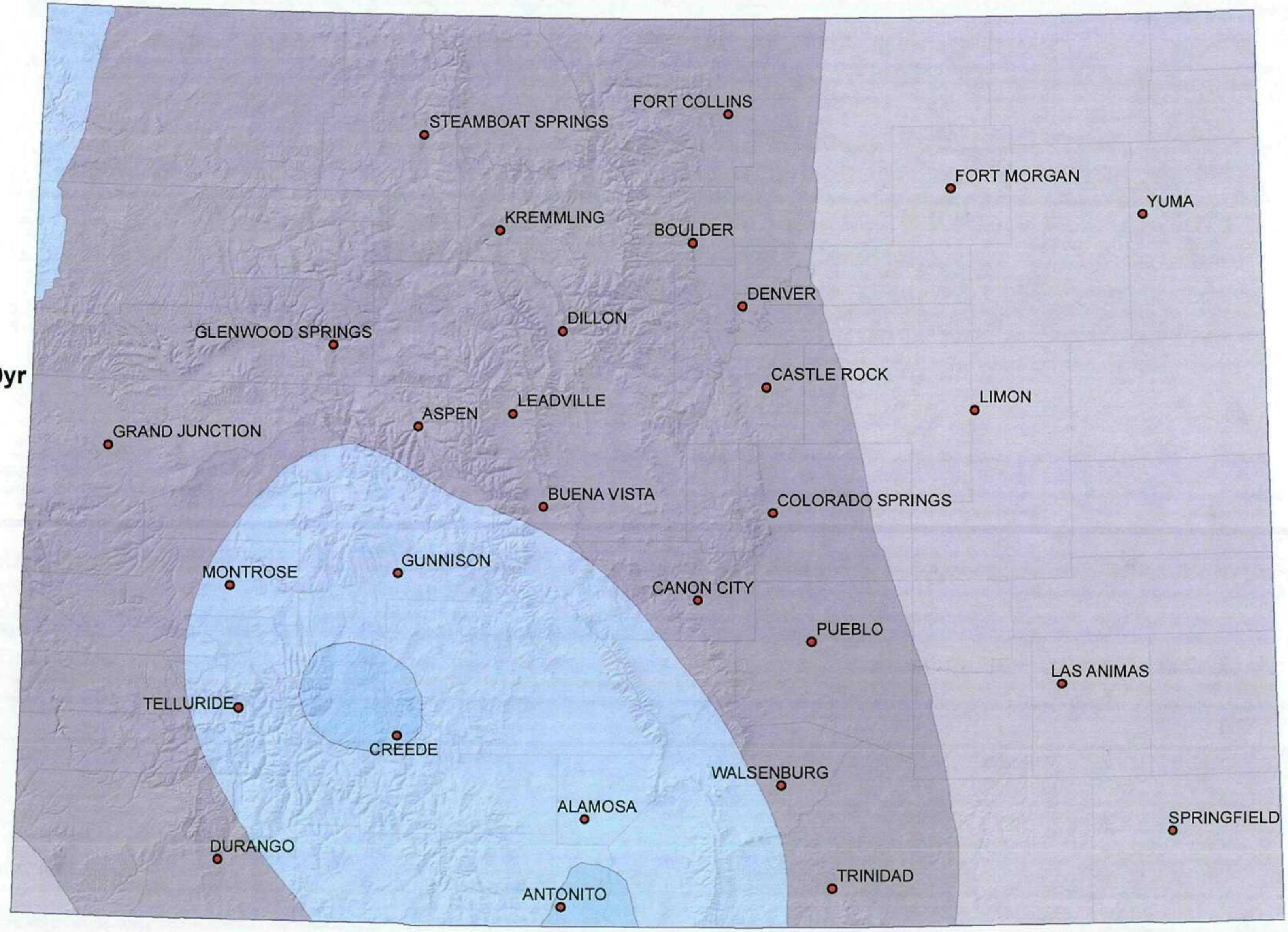
Derived from USGS National Seismic Hazard Interactive Map, 2002

Seismic Hazard Map of Colorado
1 Second Horizontal Acceleration (%g) with 2% Probability of Exceedance in 50 Years



Derived from USGS National Seismic Hazard Interactive Map, 2002

Seismic Hazard Map of Colorado
1 Second Horizontal Acceleration (%g) with 10% Probability of Exceedance in 50 Years



Legend

- Cities
- Counties

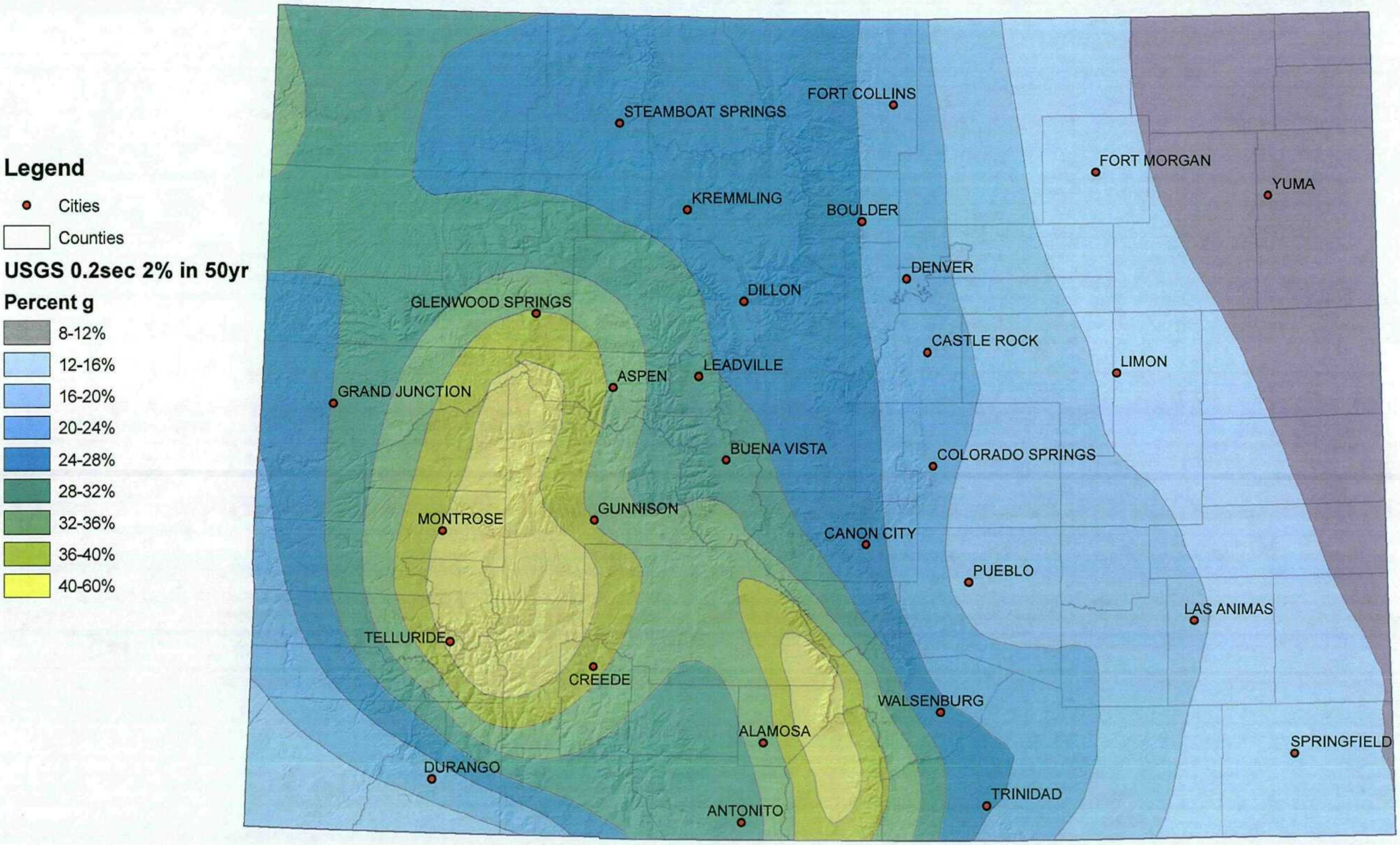
USGS 1sec 10%PE in 50yr

Percent g

- 1-2%
- 2-3%
- 3-4%
- 4-5%

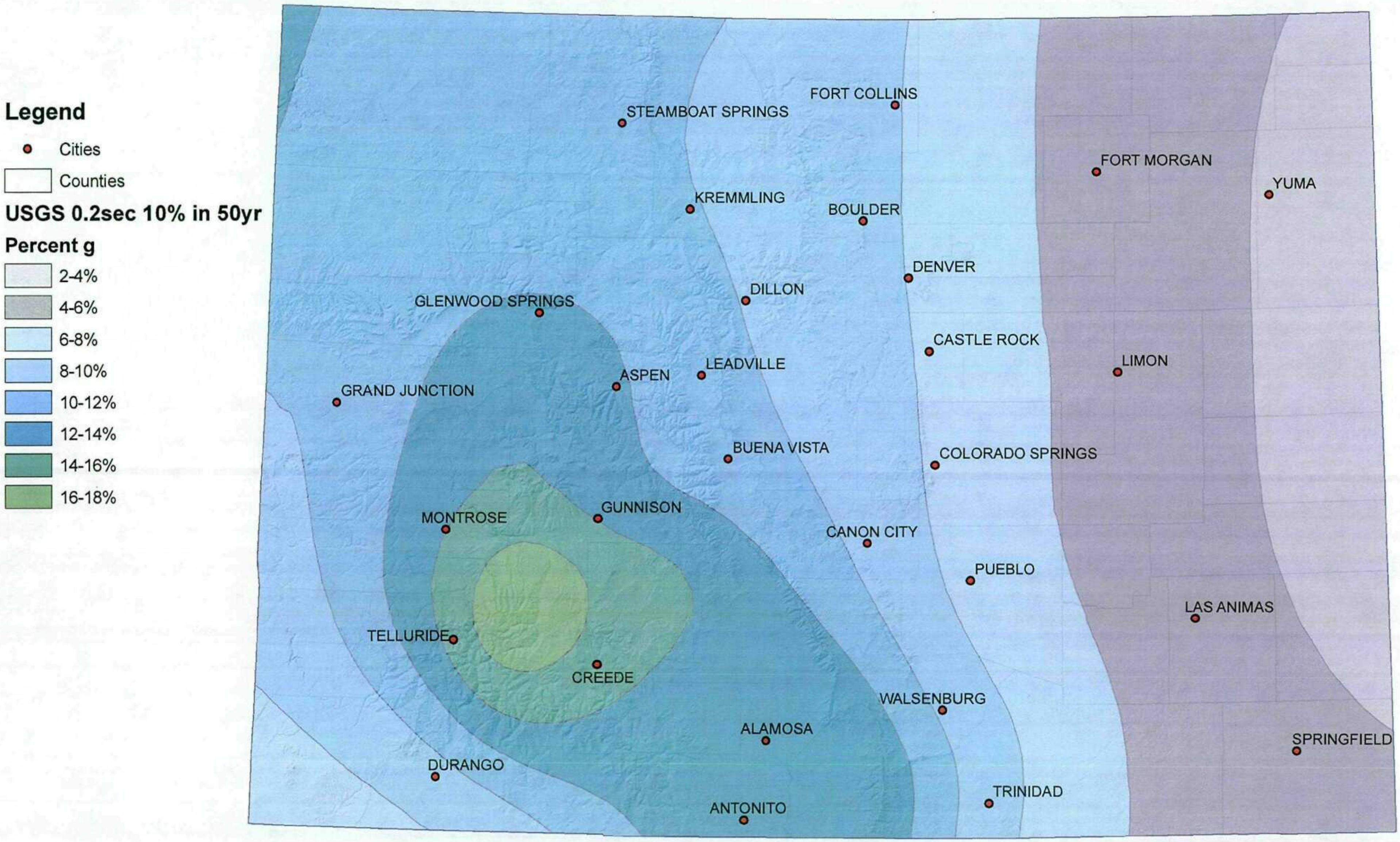
Derived from USGS National Seismic Hazard Interactive Map, 2002

Seismic Hazard Map of Colorado
0.2 Second Horizontal Acceleration (%g) with 2% Probability of Exceedance in 50 Years



Derived from USGS National Seismic Hazard Interactive Map, 2002

Seismic Hazard Map of Colorado
0.2 Second Horizontal Acceleration (%g) with 10% Probability of Exceedance in 50 Years



Derived from USGS National Seismic Hazard Interactive Map, 2002

1882 Earthquake Scenarios

PGA Maps
Intensity Maps derived from PGA

Legend

- Cities
- Counties
- 1882 Historical Epicenter

PGA

0.000000 - 0.008627
0.008628 - 0.026974
0.026975 - 0.039623
0.039624 - 0.044477
0.044478 - 0.047705
0.047706 - 0.051066
0.051067 - 0.054527
0.054528 - 0.057990
0.057991 - 0.061759
0.061760 - 0.065918
0.065919 - 0.070359
0.070360 - 0.075075
0.075076 - 0.080118
0.080119 - 0.085526
0.085527 - 0.090868
0.090869 - 0.096192
0.096193 - 0.102237
0.102238 - 0.108666
0.108667 - 0.115168
0.115169 - 0.122189
0.122190 - 0.129875
0.129876 - 0.138036
0.138037 - 0.146752
0.146753 - 0.156008
0.156009 - 0.165932
0.165933 - 0.176500
0.176501 - 0.187668
0.187669 - 0.199508
0.199509 - 0.213620
0.213621 - 0.229371
0.229372 - 0.245977
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0.264744 - 0.285369
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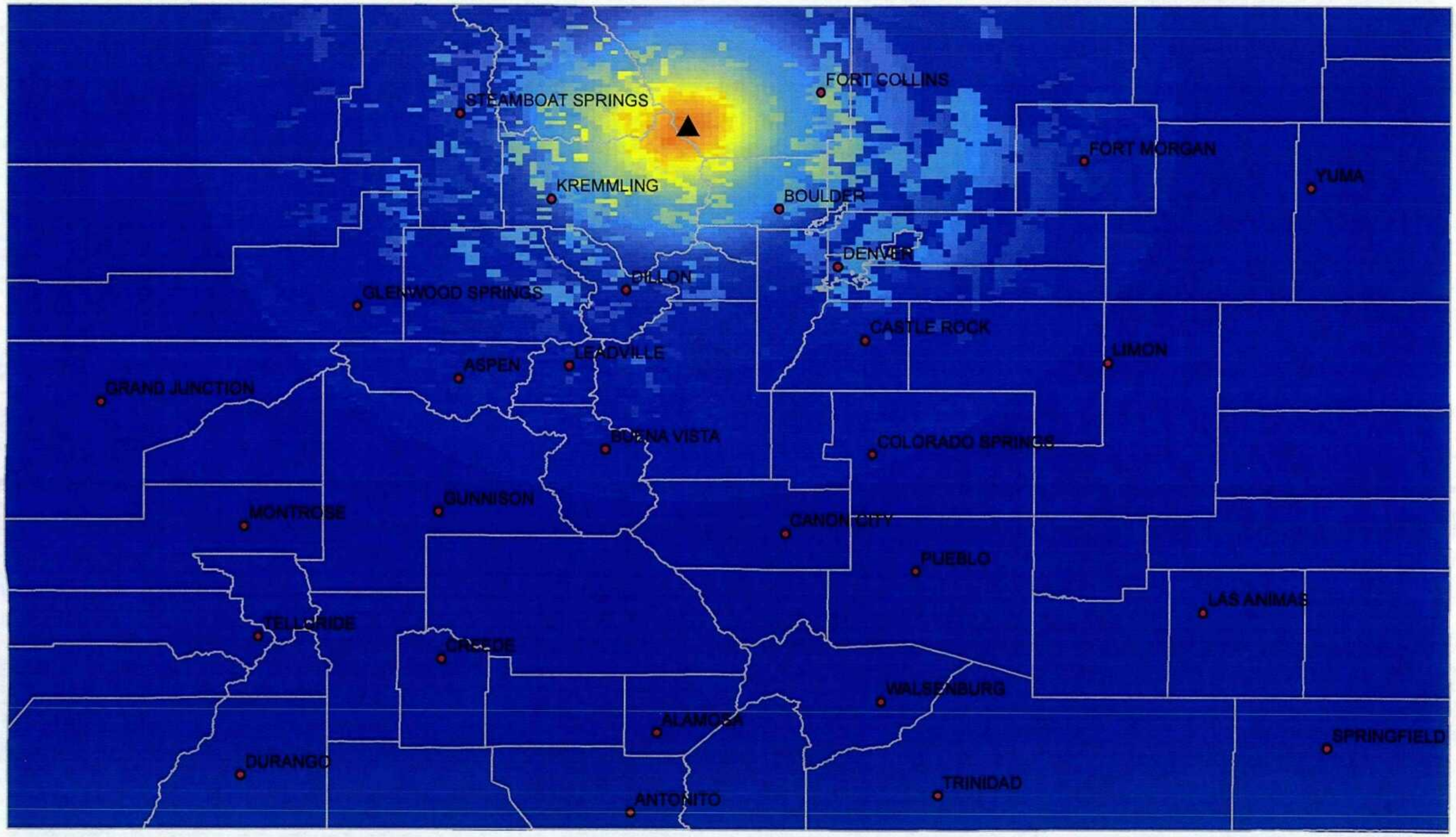
0.333130 - 0.359303
0.359304 - 0.390230
0.390231 - 0.430258
0.430259 - 0.473761
0.473762 - 0.522354
0.522355 - 0.579280
0.579281 - 0.639769
0.639770 - 0.702698
0.702699 - 0.772333
0.772334 - 0.854572
0.854573 - 0.947108
0.947109 - 1.057520
1.057521 - 1.216260
1.216261 - 1.492830
1.492831 - 1.865990

1882 Earthquake, Rocky Mountain National Park Epicenter
M 6.0, CEUS Attenuation



Epicenter 40.41 N, -105.74 W
Fault Strike N45E, Dip 60 W
Maximum PGA = 0.72 g
$950 Million, 6 fatalities

1882 Earthquake, Rocky Mountain National Park Epicenter
M 6.6, CEUS Attenuation

Legend

- ● Cities
- — Counties
- ▲ 1882 Historical Epicenter

PGA

0.000000 - 0.008627
0.008628 - 0.026974
0.026975 - 0.039623
0.039624 - 0.044477
0.044478 - 0.047705
0.047706 - 0.051066
0.051067 - 0.054527
0.054528 - 0.057990
0.057991 - 0.061759
0.061760 - 0.065918
0.065919 - 0.070359
0.070360 - 0.075075
0.075076 - 0.080118
0.080119 - 0.085526
0.085527 - 0.090868
0.090869 - 0.096192
0.096193 - 0.102237
0.102238 - 0.108666
0.108667 - 0.115168
0.115169 - 0.122189
0.122190 - 0.129875
0.129876 - 0.138036
0.138037 - 0.146752
0.146753 - 0.156008
0.156009 - 0.165932
0.165933 - 0.176500
0.176501 - 0.187668
0.187669 - 0.199508
0.199509 - 0.213620
0.213621 - 0.229371
0.229372 - 0.245977
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0.264744 - 0.285369
0.285370 - 0.308498
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0.333130 - 0.359303
0.359304 - 0.390230
0.390231 - 0.430258
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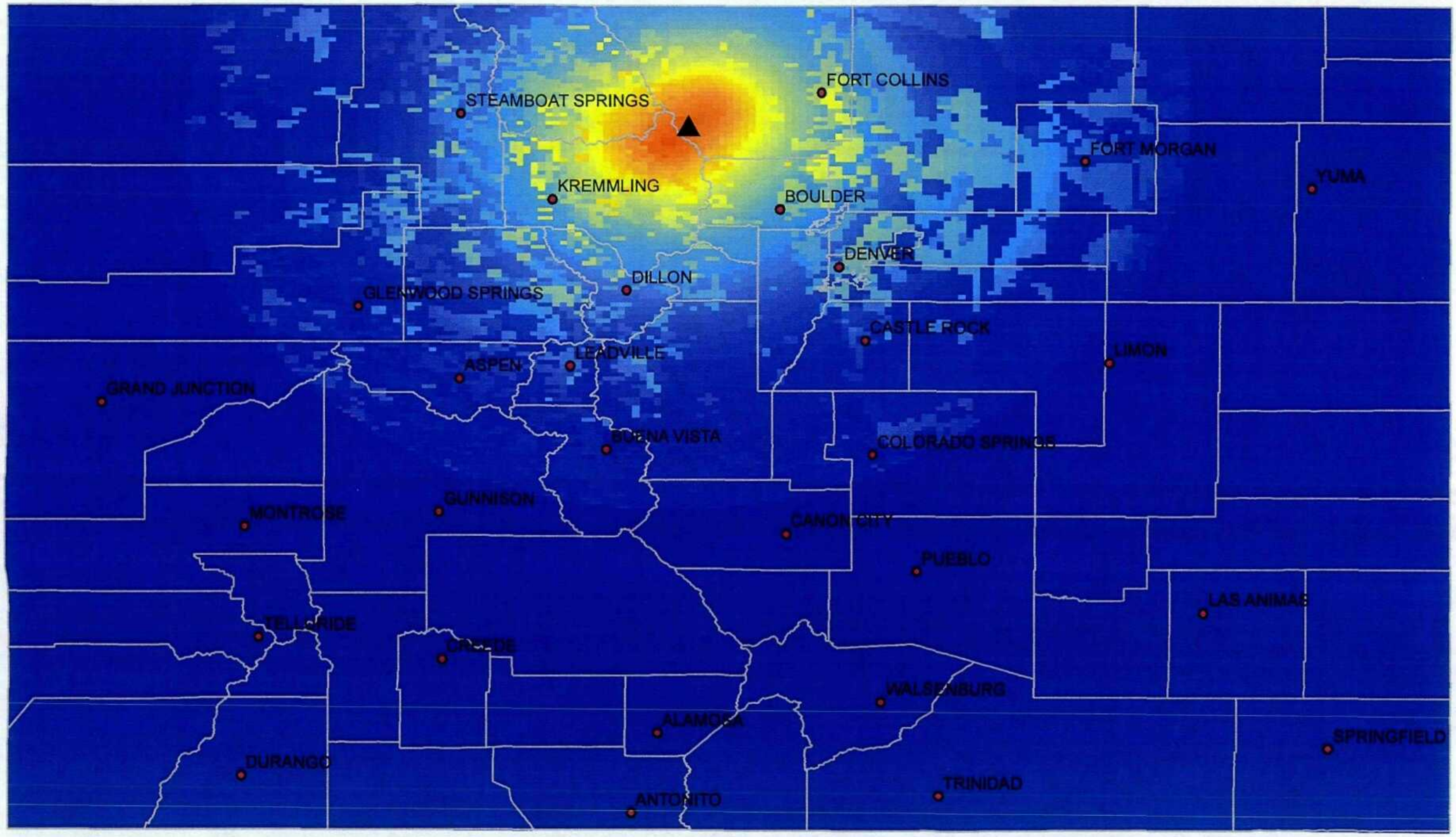
0.473762 - 0.522354
0.522355 - 0.579280
0.579281 - 0.639769
0.639770 - 0.702698
0.702699 - 0.772333
0.772334 - 0.854572
0.854573 - 0.947108
0.947109 - 1.057520
1.057521 - 1.216260
1.216261 - 1.492830
1.492831 - 1.865990



Epicenter 40.41 N, -105.74 W
Fault Strike N45E, Dip 60 W
Maximum PGA = 1.15 g
$2.76 Billion, 31 fatalities

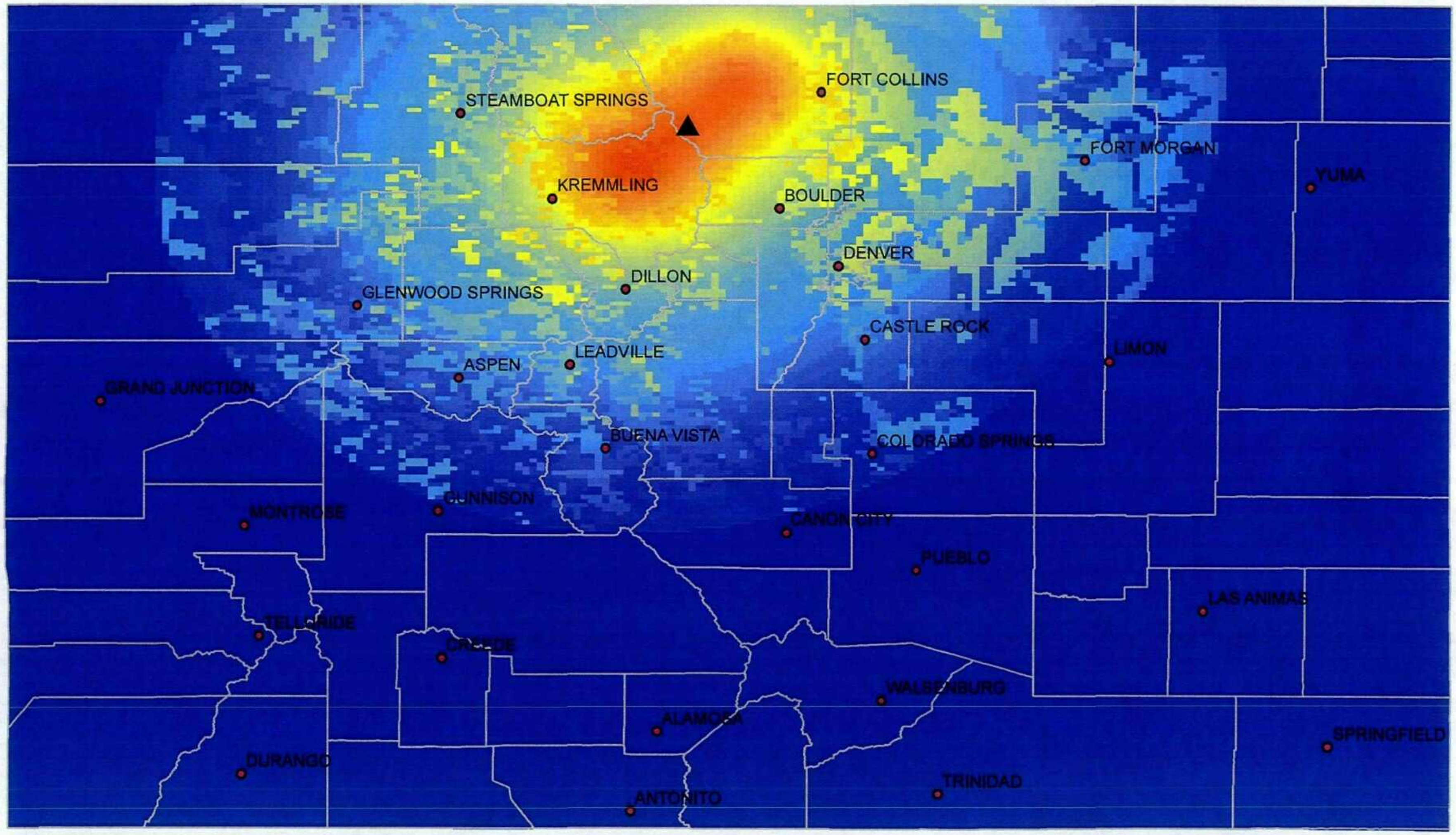
Legend

- Cities
- Counties
- 1882 Historical Epicenter

PGA

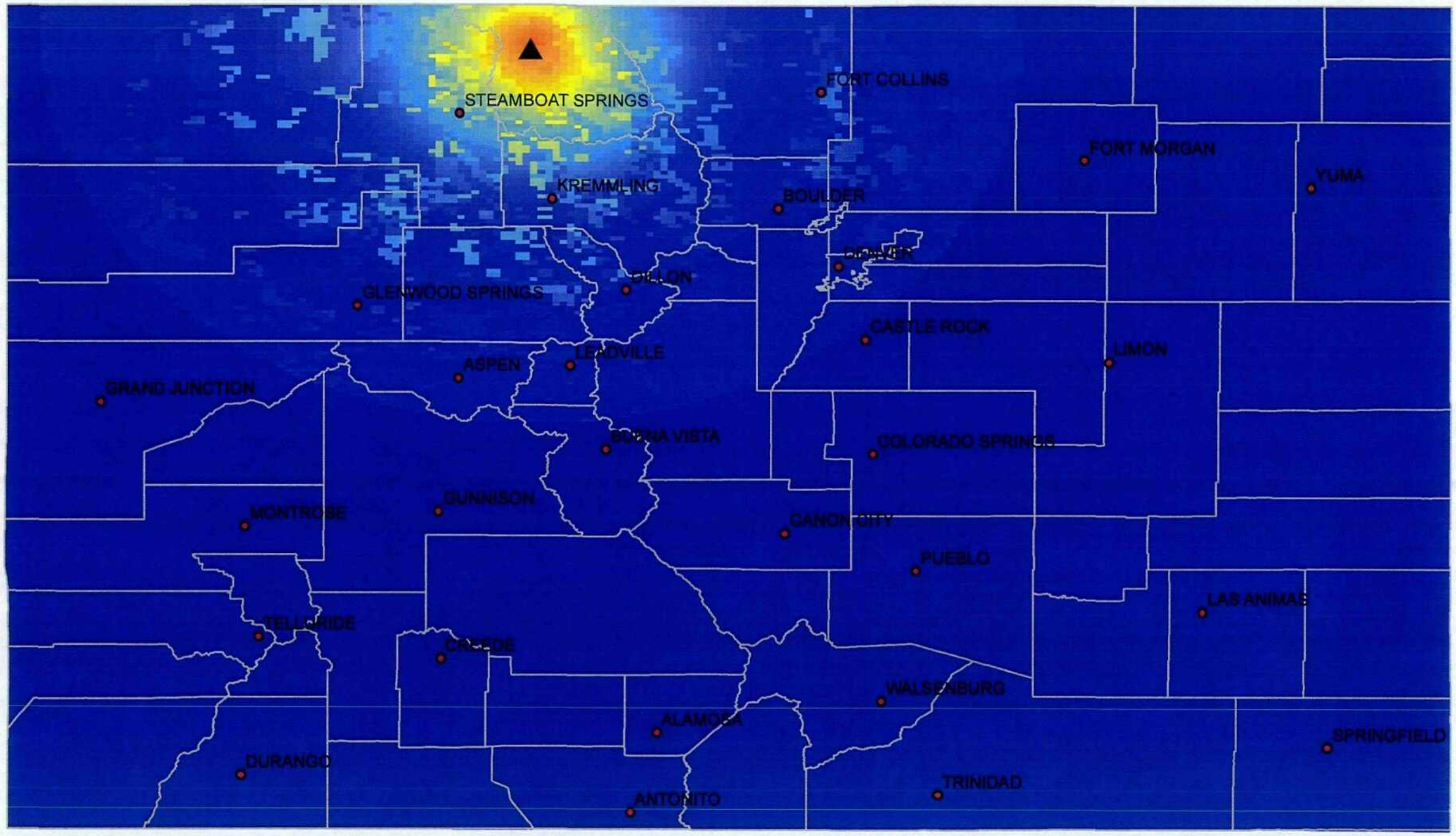
- 0.000000 - 0.008627
- 0.008628 - 0.026974
- 0.026975 - 0.039623
- 0.039624 - 0.044477
- 0.044478 - 0.047705
- 0.047706 - 0.051066
- 0.051067 - 0.054527
- 0.054528 - 0.057990
- 0.057991 - 0.061759
- 0.061760 - 0.065918
- 0.065919 - 0.070359
- 0.070360 - 0.075075
- 0.075076 - 0.080118
- 0.080119 - 0.085526
- 0.085527 - 0.090868
- 0.090869 - 0.096192
- 0.096193 - 0.102237
- 0.102238 - 0.108666
- 0.108667 - 0.115168
- 0.115169 - 0.122189
- 0.122190 - 0.129875
- 0.129876 - 0.138036
- 0.138037 - 0.146752
- 0.146753 - 0.156008
- 0.156009 - 0.165932
- 0.165933 - 0.176500
- 0.176501 - 0.187668
- 0.187669 - 0.199508
- 0.199509 - 0.213620
- 0.213621 - 0.229371
- 0.229372 - 0.245977
- 0.245978 - 0.264743
- 0.264744 - 0.285369
- 0.285370 - 0.308498
- 0.308499 - 0.333129
- 0.333130 - 0.359303
- 0.359304 - 0.390230
- 0.390231 - 0.430258
- 0.430259 - 0.473761
- 0.473762 - 0.522354
- 0.522355 - 0.579280
- 0.579281 - 0.639769
- 0.639770 - 0.702698
- 0.702699 - 0.772333
- 0.772334 - 0.854572
- 0.854573 - 0.947108
- 0.947109 - 1.057520
- 1.057521 - 1.216260
- 1.216261 - 1.492830
- 1.492831 - 1.865990

1882 Earthquake, Rocky Mountain National Park Epicenter
M 7.2, CEUS Attenuation



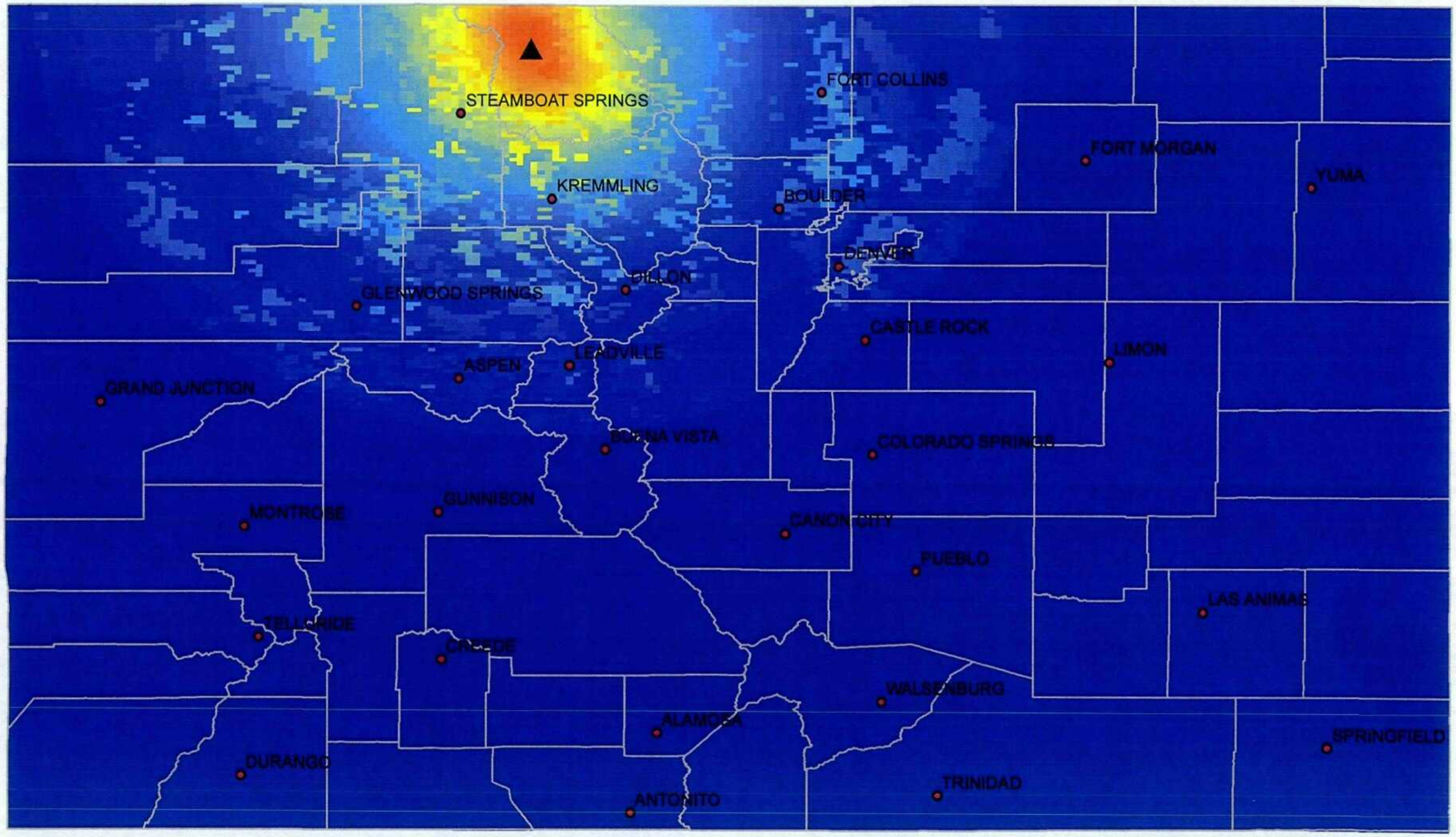
Epicenter 40.41 N, -105.74 W
Fault Strike N45E, Dip 60 W
Maximum PGA = 1.58 g
$8.98 Billion, 246 fatalities

1882 Earthquake, North Park Epicenter
M 6.0, CEUS Attenuation, 10 km Hypocenter Depth



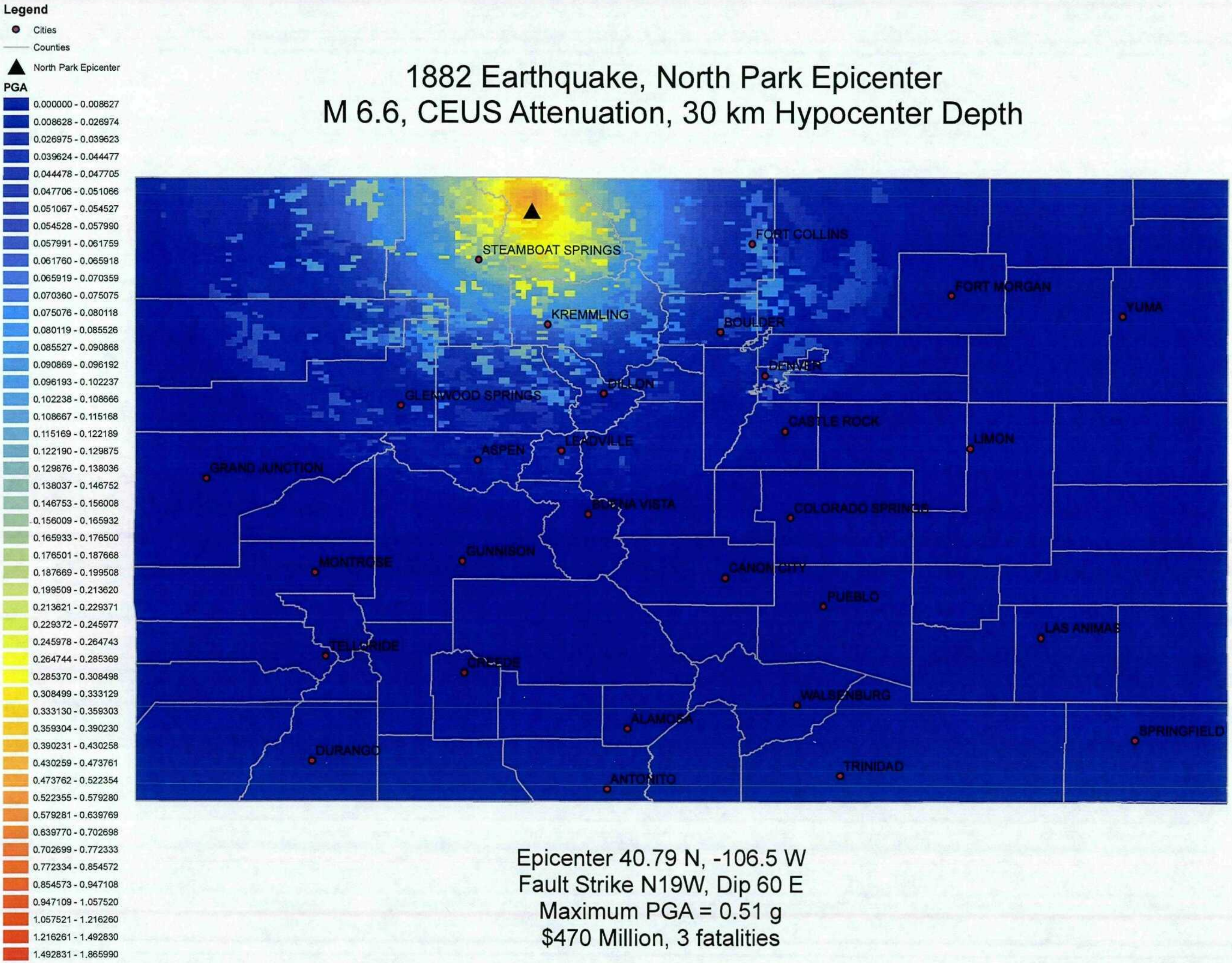
Epicenter 40.79 N, -106.5 W
Fault Strike N19W, Dip 60 E
Maximum PGA = 0.79 g
$149 Million, 1 fatality

1882 Earthquake, North Park Epicenter
M 6.6, CEUS Attenuation, 10 km Hypocenter Depth



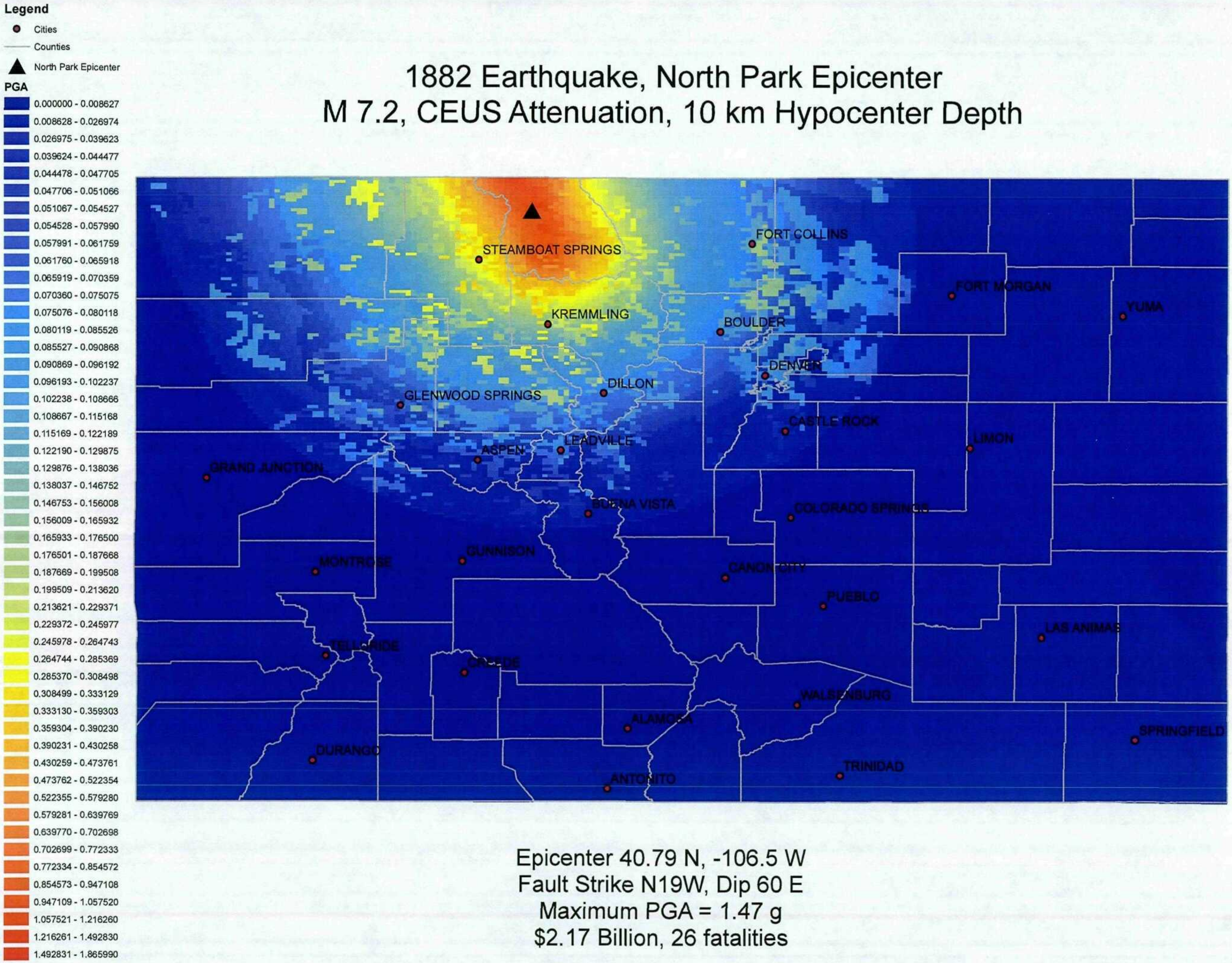
Epicenter 40.79 N, -106.5 W
Fault Strike N19W, Dip 60 E
Maximum PGA = 1.05 g
$553 Million, 3 fatalities

1882 Earthquake, North Park Epicenter
M 6.6, CEUS Attenuation, 30 km Hypocenter Depth



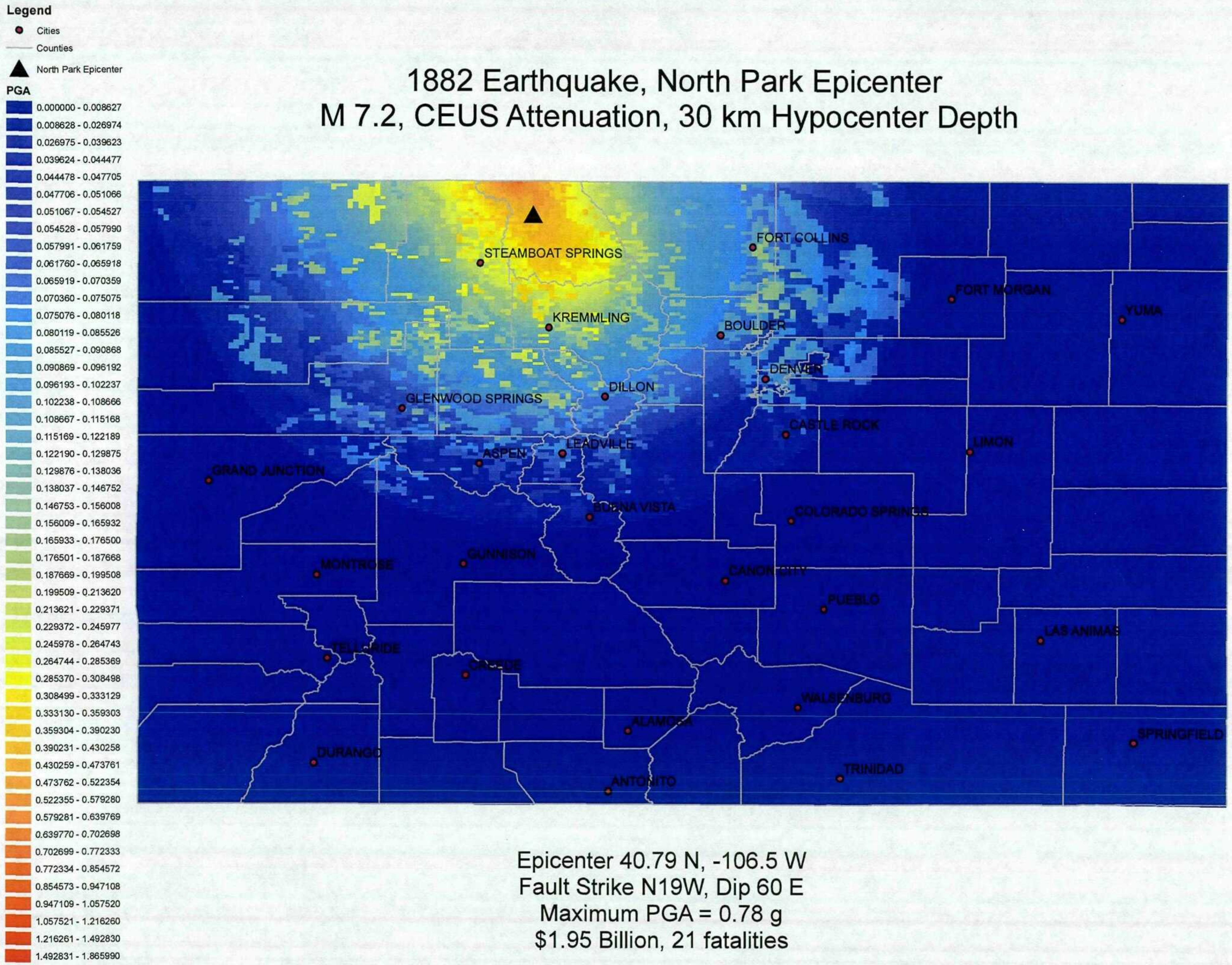
Epicenter 40.79 N, -106.5 W
Fault Strike N19W, Dip 60 E
Maximum PGA = 0.51 g
$470 Million, 3 fatalities

1882 Earthquake, North Park Epicenter
M 7.2, CEUS Attenuation, 10 km Hypocenter Depth



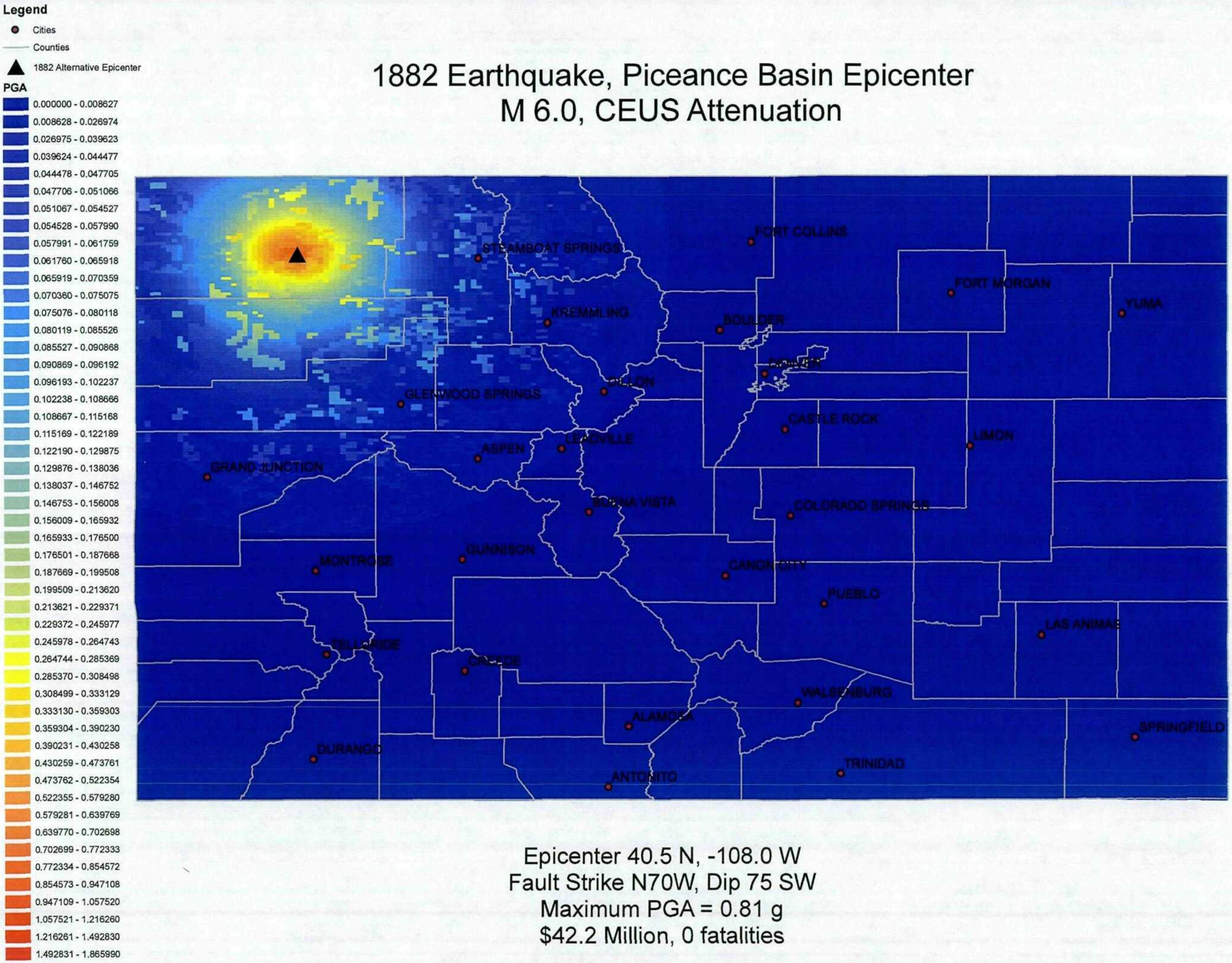
Epicenter 40.79 N, -106.5 W
Fault Strike N19W, Dip 60 E
Maximum PGA = 1.47 g
$2.17 Billion, 26 fatalities

1882 Earthquake, North Park Epicenter
M 7.2, CEUS Attenuation, 30 km Hypocenter Depth



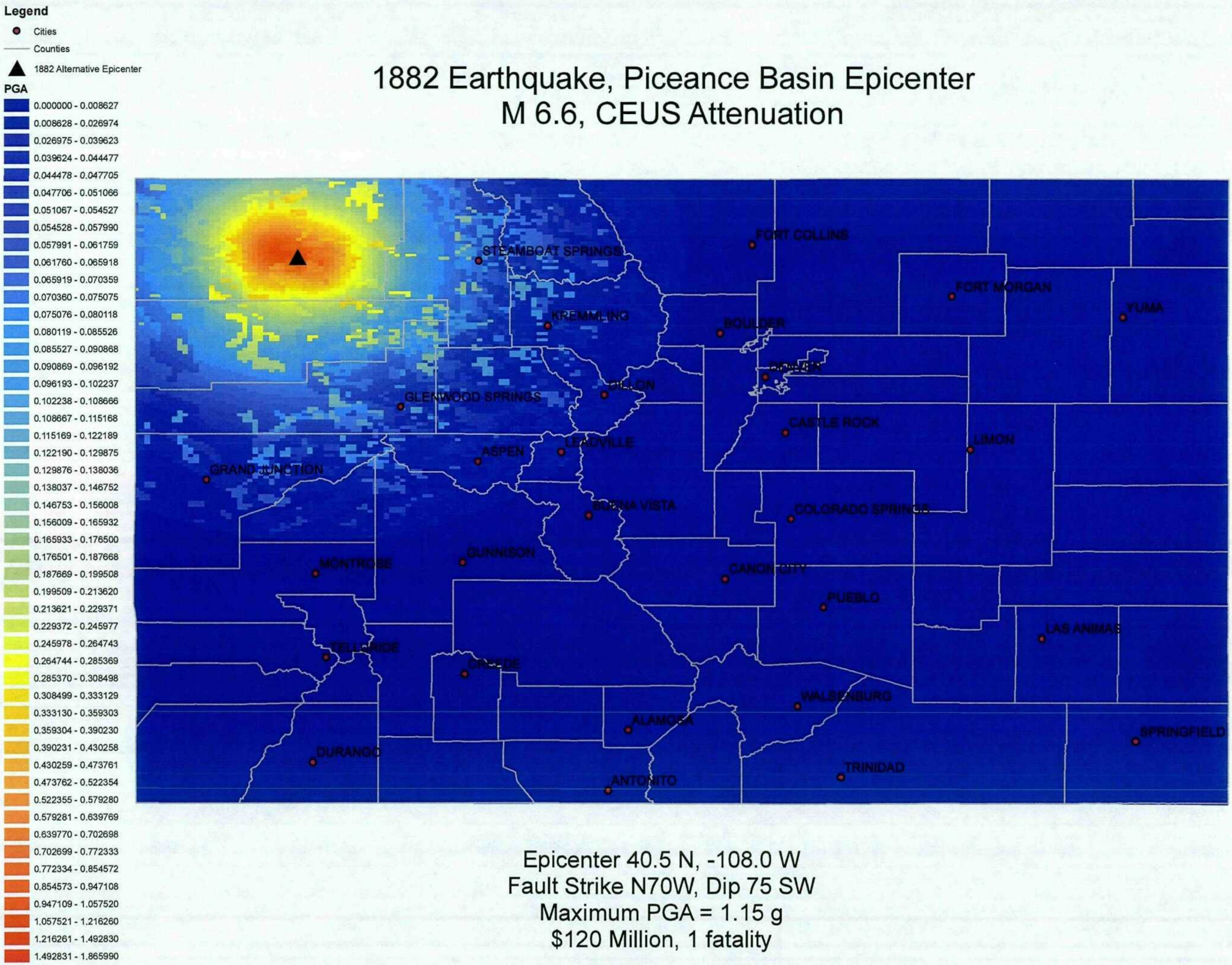
Epicenter 40.79 N, -106.5 W
Fault Strike N19W, Dip 60 E
Maximum PGA = 0.78 g
$1.95 Billion, 21 fatalities

1882 Earthquake, Piceance Basin Epicenter
M 6.0, CEUS Attenuation



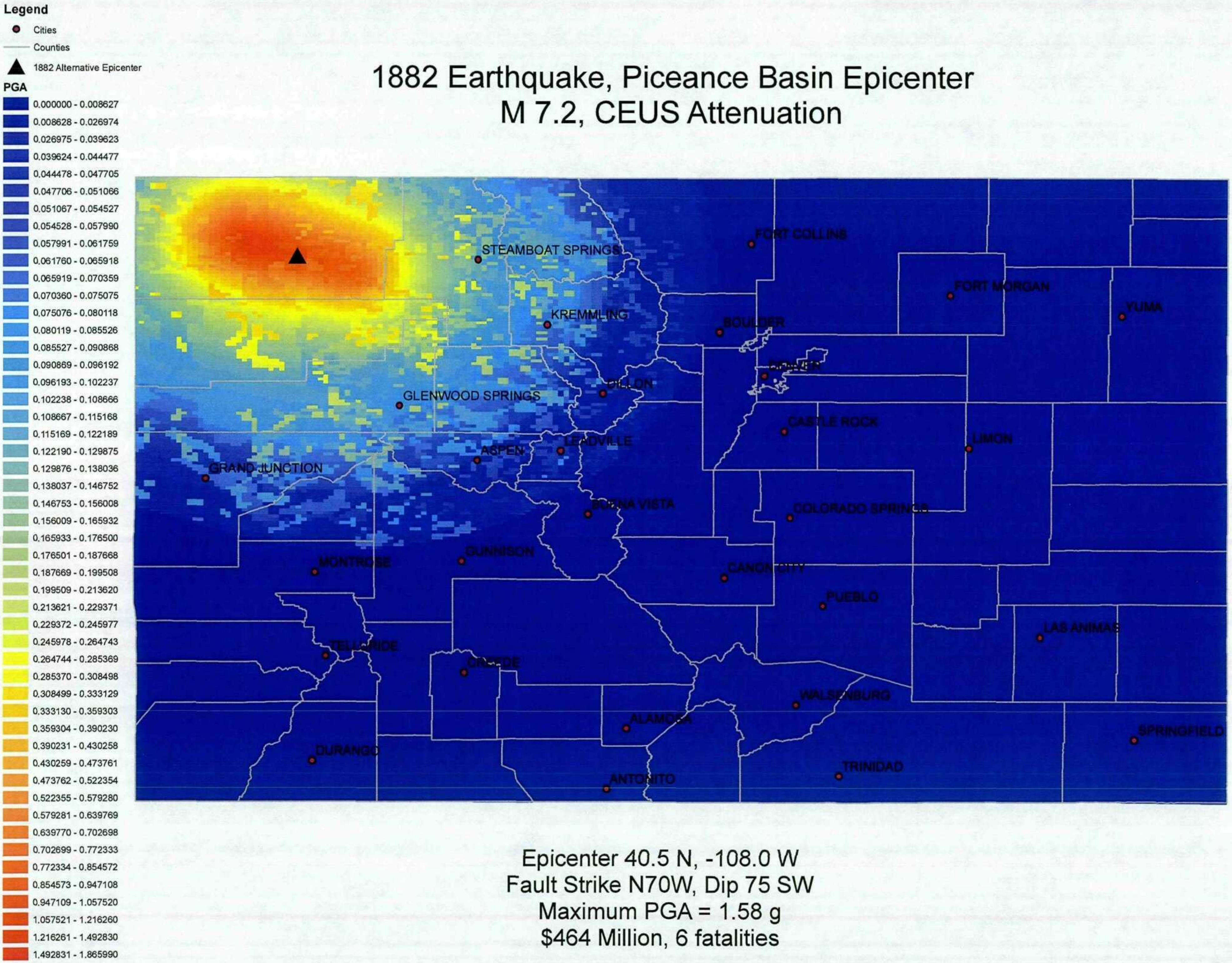
Epicenter 40.5 N, -108.0 W
Fault Strike N70W, Dip 75 SW
Maximum PGA = 0.81 g
$42.2 Million, 0 fatalities

1882 Earthquake, Piceance Basin Epicenter
M 6.6, CEUS Attenuation



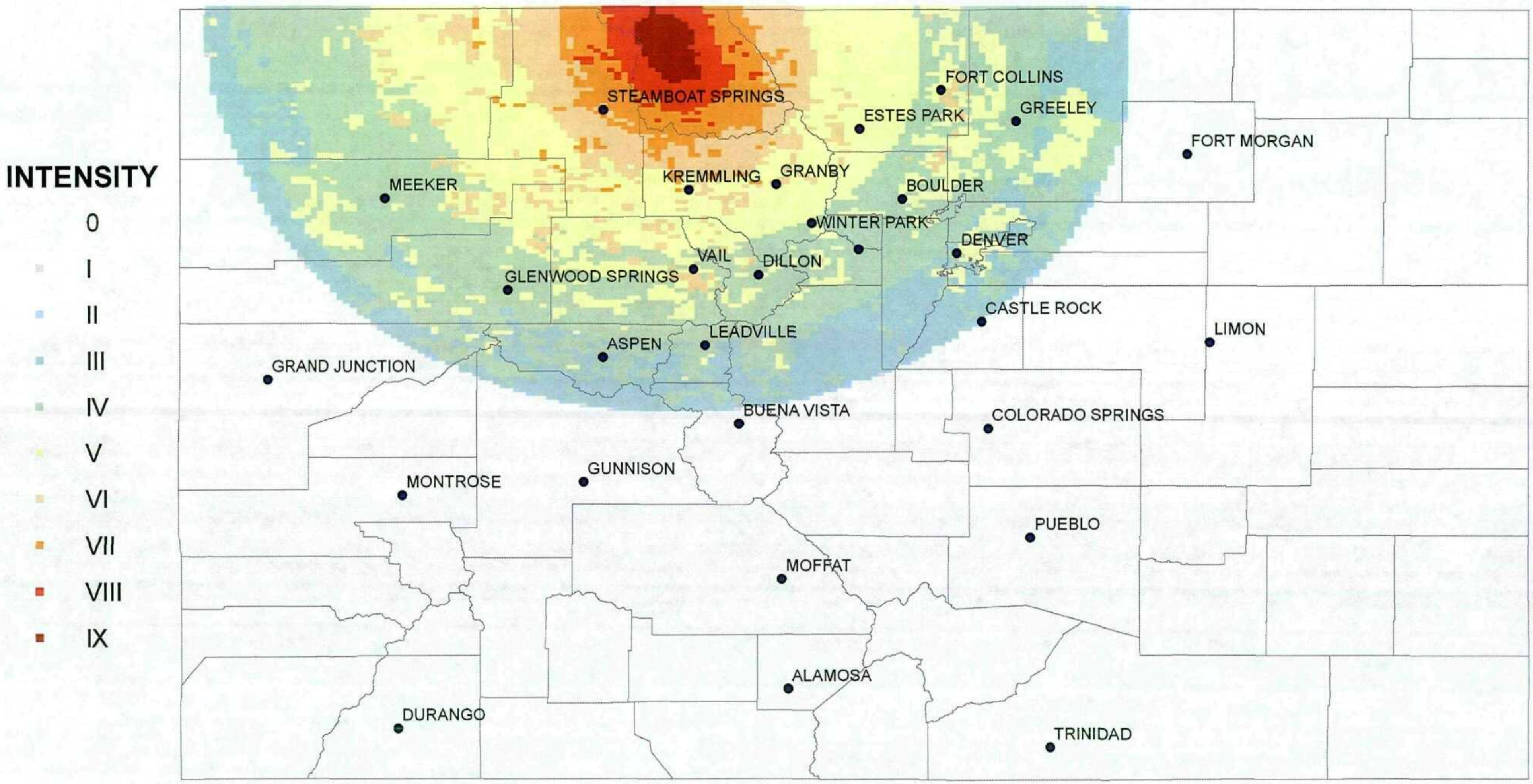
Epicenter 40.5 N, -108.0 W
Fault Strike N70W, Dip 75 SW
Maximum PGA = 1.15 g
$120 Million, 1 fatality

1882 Earthquake, Piceance Basin Epicenter
M 7.2, CEUS Attenuation

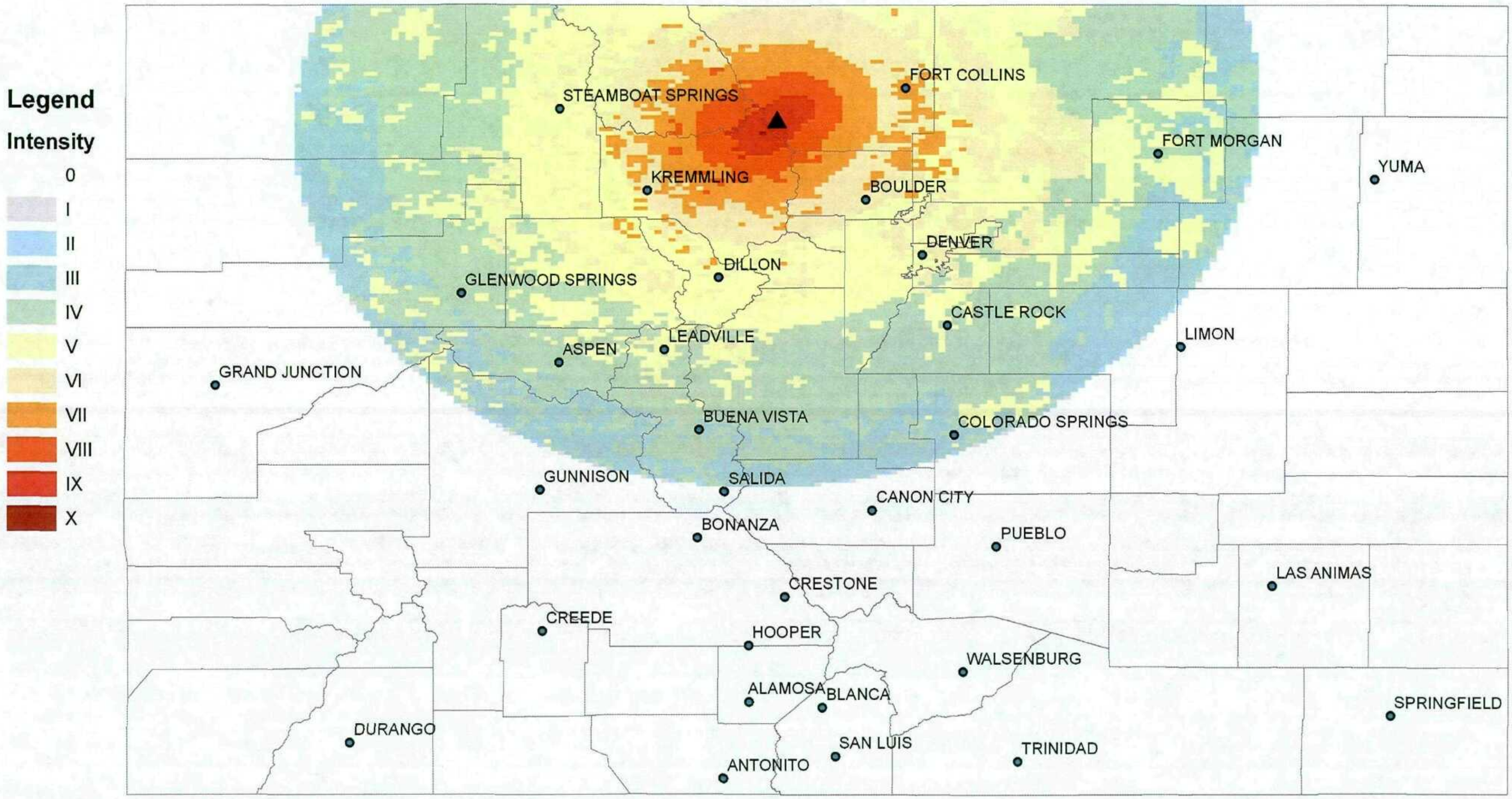


Epicenter 40.5 N, -108.0 W
Fault Strike N70W, Dip 75 SW
Maximum PGA = 1.58 g
$464 Million, 6 fatalities

Modified Mercalli Intensity Map Derived from Hazus PGA Values
1882 M6.6 North Park Epicenter



Modified Mercalli Intensity Map Derived from Hazus PGA Values
1882 M6.6 Rocky Mountain National Park Epicenter



County Scenarios

Worst-Case Results
Random EQ Results
Spreadsheet of all Scenarios

COLORADO GEOLOGICAL SURVEY

County Worst-Case Scenarios Ranked by Loss Ratio

Rank	County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)
1	Summit	Frontal	7.00	1,345.36	32.15%
2	Chaffee	S Sawatch	7.25	665.16	28.26%
3	El Paso	Rampart	7.00	9,013.76	27.67%
4	Lake	N Sawatch	7.00	302.50	27.53%
5	Lake	Mosquito	7.00	298.86	27.20%
6	Teller	Ute Pass	7.00	523.85	26.83%
7	Summit	Mosquito	7.00	1,056.71	25.26%
8	El Paso	Ute Pass	7.00	8,216.92	25.23%
9	Alamosa	N Sangre de Cristo	7.5 CEUS	433.09	23.54%
10	Denver	Golden	6.50	7,510.48	19.24%
11	Chaffee	N Sangre de Cristo	7.5 CEUS	425.76	18.09%
12	Jefferson	Golden	6.50	5,881.32	16.42%
13	Custer	N Sangre de Cristo	7.5 CEUS	138.38	15.77%
14	Adams	Rocky Mtn Arsenal	6.25	3,148.06	14.97%
15	Denver	Rocky Mtn Arsenal	6.25	5,557.58	14.24%
16	Otero	Cheraw	7.00	415.54	14.16%
17	Douglas	Rampart	7.00	1,848.03	13.49%
18	Ouray	Busted Boiler	6.50	104.19	13.33%
19	Montrose	Cimarron	6.75	497.40	13.18%
20	Arapahoe	Golden	6.50	3,900.99	12.10%
21	Denver	Rampart	7.00	4,652.06	11.92%
22	Arapahoe	Rampart	7.00	3,835.78	11.90%
23	Eagle	Frontal	7.00	571.47	11.40%
24	Fremont	N Sangre de Cristo	7.5 CEUS	393.64	10.47%
25	Hinsdale	Cannibal	7.00	35.15	10.12%

Loss Ratio = Scenario Economic Loss / Region's Total Inventory x 100

Loss Ratio presents a more *relative* view of a disaster's impact upon a community than dollar amounts alone. $500 Million loss in Denver County is a very different situation than $500 Million loss in Ouray County...

EQ SUMMARY FOR REPORT

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Adams	Random	6.50	853.52	4.06%	12,185 (12%)	105	931	246	1,013	923
Adams	Golden	6.50	1,589.25	7.56%	21,656 (21%)	257	2,194	597	0	5,691
Adams	Rocky Mtn Arsenal	6.25	3,148.06	14.97%	34,723 (34%)	623	4,764	1,231	811	80,388
Alamosa	Random	6.5 WUS	152.22	8.28%	1,628 (35%)	15	144	40	316	0
Alamosa	N Sangre de Cristo	7.5 WUS	142.06	7.72%	1,342 (29%)	19	137	37	51	0
Arapahoe	Random	6.50	2,350.41	7.29%	28,526 (19%)	317	4,927	1,197	0	1,126
Arapahoe	Golden	6.50	3,900.99	12.10%	42,239 (28%)	885	9,835	2,373	190	4,752
Arapahoe	Rampart	7.00	3,835.78	11.90%	42,105 (28%)	892	9,250	2,191	374	0
Archuleta	Random	6.50	341.25	17.51%	2,110 (44%)	16	129	30	11	2,723
Archuleta	Cannibal	7.00	42.09	2.16%	461 (10%)	1	10	2	0	0
Baca	Random	6.50	119.80	6.54%	1,011 (53%)	8	68	14	112	1,725
Baca	Cheraw	7.00	2.14	0.12%	42 (2%)	0	0	0	0	0
Bent	Random	6.50	72.32	6.69%	826 (44%)	7	49	12	0	1,787
Bent	Cheraw	7.00	18.08	1.67%	192 (10%)	0	3	0	0	0
Boulder	Random	6.50	3,282.58	15.83%	28,018 (30%)	434	5,290	1,267	315	55,571
Boulder	Golden	6.50	1,489.54	7.18%	15,073 (16%)	136	1,880	445	0	7,554
Chaffee	Random	6.50	288.32	12.25%	2,770 (39%)	17	132	32	2	3,302
Chaffee	S Sawatch	7.25	665.16	28.26%	5,321 (76%)	121	919	233	1,953	6,057
Chaffee	N Sangre de Cristo	7.50	425.76	18.09%	3,935 (56%)	134	759	195	2,207	2,061
Cheyenne	Random	6.50	51.12	3.52%	427 (45%)	2	15	2	0	786
Cheyenne	Cheraw	7.00	8.57	0.59%	35 (4%)	0	0	0	0	0
Clear Creek	Random	6.50	175.44	10.74%	1,483 (33%)	11	64	13	0	3,337
Clear Creek	Golden	6.50	42.88	2.63%	342 (8%)	1	6	1	0	0
Conejos	Random	6.5 WUS	26.37	2.27%	656 (21%)	1	10	2	0	0
Conejos	N Sangre de Cristo	7.5 WUS	9.88	0.85%	451 (15%)	2	5	1	0	0
Costilla	Random	6.5 WUS	20.66	2.04%	482 (33%)	2	16	5	2	0
Costilla	N Sangre de Cristo	7.5 WUS	51.60	5.10%	714 (48%)	13	101	24	188	476
Crowley	Random	6.50	91.11	13.66%	966 (74%)	28	143	37	200	1,211
Crowley	Cheraw	7.00	55.19	8.28%	693 (53%)	12	54	14	5	881
Custer	Random	6.50	148.28	16.90%	1,489 (60%)	10	83	17	78	1,363
Custer	N Sangre de Cristo	7.50	138.38	15.77%	1,572 (63%)	19	128	27	31	1,085
Delta	Random	6.50	287.66	10.12%	3,453 (33%)	23	194	49	0	5,515
Delta	Cimarron	6.75	53.14	1.87%	861 (8%)	1	9	2	0	0
Denver	Random	6.50	14,227.75	36.44%	73,314 (51%)	5,841	37,053	9,900	94,819	182,596
Denver	Golden	6.50	7,510.48	19.24%	56,664 (39%)	1,959	20,014	5,360	5,511	60,801
Denver	Rampart	7.00	4,652.06	11.92%	38,815 (27%)	993	12,255	3,229	287	0
Denver	Rocky Mtn Arsenal	6.25	5,557.58	14.24%	45,403 (32%)	1,257	13,992	3,809	909	6,803
Denver	Walnut Creek	6.00	3,152.92	8.08%	26,336 (18%)	395	5,779	1,599	0	290
Dolores	Random	6.50	26.18	5.08%	474 (45%)	1	11	2	0	694
Dolores	Cannibal	7.00	0.90	0.17%	28 (3%)	0	0	0	0	0

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Douglas	Random	6.50	2,036.54	14.87%	23,914 (36%)	326	1,716	312	324	38,419
Douglas	Rampart	7.00	1,848.03	13.49%	22,731 (34%)	493	1,785	327	3,183	18,030
Eagle	Random	6.50	599.67	11.96%	5,120 (36%)	70	832	168	755	7,002
Eagle	Frontal	7.00	571.47	11.40%	3,880 (27%)	120	812	163	50	1,469
El Paso	Random	6.50	4,254.96	13.06%	48,244 (31%)	903	8,292	1,968	1,173	51,038
El Paso	Rampart	7.00	9,013.76	27.67%	80,644 (52%)	2,496	19,660	4,657	18,538	135,366
El Paso	Ute Pass	7.00	8,216.92	25.23%	76,253 (50%)	2,193	17,892	4,290	18,970	118,308
Elbert	Random	6.50	72.84	3.00%	823 (12%)	6	14	2	0	549
Elbert	Rampart	7.00	98.88	4.07%	1,320 (19%)	21	36	6	0	0
Fremont	Random	6.50	299.14	7.96%	3,468 (24%)	31	293	80	0	1,783
Fremont	N Sangre de Cristo	7.50	393.64	10.47%	4,901 (34%)	89	629	170	13	790
Garfield	Random	6.50	252.92	5.34%	2,492 (18%)	27	237	53	0	3,316
Garfield	N Sawatch	7.00	76.57	1.62%	977 (7%)	4	47	10	0	0
Gilpin	Random	6.50	133.28	18.38%	1,067 (40%)	9	46	9	0	1,826
Gilpin	Golden	6.50	40.11	5.53%	323 (12%)	1	5	0	0	0
Grand	Random	6.50	194.88	6.22%	1,615 (21%)	11	86	17	44	913
Grand	Williams Fork	6.75	184.15	5.88%	1,389 (18%)	12	94	18	125	929
Gunnison	Random	6.50	164.33	6.13%	1,494 (23%)	24	306	83	0	239
Gunnison	N Sangre de Cristo	7.50	100.28	3.74%	1,001 (15%)	19	217	59	0	0
Hinsdale	Random	6.50	45.10	12.99%	627 (58%)	3	19	3	0	330
Hinsdale	Cannibal	7.00	35.15	10.12%	576 (53%)	2	15	2	0	294
Huerfano	Random	6.50	146.52	7.55%	1,193 (33%)	5	36	9	3	2,245
Huerfano	N Sangre de Cristo	7.50	83.97	4.33%	874 (25%)	5	28	7	0	0
Jackson	Random	6.50	88.91	9.36%	610 (62%)	5	35	7	67	609
Jackson	1882 RMNP	6.60	3.66	0.39%	49 (5%)	0	0	0	0	0
Jefferson	Random	6.50	5,111.00	14.27%	50,103 (29%)	603	6,403	1,403	345	113,457
Jefferson	Golden	6.50	5,881.32	16.42%	54,824 (32%)	828	8,306	1,839	927	153,809
Kiowa	Random	6.50	45.31	3.97%	483 (72%)	7	59	10	117	584
Kiowa	Cheraw	7.00	11.36	1.00%	182 (27%)	1	4	0	0	0
Kit Carson	Random	6.50	100.24	4.45%	1,192 (43%)	10	83	18	33	519
Kit Carson	Cheraw	7.00	11.25	0.50%	179 (6%)	0	3	0	0	0
La Plata	Random	6.50	640.28	14.86%	5,520 (32%)	64	632	162	0	8,925
La Plata	Cannibal	7.00	53.12	1.23%	916 (5%)	1	18	4	0	0
Lake	Random	6.50	274.37	24.97%	1,983 (68%)	39	344	86	48	2,610
Lake	Mosquito	7.00	298.86	27.20%	2,213 (75%)	54	479	120	320	2,616
Lake	N Sawatch	7.00	302.50	27.53%	2,185 (74%)	55	458	114	693	2,573
Larimer	Random	6.50	1,357.50	7.18%	17,869 (21%)	171	1,663	407	21	1,198
Larimer	1882 RMNP	6.60	887.27	4.70%	10,171 (12%)	93	831	189	0	2,844
Las Animas	Random	6.50	33.82	0.91%	345 (6%)	1	5	1	0	0

EQ SUMMARY FOR REPORT

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Las Animas	N Sangre de Cristo	7.50	31.63	0.85%	576 (10%)	1	20	6	0	0
Lincoln	Random	6.50	118.13	6.33%	818 (41%)	19	136	28	1,268	672
Lincoln	Cheraw	7.00	22.48	1.20%	371 (19%)	1	9	2	0	0
Logan	Random	6.50	346.75	11.34%	3,838 (58%)	91	629	166	372	2,095
Logan	Rocky Mtn Arsenal	6.25	2.12	0.00%	63 (1%)	0	0	0	0	0
Mesa	Random	6.50	2,122.40	23.47%	20,611 (54%)	545	4,152	1,145	18	35,626
Mesa	Random	7.00	2,960.92	32.74%	26,101 (68%)	913	6,811	1,838	1,259	38,793
Mesa	Cimarron	6.75	55.36	0.61%	1,265 (3%)	2	30	8	0	0
Mineral	Random	6.50	74.41	11.15%	688 (71%)	5	36	6	34	336
Mineral	Cannibal	7.00	43.13	6.46%	546 (56%)	3	19	3	1	267
Moffat	Random	6.50	36.09	1.30%	348 (8%)	1	6	1	12	251
Moffat	Frontal	7.00	5.11	0.18%	77 (2%)	0	0	0	0	0
Montezuma	Random	6.50	259.84	8.45%	2,903 (33%)	17	122	33	0	5,304
Montezuma	Cannibal	7.00	9.80	0.32%	234 (3%)	0	1	0	0	0
Montrose	Random	6.50	256.99	6.81%	3,361 (28%)	24	183	49	0	0
Montrose	*Cimarron*	6.75	497.40	13.18%	4,969 (41%)	130	856	213	708	1,863
Morgan	Random	6.50	1,384.96	25.63%	5,359 (62%)	132	921	244	1,316	6,410
Morgan	Rocky Mtn Arsenal	6.25	21.84	0.40%	272 (3%)	0	2	0	0	0
Otero	Random	6.50	334.00	11.38%	2,945 (44%)	39	329	88	2,804	4,935
Otero	Cheraw	7.00	415.54	14.16%	3,676 (55%)	78	588	166	3,050	5,410
Ouray	Random	6.50	147.27	18.84%	746 (40%)	6	30	6	0	1,390
Ouray	Busted Boiler	6.50	104.19	13.33%	598 (32%)	4	18	3	0	1,305
Park	Random	6.50	152.72	5.44%	2,356 (25%)	7	53	7	116	575
Park	Chase Gulch	6.75	165.45	5.90%	2,784 (29%)	8	76	14	304	1,198
Park	Mosquito	7.00	169.29	6.03%	2,308 (24%)	15	144	26	22	714
Phillips	Random	6.50	74.10	6.44%	800 (47%)	7	50	9	5	1,520
Phillips	Rocky Mtn Arsenal	6.25	0.00	0.00%	0 (0%)	0	0	0	0	0
Pitkin	Random	6.50	375.02	16.86%	1,567 (24%)	20	204	41	0	4,611
Pitkin	N Sawatch	7.00	168.78	7.59%	1,060 (16%)	14	100	20	0	616
Prowers	Random	6.50	209.69	9.09%	2,383 (51%)	42	296	82	109	1,788
Prowers	Cheraw	7.00	60.89	2.64%	777 (16%)	5	31	9	0	0
Pueblo	Random	6.50	2,315.75	21.99%	21,293 (47%)	515	4,079	1,255	410	43,103
Pueblo	N Sangre de Cristo	7.50	483.70	4.59%	6,793 (15%)	124	739	224	0	0
Pueblo	Ute Pass	7.00	288.21	2.74%	4,327 (10%)	29	248	75	0	0
Rio Blanco	Random	6.50	51.43	3.28%	647 (27%)	4	31	7	0	0
Rio Blanco	Frontal	7.00	6.69	0.43%	132 (5%)	0	2	0	0	0
Rio Grande	Random	6.5 WUS	88.75	4.98%	1,556 (33%)	18	145	41	0	0
Rio Grande	Cannibal	7.0 CEUS	36.60	2.05%	629 (13%)	2	18	5	0	0
Routt	Random	6.50	461.55	14.82%	2,665 (34%)	70	347	69	0	3,934

County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)	Buildings with at least Moderate Damage (# and % total)	Casualties Requiring Hospitalization	Displaced Households	People Seeking Public Shelter	Households without Water	Households without Electric Power
Routt	Frontal	7.00	55.99	1.80%	626 (8%)	4	32	6	0	0
Saguache	Random	6.5 WUS	53.11	3.50%	1,145 (48%)	8	65	17	139	625
Saguache	N Sangre de Cristo	7.5 WUS	25.23	1.66%	421 (18%)	2	12	3	0	0
San Juan	Random	6.50	20.06	5.43%	214 (42%)	1	6	1	0	241
San Juan	Cannibal	7.00	2.36	0.64%	38 (7%)	0	0	0	0	0
San Miguel	Random	6.50	32.62	2.40%	324 (10%)	1	10	2	0	466
San Miguel	Busted Boiler	6.50	36.15	2.65%	201 (6%)	1	13	2	0	0
Sedgwick	Random	6.50	62.77	5.86%	659 (59%)	7	79	17	48	1,075
Sedgwick	Rocky Mtn Arsenal	6.25	0.00	0.00%	0 (0%)	0	0	0	0	0
Summit	Random	6.50	829.99	19.84%	4,028 (37%)	67	602	116	0	7,071
Summit	Frontal	7.00	1,345.36	32.15%	6,602 (60%)	179	1,379	267	1,491	7,862
Summit	Mosquito	7.00	1,056.71	25.26%	5,177 (47%)	117	849	162	69	6,861
Teller	Random	6.50	255.40	13.08%	2,849 (30%)	13	90	18	0	6,043
Teller	Ute Pass	7.00	523.85	26.83%	5,099 (54%)	65	514	104	87	6,384
Washington	Random	6.50	71.76	3.34%	784 (42%)	7	49	7	85	819
Washington	Rocky Mtn Arsenal	6.25	1.09	0.00%	5 (0%)	0	0	0	0	0
Weld	Random	6.50	944.83	6.61%	13,382 (25%)	125	1,414	393	0	887
Weld	Rocky Mtn Arsenal	6.25	501.92	3.51%	6,871 (13%)	42	322	80	0	1,610
Yuma	Random	6.50	201.22	7.64%	2,069 (60%)	40	325	68	1,261	1,161
Yuma	Cheraw	7.00	3.29	0.13%	84 (2%)	0	0	0	0	0

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage	Loss Ratio %
28-Jun-05	712	Anton M7.6 Denver	7.6	Denver County	CEUS Event	0h6m	2219, 569, 88, 172	3,045.36	7.8
11-Jul-05	754	Anton M7.6 State	7.6	State	CEUS Event	1h17m	6914, 1796, 279, 542	12,145.18	3.37
24-Jan-06	800	Anton M7.6 Cheyenne	7.6	Cheyenne Co	CEUS Event	0h1m	3, 1, 0, 0	27.06	1.87
27-Jan-06	905	Anton M7.6 Kit Carson	7.6	Kit Carson Co	CEUS Event	0h2m	189, 56, 10, 17	285.07	12.66
30-Jan-06	925	Anton M7.6 Lincoln	7.6	Lincoln County	CEUS Event	0h2m	27, 6, 1, 2	59.21	3.17
30-Jan-06	927	Anton M7.6 Logan	7.6	Logan County	CEUS Event	0h2m	203, 62, 11, 20	300.21	9.82
31-Jan-06	939	Anton M7.6 Morgan	7.6	Morgan	CEUS Event	0h2m	463, 147, 27, 48	2441.92	45.18
31-Jan-06	956	Anton M7.6 Phillips	7.6	Phillips	CEUS Event	0h1m	3, 0, 0, 0	17.63	1.53
1-Feb-06	989	Anton M7.6 Sedgwick	7.6	Sedgwick	CEUS Event	0h1m	1, 0, 0, 0	4.01	0.37
1-Feb-06	1001	Anton M7.6 Washington	7.6	Washington	CEUS Event	0h1m	126, 36, 7, 10	227.65	10.59
1-Feb-06	1006	Anton M7.6 Yuma	7.6	Yuma	CEUS Event	0h1m	131, 38, 8, 12	214.1	8.13

Every HAZUS scenario run with the latest version, MR1, is recorded in these tables.
Scenario result spreadsheets are alphabetized by fault or epicenter. Results are listed in chronological order of when scenario was run.
Casualties are ordered by severity, from level 1 to 4.
The loss ratio is the total damage divided by the total region inventory, multiplied by 100. Loss ratios are highlighted if greater than 5%.

Busted Boiler

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage ($M)	Loss Ratio (%)
11-Jul-05	752	Busted Boiler M6.5 State	6.50	State	CEUS Event	1h15m	273, 73, 14, 22	694.02	0.19
25-Jan-06	832	Busted Boiler M6.5 Dolores	6.50	Dolores Co	CEUS Event	0h1m	0, 0, 0, 0	0.85	0.16
26-Jan-06	872	Busted Boiler M6.5 Gunnison	6.50	Gunnison	CEUS Event	0h1m	3, 0, 0, 0	13.13	0.49
26-Jan-06	881	Busted Boiler M6.5 Hinsdale	6.50	Hinsdale	CEUS Event	0h1m	0, 0, 0, 0	1.14	0.33
27-Jan-06	906	Busted Boiler M6.5 La Plata	6.50	La Plata	CEUS Event	0h2m	3, 0, 0, 0	14.42	0.33
31-Jan-06	935	Busted Boiler M6.5 Montrose	6.50	Montrose	CEUS Event	0h2m	233, 67, 13, 21	432.16	11.45
31-Jan-06	942	Busted Boiler M6.5 Ouray	6.50	Ouray	CEUS Event	0h1m	11, 2, 1, 1	104.19	13.33
1-Feb-06	984	Busted Boiler M6.5 San Juan	6.50	San Juan	CEUS Event	0h1m	0, 0, 0, 0	0.89	0.24
1-Feb-06	986	Busted Boiler M6.5 San Miguel	6.50	San Miguel	CEUS Event	0h1m	4, 1, 0, 0	36.15	2.65

Cannibal

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage ($M)	Loss Ratio (%)
11-Jul-05	753	Cannibal M7.0 State	7.0	State	CEUS Event	1h14m	178, 33, 6, 8	674.66	0.19
24-Jan-06	783	Cannibal M7.0 Archuleta	7.0	Archuleta	CEUS Event	0h1m	6, 1, 0, 0	42.09	2.16
25-Jan-06	833	Cannibal M7.0 Dolores	7.0	Dolores	CEUS Event	0h1m	0, 0, 0, 0	0.90	0.17
26-Jan-06	873	Cannibal M7.0 Gunnison	7.0	Gunnison	CEUS Event	0h1m	26, 6, 1, 2	70.09	2.61
26-Jan-06	882	Cannibal M7.0 Hinsdale	7.0	Hinsdale	CEUS Event	0h1m	6, 2, 0, 0	35.15	10.12
27-Jan-06	907	Cannibal M7.0 La Plata	7.0	La Plata	CEUS Event	0h2m	11, 1, 0, 0	53.12	1.23
30-Jan-06	930	Cannibal M7.0 Mineral	7.0	Mineral	CEUS Event	0h1m	7, 2, 0, 1	43.13	6.46
30-Jan-06	933	Cannibal M7.0 Montezuma	7.0	Montezuma	CEUS Event	0h2m	2, 0, 0, 0	9.80	0.32
31-Jan-06	936	Cannibal M7.0 Montrose	7.0	Montrose	CEUS Event	0h2m	66, 15, 3, 4	174.27	4.62
31-Jan-06	943	Cannibal M7.0 Ouray	7.0	Ouray	CEUS Event	0h1m	2, 0, 0, 0	36.48	4.67
31-Jan-06	971	Cannibal M7.0 Rio Grande	7.0	Rio Grande	CEUS Event	0h2m	10, 2, 0, 0	36.60	2.05
1-Feb-06	979	Cannibal M7.0 Saguache	7.0	Saguache	CEUS Event	0h1m	8, 1, 0, 0	16.31	1.08
1-Feb-06	985	Cannibal M7.0 San Juan	7.0	San Juan	CEUS Event	0h1m	0, 0, 0, 0	2.36	0.64

Chase Gulch E

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage (Mil)	Loss Ratio (%)
11-Jul-05	755	Chase Gulch M6.75 State	6.75	State	CEUS Event	1h17m	1249, 202, 23, 40	3,760.43	1.04
24-Jan-06	781	Chase Gulch M6.75 Arapahoe	6.75	Arapahoe	CEUS Event	0h5m	267, 45, 6, 9	678.30	2.10
24-Jan-06	793	Chase Gulch M6.75 Chaffee	6.75	Chaffee	CEUS Event	0h2m	5, 1, 0, 0	33.91	1.44
24-Jan-06	801	Chase Gulch M6.75 Clear Cr	6.75	Cl Creek	CEUS Event	0h1m	1, 0, 0, 0	9.71	0.60
25-Jan-06	819	Chase Gulch M6.75 Denver	6.75	Denver	CEUS Event	0h7m	407, 67, 7, 13	1,008.01	2.58
25-Jan-06	834	Chase Gulch M6.75 Douglas	6.75	Douglas	CEUS Event	0h3m	29, 4, 1, 1	117.42	0.86
25-Jan-06	840	Chase Gulch M6.75 Eagle	6.75	Eagle	CEUS Event	0h1m	9, 1, 0, 0	33.91	0.68
25-Jan-06	845	Chase Gulch M6.75 El Paso	6.75	El Paso	CEUS Event	0h5m	209, 36, 5, 8	636.41	1.95
26-Jan-06	856	Chase Gulch M6.75 Fremont	6.75	Fremont	CEUS Event	0h3m	16, 3, 0, 1	79.48	2.11
26-Jan-06	891	Chase Gulch M6.75 Jefferson	6.75	Jefferson	CEUS Event	0h5m	83, 12, 1, 2	306.98	0.86
27-Jan-06	909	Chase Gulch M6.75 Lake	6.75	Lake	CEUS Event	0h2m	5, 1, 0, 0	27.31	2.49
31-Jan-06	946	Chase Gulch M6.75 Park	6.75	Park	CEUS Event	0h1m	30, 6, 1, 1	165.45	5.90
31-Jan-06	957	Chase Gulch M6.75 Pitkin	6.75	Pitkin	CEUS Event	0h1m	2, 0, 0, 0	10.86	0.49
1-Feb-06	990	Chase Gulch M6.75 Summit	6.75	Summit	CEUS Event	0h1m	11, 2, 0, 0	73.31	1.75
1-Feb-06	997	Chase Gulch M6.75 Teller	6.75	Teller	CEUS Event	0h1m	8, 1, 0, 0	50.02	2.56

Cheraw

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Damage (Mil)	Loss Ratio (%)
11-Jul-05	756	Cheraw M7.0 State	7.0	State	CEUS Event	1h15m	451, 93, 24, 25	1,260.53	0.35
24-Jan-06	782	Cheraw M7.0 Arapahoe	7.0	Arapahoe	CEUS Event	0h4m	23, 3, 0, 0	57.94	0.18
24-Jan-06	784	Cheraw M7.0 Baca	7.0	Baca	CEUS Event	0h1m	0, 0, 0, 0	2.14	0.12
24-Jan-06	785	Cheraw M7.0 Bent	7.0	Bent	CEUS Event	0h1m	3, 0, 0, 0	18.08	1.67
24-Jan-06	799	Cheraw M7.0 Cheyenne	7.0	Cheyenne	CEUS Event	0h1m	0, 0, 0, 0	8.57	0.59
25-Jan-06	813	Cheraw M7.0 Crowley	7.0	Crowley	CEUS Event	0h1m	39, 9, 2, 2	55.19	8.28
25-Jan-06	820	Cheraw M7.0 Denver	7.0	Denver	CEUS Event	0h6m	3, 0, 0, 0	8.02	0.00
25-Jan-06	835	Cheraw M7.0 Douglas	7.0	Douglas	CEUS Event	0h3m	6, 1, 0, 0	19.20	0.14
25-Jan-06	846	Cheraw M7.0 El Paso	7.0	El Paso	CEUS Event	0h5m	128, 20, 5, 4	353.22	1.08
26-Jan-06	853	Cheraw M7.0 Elbert	7.0	Elbert	CEUS Event	0h2m	1, 0, 0, 0	5.29	0.22
26-Jan-06	884	Cheraw M7.0 Huerfano	7.0	Huerfano	CEUS Event	0h2m	1, 0, 0, 0	4.62	0.24
27-Jan-06	904	Cheraw M7.0 Kiowa	7.0	Kiowa	CEUS Event	0h2m	3, 1, 0, 0	11.36	1.00
30-Jan-06	922	Cheraw M7.0 Las Animas	7.0	Las Animas	CEUS Event	0h3m	1, 0, 0, 0	3.97	0.11
30-Jan-06	926	Cheraw M7.0 Lincoln	7.0	Lincoln	CEUS Event	0h2m	7, 1, 0, 0	22.48	1.20
31-Jan-06	941	Cheraw M7.0 Otero	7.0	Otero	CEUS Event	0h3m	173, 48, 15, 15	415.54	14.16
31-Jan-06	964	Cheraw M7.0 Prowers	7.0	Prowers	CEUS Event	0h2m	17, 4, 0, 1	60.89	2.64
31-Jan-06	965	Cheraw M7.0 Pueblo	7.0	Pueblo	CEUS Event	0h5m	59, 11, 1, 2	170.75	1.62
17-Mar-06	1076	Cheraw M7.0 Kit Carson	7.0	Kit Carson	CEUS Event	0h2m	3, 0, 0, 0	11.25	0.50
17-Mar-06	1082	Cheraw M7.0 Yuma	7.0	Yuma	CEUS Event	0h2m	1, 0, 0, 0	3.29	0.13

Cimarron

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Damage (Mil)	Loss Ratio (%)
12-Jul-05	758	Cimarron M6.75 State	6.75	State	CEUS Event	1h14m	354, 97, 20, 30	807.50	0.22
25-Jan-06	817	Cimarron M6.75 Delta	6.75	Delta	CEUS Event	0h2m	10, 1, 0, 0	53.14	1.87
26-Jan-06	874	Cimarron M6.75 Gunnison	6.75	Gunnison	CEUS Event	0h1m	21, 4, 1, 1	67.62	2.52
26-Jan-06	883	Cimarron M6.75 Hinsdale	6.75	Hinsdale	CEUS Event	0h1m	0, 0, 0, 0	1.90	0.55
27-Jan-06	908	Cimarron M6.75 La Plata	6.75	La Plata	CEUS Event	0h2m	3, 0, 0, 0	12.27	0.29
30-Jan-06	928	Cimarron M6.75 Mesa	6.75	Mesa	CEUS Event	0h3m	17, 2, 0, 0	55.36	0.61
30-Jan-06	931	Cimarron M6.75 Mineral	6.75	Mineral	CEUS Event	0h1m	0, 0, 0, 0	2.75	0.41
31-Jan-06	937	Cimarron M6.75 Montrose	6.75	Montrose	CEUS Event	0h2m	291, 87, 19, 28	497.40	13.18
31-Jan-06	944	Cimarron M6.75 Ouray	6.75	Ouray	CEUS Event	0h1m	2, 0, 0, 0	32.65	4.18
31-Jan-06	958	Cimarron M6.75 Pitkin	6.75	Pitkin	CEUS Event	0h1m	2, 0, 0, 0	12.58	0.57
1-Feb-06	987	Cimarron M6.75 San Miguel	6.75	San Miguel	CEUS Event	0h1m	1, 0, 0, 0	7.53	0.55

Frontal

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage (Mil)	Loss Ratio (%)
12-Jul-05	759	Frontal M7.0 State	7.00	State	CEUS Event	1h15m	2523, 529, 86, 137	6,733.82	1.87
24-Jan-06	786	Frontal M7.0 Boulder	7.00	Boulder	CEUS Event	0h4m	93, 15, 3, 3	330.08	1.59
24-Jan-06	794	Frontal M7.0 Chaffee	7.00	Chaffee	CEUS Event	0h1m	3, 0, 0, 0	17.51	0.74
24-Jan-06	802	Frontal M7.0 Clear Cr	7.00	Cl Creek	CEUS Event	0h1m	5, 1, 1, 0	38.02	2.33
25-Jan-06	821	Frontal M7.0 Denver	7.00	Denver	CEUS Event	0h6m	681, 128, 15, 30	1,479.89	3.79
25-Jan-06	836	Frontal M7.0 Douglas	7.00	Douglas	CEUS Event	0h3m	30, 4, 1, 1	113.62	0.83
25-Jan-06	841	Frontal M7.0 Eagle	7.00	Eagle	CEUS Event	0h1m	285, 81, 13, 26	571.47	11.40
26-Jan-06	862	Frontal M7.0 Garfield	7.00	Garfield	CEUS Event	0h2m	8, 1, 0, 0	35.28	0.75
26-Jan-06	865	Frontal M7.0 Gilpin	7.00	Gilpin	CEUS Event	0h1m	2, 0, 0, 0	10.82	1.49
26-Jan-06	868	Frontal M7.0 Grand	7.00	Grand	CEUS Event	0h2m	27, 6, 2, 2	157.11	5.02
26-Jan-06	888	Frontal M7.0 Jackson	7.00	Jackson	CEUS Event	0h1m	0, 0, 0, 0	2.98	0.31
26-Jan-06	892	Frontal M7.0 Jefferson	7.00	Jefferson	CEUS Event	0h5m	143, 24, 4, 5	460.39	1.28
27-Jan-06	910	Frontal M7.0 Lake	7.00	Lake	CEUS Event	0h1m	18, 4, 1, 1	69.45	6.32
30-Jan-06	933	Frontal M7.0 Moffat	7.00	Moffat	CEUS Event	0h2m	1, 0, 0, 0	5.11	0.18
31-Jan-06	947	Frontal M7.0 Park	7.00	Park	CEUS Event	0h1m	15, 3, 0, 1	75.85	2.70
31-Jan-06	959	Frontal M7.0 Pitkin	7.00	Pitkin	CEUS Event	0h1m	5, 1, 0, 0	32.48	1.46
31-Jan-06	970	Frontal M7.0 Rio Blanco	7.00	Rio Blanco	CEUS Event	0h1m	2, 0, 0, 0	6.69	0.43
1-Feb-06	975	Frontal M7.0 Routt	7.00	Routt	CEUS Event	0h2m	17, 3, 1, 1	55.99	1.80
1-Feb-06	991	Frontal M7.0 Summit	7.00	Summit	CEUS Event	0h1m	395, 120, 29, 39	1,345.36	32.15

Golden

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage	Loss Ratio (%)
28-Jun-05	717	Golden M6.5 Jefferson	6.50	Jefferson County	CEUS Event	0h5m	2067, 563, 127, 174	5,881.32	16.42
28-Jun-05	718	Golden M6.5 Boulder	6.50	Boulder County	CEUS Event	0h4m	418, 90, 24, 24	1,489.54	7.18
28-Jun-05	719	Golden M6.5 Denver	6.50	Denver County	CEUS Event	0h6m	4786, 1330, 213, 416	7,510.48	19.24
28-Jun-05	720	Golden M6.5 Adams	6.50	Adams County	CEUS Event	0h5m	738, 179, 38, 51	1,589.25	7.56
28-Jun-05	721	Golden M6.5 Arapahoe	6.50	Arapahoe County	CEUS Event	0h4m	2241, 604, 117, 185	3,900.99	12.10
12-Jul-05	760	Golden M6.5 State	6.50	State	CEUS Event	1h16m	10627, 2827, 529, 862	21,890.05	6.08
24-Jan-06	803	Golden M6.5 Clear Cr	6.50	Clear Creek	CEUS Event	0h1m	4, 1, 0, 0	42.88	2.63
25-Jan-06	837	Golden M6.5 Douglas	6.50	Douglas County	CEUS Event	0h3m	155, 28, 5, 7	577.72	4.22
26-Jan-06	854	Golden M6.5 Elbert	6.50	Elbert County	CEUS Event	0h1m	2, 0, 0, 0	15.62	0.64
26-Jan-06	866	Golden M6.5 Gilpin	6.50	Gilpin County	CEUS Event	0h1m	4, 1, 0, 0	40.11	5.53
26-Jan-06	893	Golden M5.5 Jefferson	5.50	Jefferson County	CEUS Event	0h5m	113, 17, 2, 3	1,025.06	2.86
30-Jan-06	918	Golden M6.5 Larimer	6.50	Larimer County	CEUS Event	0h5m	92, 15, 1, 3	236.73	1.25
31-Jan-06	948	Golden M6.5 Park	6.50	Park County	CEUS Event	0h1m	2, 0, 0, 0	13.01	0.46
1-Feb-06	992	Golden M6.5 Summit	6.50	Summit County	CEUS Event	0h1m	4, 1, 0, 0	27.05	0.65
1-Feb-06	1002	Golden M6.5 Weld	6.50	Weld County	CEUS Event	0h5m	89, 15, 3, 3	298.85	2.09

Goodpasture

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage ($M)	Loss Ratio (%)
12-Jul-05	761	Goodpasture M6.0 State	6.0	State	CEUS Event	1h14m	100, 13, 1, 2	478.59	0.13
25-Jan-06	814	Goodpasture M6.0 Custer	6.0	Custer	CEUS Event	0h1m	1, 0, 0, 0	6.22	0.71
25-Jan-06	847	Goodpasture M6.0 El Paso	6.0	El Paso	CEUS Event	0h5m	30, 3, 0, 0	102.64	0.32
26-Jan-06	857	Goodpasture M6.0 Fremont	6.0	Fremont	CEUS Event	0h3m	6, 1, 0, 0	56.07	1.49
26-Jan-06	885	Goodpasture M6.0 Huerfano	6.0	Huerfano	CEUS Event	0h2m	0, 0, 0, 0	10.07	0.52
31-Jan-06	966	Goodpasture M6.0 Pueblo	6.0	Pueblo	CEUS Event	0h5m	42, 7, 1, 1	242.57	2.30

Mosquito

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage (Mil)	Loss Ratio (%)
12-Jul-05	762	Mosquito M7.0 State	7.00	State	CEUS Event	1h16m	2207, 442, 72, 110	6,189.80	1.72
24-Jan-06	787	Mosquito M7.0 Boulder	7.00	Boulder	CEUS Event	0h4m	70, 10, 2, 2	251.96	1.22
24-Jan-06	795	Mosquito M7.0 Chaffee	7.00	Chaffee	CEUS Event	0h1m	12, 2, 0, 0	65.82	2.80
24-Jan-06	804	Mosquito M7.0 Cl Creek	7.00	Cl Creek	CEUS Event	0h1m	4, 1, 1, 0	31.83	1.95
25-Jan-06	822	Mosquito M7.0 Denver	7.00	Denver	CEUS Event	0h6m	604, 110, 13, 25	1,318.61	3.38
25-Jan-06	838	Mosquito M7.0 Douglas	7.00	Douglas	CEUS Event	0h3m	30, 4, 1, 1	110.96	0.81
25-Jan-06	842	Mosquito M7.0 Eagle	7.00	Eagle	CEUS Event	0h1m	191, 50, 8, 15	416.76	8.31
26-Jan-06	863	Mosquito M7.0 Garfield	7.00	Garfield	CEUS Event	0h2m	8, 1, 0, 0	35.25	0.74
26-Jan-06	869	Mosquito M7.0 Grand	7.00	Grand	CEUS Event	0h2m	5, 1, 0, 0	47.21	1.51
26-Jan-06	875	Mosquito M7.0 Gunnison	7.00	Gunnison	CEUS Event	0h1m	10, 2, 0, 0,	32.43	1.21
26-Jan-06	894	Mosquito M7.0 Jefferson	7.00	Jefferson	CEUS Event	0h5m	124, 20, 3, 4	401.79	1.12
27-Jan-06	911	Mosquito M7.0 Lake	7.00	Lake	CEUS Event	0h1m	118, 33, 11, 10	298.86	27.20
31-Jan-06	949	Mosquito M7.0 Park	7.00	Park	CEUS Event	0h1m	42, 10, 2, 3	169.29	6.03
31-Jan-06	960	Mosquito M7.0 Pitkin	7.00	Pitkin	CEUS Event	0h1m	12, 2, 0, 0	61.43	2.76
1-Feb-06	976	Mosquito M7.0 Routt	7.00	Routt	CEUS Event	0h2m	7, 1, 0, 0	23.17	0.74
1-Feb-06	993	Mosquito M7.0 Summit	7.00	Summit	CEUS Event	0h1m	272, 79, 17, 25	1,056.71	25.26

Rampart

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Damage (Millions)	Loss Ratio (%)
28-Jun-05	713	Rampart M7 El Paso	7.0	El Paso County	CEUS Event	0h5m	5498, 1668, 403, 545	9,013.76	27.67
28-Jun-05	714	Rampart M7 Douglas	7.0	Douglas County	CEUS Event	0h3m	797, 263, 151, 79	1,848.03	13.49
28-Jun-05	715	Rampart M7 Denver	7.0	Denver County	CEUS Event	0h6m	2704, 686, 104, 203	4,652.06	11.92
28-Jun-05	716	Rampart M7 Arapahoe	7.0	Arapahoe County	CEUS Event	0h5m	2292, 610, 121, 186	3,835.78	11.90
12-Jul-05	763	Rampart M7 State	7.0	State	CEUS Event	1h15m	12557, 3440, 835, 1066	23,046.35	6.40
24-Jan-06	778	Rampart M7 Adams	7.0	Adams County	CEUS Event	0h5m	419, 95, 17, 26	773.82	3.68
25-Jan-06	848	Rampart M6 El Paso	6.0	El Paso County	CEUS Event	0h5m	445, 82, 12, 20	1,669.57	5.13
26-Jan-06	855	Rampart M7 Elbert	7.0	Elbert County	CEUS Event	0h1m	27, 9, 9, 3	98.88	4.07
26-Jan-06	858	Rampart M7 Fremont	7.0	Fremont County	CEUS Event	0h3m	33, 6, 1, 2	127.02	3.38
26-Jan-06	895	Rampart M7 Jefferson	7.0	Jefferson County	CEUS Event	0h5m	437, 94, 19, 25	1,297.64	3.62
31-Jan-06	950	Rampart M7 Park	7.0	Park County	CEUS Event	0h1m	5, 1, 0, 0	25.94	0.92
31-Jan-06	967	Rampart M7 Pueblo	7.0	Pueblo County	CEUS Event	0h4m	68, 13, 1, 3	202.87	1.93
1-Feb-06	998	Rampart M7 Teller	7.0	Teller County	CEUS Event	0h1m	60, 15, 3, 4	260.05	13.32

RM Arsenal

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage ($ Mil)	Loss Ratio %
28-Jun-05	722	RMA M6.25 Adams CEUS Event	6.25	Adams County	CEUS Event	0h5m	1552, 425, 104, 130	3,148.06	14.97
28-Jun-05	723	RMA M6.25 Denver CEUS Event	6.25	Denver County	CEUS Event	0h6m	3249, 861, 157, 262	5,557.58	14.24
28-Jun-05	724	RMA M6.25 Arapahoe CEUS Event	6.25	Arapahoe County	CEUS Event	0h4m	1118, 266, 44, 74	2,626.60	8.15
15-Jul-05	765	RMA M6.25 State	6.25	State	CEUS Event	1h15m	6821, 1732, 338, 511	14,867.04	4.13
18-Jul-05	773	RMA M6.0 State	6.00	State	CEUS Event	1h15m	3861, 888, 157, 244	10,179.43	2.83
19-Jul-05	776	RMA M6.0 Denver	6.00	Denver County	CEUS Event	0h6m	1858, 445, 75, 126	3,887.85	1.08
24-Jan-06	792	RMA M6.25 Boulder	6.25	Boulder County	CEUS Event	0h4m	247, 47, 10, 11	1,099.49	5.30
25-Jan-06	823	RMA M5.5 Denver	5.50	Denver County	CEUS Event	0h6m	311, 51, 5, 10	1,412.63	3.62
25-Jan-06	824	RMA M5.0 Denver	5.00	Denver County	CEUS Event	0h6m	54, 6, 0, 1	543.70	1.39
26-Jan-06	896	RMA M6.25 Jefferson	6.25	Jefferson County	CEUS Event	0h5m	394, 86, 16, 23	1,416.08	3.95
31-Jan-06	940	RMA M6.25 Morgan	6.25	Morgan County	CEUS Event	0h2m	4, 0, 0, 0	21.84	0.40
1-Feb-06	1003	RMA M6.25 Weld	6.25	Weld County	CEUS Event	0h5m	153, 29, 6, 7	501.92	3.51
17-Mar-06	1077	RMA M6.25 Logan	6.25	Logan County	CEUS Event	0h2m	1, 0, 0, 0	2.12	0.00
17-Mar-06	1078	RMA M6.25 Phillips	6.25	Phillips County	CEUS Event	0h1m	0, 0, 0, 0	0.00	0.00
17-Mar-06	1079	RMA M6.25 Sedgwick	6.25	Sedgwick Co	CEUS Event	0h1m	0, 0, 0, 0	0.00	0.00
17-Mar-06	1080	RMA M6.25 Washington	6.25	Washington Co	CEUS Event	0h1m	0, 0, 0, 0	1.09	0.00
17-Mar-06	1081	RMA M6.25 Yuma	6.25	Yuma County	CEUS Event	0h1m	0, 0, 0, 0	0.37	0.00

Roubideau Cr. E

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage (%M)	Loss Ratio (%)
15-Jul-05	766	Roubideau M5.5 State	5.50	State	CEUS Event	1h13m	9, 1, 0, 0	94.23	0.00
25-Jan-06	818	Roubideau M5.5 Delta	5.50	Delta County	CEUS Event	0h2m	0, 0, 0, 0	5.93	0.21
26-Jan-06	876	Roubideau M5.5 Gunnison	5.50	Gunnison	CEUS Event	0h1m	0, 0, 0, 0	0.54	0.00
30-Jan-06	929	Roubideau M5.5 Mesa	5.50	Mesa	CEUS Event	0h3m	1, 0, 0, 0	4.71	0.00
31-Jan-06	938	Roubideau M5.5 Montrose	5.50	Montrose	CEUS Event	0h2m	7, 1, 0, 0	78.24	2.07
31-Jan-06	945	Roubideau M5.5 Ouray	5.50	Ouray	CEUS Event	0h1m	0, 0, 0, 0	2.80	0.36
1-Feb-06	988	Roubideau M5.5 San Miguel	5.50	San Miguel	CEUS Event	0h1m	0, 0, 0, 0	0.81	0.00

N Sangre de Cristo

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Damage ($ Mil)	Loss Ratio (%)	CEUS-WUS Mean ($M)
30-Jun-05	745	N Sangre M7.5 Saguache	7.5	Saguache County	WUS Shallow - Ext.	0h1m	9, 2, 0, 0	25.23	1.66	
30-Jun-05	746	N Sangre M7.5 Alamosa	7.5	Alamosa County	WUS Shallow - Ext.	0h2m	54, 13, 2, 4	142.06	7.72	
30-Jun-05	748	N Sangre M7.5 Chaffee WUS	7.5	Chaffee County	WUS Shallow - Ext.	0h1m	95, 28, 5, 9	133.36	5.67	Chaffee County:
30-Jun-05	749	N Sangre M7.5 Chaffee CEUS	7.5	Chaffee County	CEUS Event	0h1m	287, 90, 15, 29	425.76	18.09	279.56
15-Jul-05	765	N Sangre M7.5 State WUS	7.5	State	WUS Shallow - Ext.	4h28m	306, 65, 12, 17	767.07	0.21	State:
18-Jul-05	772	N Sangre M7.5 State CEUS	7.5	State	CEUS Event	1h15m	4615, 1147, 186, 335	8,020.95	2.23	4394.01
25-Jan-06	808	N Sangre M7.5 Conejos CEUS	7.5	Conejos County	CEUS Event	0h1m	48, 11, 1, 3	56.31	4.84	Conejos County:
25-Jan-06	809	N Sangre M7.5 Conejos WUS	7.5	Conejos County	WUS - Ext.	0h1m	9, 2, 0, 0	9.88	0.85	33.1
25-Jan-06	810	N Sangre M7.5 Costilla CEUS	7.5	Costilla County	CEUS Event	0h1m	57, 15, 2, 4	85.15	8.40	Costilla County:
25-Jan-06	811	N Sangre M7.5 Costilla WUS	7.5	Costilla County	WUS - Ext.	0h1m	37, 10, 1, 2	51.60	5.10	68.38
25-Jan-06	812	N Sangre M7.5 Alamosa CEUS	7.5	Alamosa County	CEUS Event	0h2m	193, 55, 9, 18	433.09	23.54	Alamosa: 287.58
25-Jan-06	815	N Sangre M7.5 Custer WUS Ext	7.5	Custer County	WUS - Ext.	0h1m	9, 2, 1, 1	28.50	3.25	
25-Jan-06	816	N Sangre M7.5 Custer WUS Sh	7.5	Custer County	WUS Shallow - Ext.	0h1m	9, 2, 1, 1	28.50	3.25	
25-Jan-06	825	N Sangre M7.5 Denver CEUS	7.5	Denver County	CEUS Event	0h6m	895, 188, 25, 48	1,474.46	3.78	Denver County:
25-Jan-06	826	N Sangre M7.5 Denver WUS	7.5	Denver County	WUS - Ext.	0h6m	30, 3, 0, 0	69.87	0.18	772.17
25-Jan-06	849	N Sangre M7.5 El Paso CEUS	7.5	El Paso County	CEUS Event	0h5m	1459, 400, 78, 125	2,115.97	6.50	El Paso County:
25-Jan-06	850	N Sangre M7.5 El Paso WUS	7.5	El Paso County	WUS - Ext.	0h5m	33, 5, 2, 1	90.76	0.28	1103.37
26-Jan-06	859	N Sangre M7.5 Fremont CEUS	7.5	Fremont County	CEUS Event	0h3m	204, 60, 13, 19	393.64	10.47	Fremont County:
26-Jan-06	860	N Sangre M7.5 Fremont WUS	7.5	Fremont County	WUS - Ext.	0h3m	42, 11, 2, 3	89.58	2.38	241.61
26-Jan-06	877	N Sangre M7.5 Gunnison CEUS	7.5	Gunnison Co	CEUS Event	0h1m	50, 13, 2, 4	100.28	3.74	Gunnison County:
26-Jan-06	878	N Sangre M7.5 Gunnison WUS	7.5	Gunnison Co	WUS - Ext.	0h1m	1, 0, 0, 0	4.17	0.16	52.23
26-Jan-06	886	N Sangre M7.5 Huerfano CEUS	7.5	Huerfano Co	CEUS Event	0h2m	14, 3, 1, 1	83.97	4.33	Huerfano County:
26-Jan-06	887	N Sangre M7.5 Huerfano WUS	7.5	Huerfano Co	WUS - Ext.	0h2m	2, 0, 0, 0	18.96	0.98	51.47
26-Jan-06	897	N Sangre M7.5 Jefferson CEUS	7.5	Jefferson Co	CEUS Event	0h5m	125, 23, 3, 5	285.25	0.80	Jefferson County:
26-Jan-06	898	N Sangre M7.5 Jefferson WUS	7.5	Jefferson Co	WUS - Ext.	0h5m	6, 1, 0, 0	15.55	0.00	150.4
27-Jan-06	915	N Sangre M7.5 Archuleta CEUS	7.5	Archuleta Co	CEUS Event	0h2m	10, 2, 1, 1	28.10	1.44	Archuleta County:
27-Jan-06	916	N Sangre M7.5 Archuleta WUS	7.5	Archuleta Co	WUS - Ext.	0h2m	0, 0, 0, 0	1.04	0.00	14.57
27-Jan-06	917	N Sangre M7.5 Custer CEUS	7.5	Custer County	CEUS Event	0h1m	42, 13, 2, 4	138.38	15.77	
30-Jan-06	923	N Sangre M7.5 Las Animas CEUS	7.5	Las Animas Co	CEUS Event	0h2m	8, 1, 0, 0	31.63	0.85	Las Animas County:
30-Jan-06	924	N Sangre M7.5 Las Animas WUS	7.5	Las Animas Co	WUS - Ext.	0h2m	1, 0, 0, 0	3.40	0.00	17.52
30-Jan-06	932	N Sangre M7.5 Mineral CEUS	7.5	Mineral Co	CEUS Event	0h1m	1, 0, 0, 0	9.52	1.43	
31-Jan-06	951	N Sangre M7.5 Park WUS	7.5	Park County	WUS Shallow - Ext.	0h1m	1, 0, 0, 0	4.17	0.15	
31-Jan-06	968	N Sangre M7.5 Pueblo CEUS	7.5	Pueblo County	CEUS Event	0h4m	321, 85, 13, 26	483.70	4.59	Pueblo County:
31-Jan-06	969	N Sangre M7.5 Pueblo WUS	7.5	Pueblo County	WUS - Ext.	0h4m	9, 1, 0, 0	25.57	0.24	254.64
31-Jan-06	972	N Sangre M7.5 Rio Grande CEUS	7.5	Rio Grande Co	CEUS Event	0h2m	78, 21, 4, 7	124.26	7.00	Rio Grande County:
31-Jan-06	973	N Sangre M7.5 Rio Grande WUS	7.5	Rio Grande Co	WUS - Ext.	0h2m	8, 1, 0, 0	16.28	0.91	70.27
1-Feb-06	980	N Sangre M7.5 Saguache CEUS	7.5	Saguache County	CEUS Event	0h1m	66, 17, 2, 4	104.00	6.86	
1-Feb-06	981	N Crestone M7.28 Saguache WUS	7.3	Saguache County	WUS Shallow - Ext.	0h1m	4, 1, 0, 0	21.19	1.40	
1-Feb-06	999	N Sangre M7.5 Teller WUS	7.5	Teller County	WUS - Ext.	0h1m	1, 0, 0, 0	2.44	0.13	

N Sawatch

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage (Mil)	Loss Ratio (%)
15-Jul-05	767	N Sawatch M7.0 State	7.0	State	CEUS Event	1h15m	1211, 215, 35, 47	3,617.52	1.01
24-Jan-06	796	N Sawatch M7.0 Chaffee	7.0	Chaffee	CEUS Event	0h1m	34, 7, 1, 2	152.75	6.49
24-Jan-06	805	N Sawatch M7.0 Clear Creek	7.0	Cl Creek	CEUS Event	0h1m	1, 0, 0, 0	8.96	5.49
25-Jan-06	827	N Sawatch M7.0 Denver	7.0	Denver	CEUS Event	0h6m	269, 41, 4, 7	651.85	1.67
25-Jan-06	839	N Sawatch M7.0 Douglas	7.0	Douglas	CEUS Event	0h3m	18, 2, 0, 0	64.11	0.47
25-Jan-06	843	N Sawatch M7.0 Eagle	7.0	Eagle	CEUS Event	0h1m	148, 34, 5, 9	386.86	7.71
26-Jan-06	864	N Sawatch M7.0 Garfield	7.0	Garfield	CEUS Event	0h2m	18, 3, 0, 1	76.57	1.62
26-Jan-06	870	N Sawatch M7.0 Grand	7.0	Grand	CEUS Event	0h2m	3, 0, 0, 0	24.12	0.77
26-Jan-06	879	N Sawatch M7.0 Gunnison	7.0	Gunnison	CEUS Event	0h1m	15, 3, 0, 1	46.15	1.72
26-Jan-06	899	N Sawatch M7.0 Jefferson	7.0	Jefferson	CEUS Event	0h5m	64, 9, 1, 1	205.49	0.57
27-Jan-06	912	N Sawatch M7.0 Lake	7.0	Lake	CEUS Event	0h1m	112, 33, 12, 10	302.50	27.53
31-Jan-06	952	N Sawatch M7.0 Park	7.0	Park	CEUS Event	0h1m	13, 3, 0, 1	66.92	2.38
31-Jan-06	961	N Sawatch M7.0 Pitkin	7.0	Pitkin	CEUS Event	0h1m	42, 10, 1, 3	168.78	7.59
1-Feb-06	994	N Sawatch M7.0 Summit	7.0	Summit	CEUS Event	0h1m	54, 13, 2, 3	217.41	5.20

S Sawatch

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Damage (Mil)	Loss Ratio (%)
15-Jul-05	768	S Sawatch M7.25 State	7.25	State	CEUS Event	1h16m	1764, 340, 56, 81	4742.32	1.32
24-Jan-06	797	S Sawatch M7.25 Chaffee CEUS	7.25	Chaffee	CEUS Event	0h1m	271, 82, 13, 26	665.16	28.26
24-Jan-06	798	S Sawatch M7.25 Chaffee WUS	7.25	Chaffee	WUS Shallow Ext	0h1m	223, 67, 11, 21	425.99	18.10
25-Jan-06	828	S Sawatch M7.25 Denver	7.25	Denver	CEUS Event	0h9m	384, 63, 6, 12	866.07	2.22
25-Jan-06	844	S Sawatch M7.25 Eagle	7.25	Eagle	CEUS Event	0h1m	48, 9, 1, 2	145.56	2.90
25-Jan-06	851	S Sawatch M7.25 El Paso	7.25	El Paso	CEUS Event	0h5m	267, 50, 10, 11	658.81	2.02
26-Jan-06	861	S Sawatch M7.25 Fremont	7.25	Fremont	CEUS Event	0h3m	31, 6, 1, 2	120.48	3.21
26-Jan-06	880	S Sawatch M7.25 Gunnison	7.25	Gunnison	CEUS Event	0h1m	33, 7, 1, 2	88.33	3.29
26-Jan-06	900	S Sawatch M7.25 Jefferson	7.25	Jefferson	CEUS Event	0h5m	81, 12, 2, 2	253.29	0.71
27-Jan-06	913	S Sawatch M7.25 Lake	7.25	Lake	CEUS Event	0h1m	64, 20, 8, 6	182.95	16.65
31-Jan-06	953	S Sawatch M7.25 Park	7.25	Park	CEUS Event	0h1m	14, 3, 0, 1	72.20	2.57
31-Jan-06	962	S Sawatch M7.25 Pitkin	7.25	Pitkin	CEUS Event	0h1m	31, 7, 1, 2	114.85	5.16
1-Feb-06	982	S Sawatch M7.25 Saguache WUS	7.25	Saguache	WUS Shallow Ext	0h1m	2, 0, 0, 0	7.30	0.48
1-Feb-06	983	S Sawatch M7.25 Saguache CEUS	7.25	Saguache	CEUS Event	0h1m	10, 2, 0, 0	28.57	1.88
1-Feb-06	995	S Sawatch M7.25 Summit	7.25	Summit	CEUS Event	0h1m	33, 7, 1, 2	140.74	3.36
1-Feb-06	1000	S Sawatch M7.25 Teller	7.25	Teller	CEUS Event	0h1m	4, 1, 0, 0	17.96	0.92

Ute Pass

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Damage ($Mil)	Loss Ratio (%)
30-Jun-05	727	Ute Pass M7.0 El Paso	7.0	El Paso County	CEUS Event	0h5m	4889, 1468, 390, 477	8,216.92	25.23
30-Jun-05	728	Ute Pass M7.0 Douglas	7.0	Douglas County	CEUS Event	0h4m	211, 54, 29, 15	652.44	4.76
30-Jun-05	729	Ute Pass M7.0 Teller	7.0	Teller County	CEUS Event	0h1m	155, 44, 11, 14	523.85	26.83
30-Jun-05	730	Ute Pass M7.0 Denver	7.0	Denver County	CEUS Event	0h6m	1394, 310, 43, 84	2,749.25	7.04
30-Jun-05	731	Ute Pass M7.0 Pueblo	7.0	Pueblo County	CEUS Event	0h4m	105, 21, 3, 5	288.21	2.74
30-Jun-05	732	Ute Pass M7.0 Fremont	7.0	Fremont County	CEUS Event	0h2m	56, 12, 2, 3	183.77	4.89
30-Jun-05	733	Ute Pass M7.0 Elbert	7.0	Elbert County	CEUS Event	0h1m	9, 3, 4, 1	44.25	1.82
30-Jun-05	734	Ute Pass M7.0 Arapahoe	7.0	Arapahoe County	CEUS Event	0h5m	1046, 242, 43, 67	2,106.05	6.53
30-Jun-05	735	Ute Pass M7.0 Jefferson	7.0	Jefferson County	CEUS Event	0h5m	240, 45, 9, 11	769.60	2.15
30-Jun-05	736	Ute Pass M7.0 Adams	7.0	Adams County	CEUS Event	0h5m	246, 50, 8, 12	495.75	2.36
18-Jul-05	769	Ute Pass M7.0 State	7.0	State	CEUS Event	1h15m	8542, 2266, 545, 690	16,774.21	4.66
24-Jan-06	788	Ute Pass M7.0 Boulder	7.0	Boulder County	CEUS Event	0h4m	70, 10, 2, 2	245.00	1.18
24-Jan-06	806	Ute Pass M7.0 Cl Creek	7.0	Clear Creek Co	CEUS Event	0h1m	2, 0, 0, 0	10.57	0.65
25-Jan-06	852	Ute Pass M6.0 El Paso	6.0	El Paso County	CEUS Event	0h5m	522, 108, 15, 27	1,908.61	5.86
31-Jan-06	954	Ute Pass M6.0 Park	7.0	Park County	CEUS Event	0h1m	6, 1, 0, 0	34.50	1.23
1-Feb-06	996	Ute Pass M6.0 Summit	7.0	Summit County	CEUS Event	0h1m	8, 1, 0, 0	42.72	1.02

Valmont

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage ($Mil)	Loss Ratio (%)
18-Jul-05	770	Valmont M5.0 State	5.0	State	CEUS Event	1h15m	40, 4, 0, 0	711.46	0.20
24-Jan-06	779	Valmont M5.0 Adams	5.0	Adams	CEUS Event	0h5m	4, 0, 0, 0	64.14	0.31
24-Jan-06	789	Valmont M5.0 Boulder	5.0	Boulder	CEUS Event	0h4m	14, 2, 0, 0	410.72	1.98
25-Jan-06	829	Valmont M5.0 Denver	5.0	Denver	CEUS Event	0h6m	12, 1, 0, 0	98.40	0.25
26-Jan-06	901	Valmont M5.0 Jefferson	5.0	Jefferson	CEUS Event	0h5m	3, 0, 0, 0	50.44	0.14
30-Jan-06	919	Valmont M5.0 Larimer	5.0	Larimer	CEUS Event	0h4m	1, 0, 0, 0	11.43	0.00
1-Feb-06	1004	Valmont M5.0 Weld	5.0	Weld	CEUS Event	0h5m	1, 0, 0, 0	40.15	0.28

Walnut Creek

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage ($Mil)	Loss Ratio (%)
30-Jun-05	737	Walnut Creek M6.0 Jefferson	6.0	Jefferson County	CEUS Event	0h5m	631, 151, 33, 43	2,307.28	6.44
30-Jun-05	738	Walnut Creek M6.0 Boulder	6.0	Boulder County	CEUS Event	0h4m	225, 43, 10, 10	1,211.73	5.84
30-Jun-05	739	Walnut Creek M6.0 Denver	6.0	Denver County	CEUS Event	0h6m	1291, 282, 38, 75	3,152.92	8.08
30-Jun-05	740	Walnut Creek M6.0 Adams	6.0	Adams County	CEUS Event	0h5m	377, 78, 13, 20	1,276.87	6.07
30-Jun-05	741	Walnut Creek M6.0 Arapahoe	6.0	Arapahoe County	CEUS Event	0h4m	387, 73, 9, 17	1,245.01	3.86
18-Jul-05	771	Walnut Creek M6.5 State	6.5	State	CEUS Event	1h15m	10737, 2840, 559, 862	22,410.30	6.23
1-Feb-06	1005	Walnut Creek M6.5 Weld	6.0	Weld County	CEUS Event	0h5m	47, 7, 1, 1	212.07	1.48
2-Feb-06	1007	Walnut Creek M6.0 State	6.0	State	CEUS Event	4h46m	3020, 642, 101, 166	9,704.00	2.70

Williams Fork

Date Run	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage ($M)	Loss Ratio (%)
30-Jun-05	742	Williams Fork M6.75 Grand	6.75	Grand County	CEUS Event	0h2m	35, 8, 2, 2	184.15	5.88
30-Jun-05	743	Williams Fork M6.75 Summit	6.75	Summit County	CEUS Event	0h1m	109, 30, 8, 9	436.15	10.42
30-Jun-05	744	Williams Fork M6.75 Eagle	6.75	Eagle County	CEUS Event	0h2m	74, 17, 2, 5	206.95	4.13
18-Jul-05	773	Williams Fork M6.75 State	6.75	State	CEUS Event	1h15m	1129, 192, 26, 41	3,482.99	0.97
24-Jan-06	790	Williams Fork M6.75 Boulder	6.75	Boulder	CEUS Event	0h4m	58, 8, 1, 1	232.76	1.12
24-Jan-06	807	Williams Fork M6.75 Cl Creek	6.75	Clear Creek	CEUS Event	0h1m	4, 1, 1, 0	31.93	1.96
25-Jan-06	830	Williams Fork M6.75 Denver	6.75	Denver	CEUS Event	0h6m	339, 53, 5, 10	849.99	2.18
26-Jan-06	867	Williams Fork M6.75 Gilpin	6.75	Gilpin	CEUS Event	0h1m	1, 0, 0, 0	9.96	1.37
26-Jan-06	889	Williams Fork M6.75 Jackson	6.75	Jackson	CEUS Event	0h1m	0, 0, 0, 0	2.25	0.24
26-Jan-06	902	Williams Fork M6.75 Jefferson	6.75	Jefferson	CEUS Event	0h5m	78, 11, 1, 2	273.83	0.76
27-Jan-06	914	Williams Fork M6.75 Lake	6.75	Lake	CEUS Event	0h1m	3, 0, 0, 0	17.20	1.57
30-Jan-06	920	Williams Fork M6.75 Larimer	6.75	Larimer	CEUS Event	0h4m	69, 10, 1, 2	177.66	0.94
31-Jan-06	955	Williams Fork M6.75 Park	6.75	Park	CEUS Event	0h1m	3, 0, 0, 0	18.52	0.66
31-Jan-06	963	Williams Fork M6.75 Pitkin	6.75	Pitkin	CEUS Event	0h1m	2, 0, 0, 0	13.21	0.59
1-Feb-06	977	Williams Fork M6.75 Routt	6.75	Routt	CEUS Event	0h2m	11, 2, 0, 0	40.36	1.30

1882 EQ

Run Date	#	Scenario Name	Mag.	Region	Q Function	RunTime	Casualties	Total Damage	Loss Ratio (%)
21-Jun-05	710	1882 M6.6 State RMNP epicenter	6.6	State	CEUS Event	1h20m	865, 146, 16, 31	2,761.30	0.77
21-Jun-05	711	1882 M6.0 State RMNP epicenter	6.0	State	CEUS Event	4h22m	243, 35, 3, 6	950.43	0.26
28-Jun-05	725	1882 M7.2 State RMNP epicenter	7.2	State	CEUS Event	4h41m	3981, 898, 149, 246	8,976.99	2.49
29-Jun-05	726	1882 M7.2 State Piceance epicenter	7.2	State	CEUS Event	overnight	112, 23, 9, 6	464.05	0.13
30-Jun-05	750	1882 M7.2 State Npark epicenter	7.2	State	CEUS Event	4h41m	796, 130, 16, 26	2,166.66	0.60
8-Jul-05	751	1882 M6.0 State Npark epicenter	6.0	State	CEUS Event	4h19m	48, 5, 0, 1	148.45	0.00
12-Jul-05	757	1882 M6.0 State Piceance epicenter	6.0	State	CEUS Event	4h46m	5, 1, 0, 0	42.20	0.00
19-Jul-05	775	1882 M6.6 State Piceance epicenter	6.6	State	CEUS Event	1h13m	21, 3, 1, 1	120.00	0.00
19-Jul-05	777	1882 M6.6 State Npark epicenter	6.6	State	CEUS Event	1h15m	181, 24, 2, 3	553.20	0.15
24-Jan-06	780	1882 M6.6 RMNP Adams	6.6	Adams	CEUS Event	0h5m	53, 7, 1, 1	149.77	0.71
24-Jan-06	791	1882 M6.6 RMNP Boulder	6.6	Boulder	CEUS Event	0h4m	76, 11, 2, 2	328.24	1.58
25-Jan-06	831	1882 M6.6 RMNP Denver	6.6	Denver	CEUS Event	0h6m	200, 28, 2, 5	527.25	1.35
26-Jan-06	871	1882 M6.6 RMNP Grand	6.6	Grand	CEUS Event	0h2m	9, 2, 0, 0	110.19	3.52
26-Jan-06	890	1882 M6.6 RMNP Jackson	6.6	Jackson	CEUS Event	0h1m	0, 0, 0, 0	3.66	0.39
30-Jan-06	921	1882 M6.6 RMNP Larimer	6.6	Larimer	CEUS Event	0h4m	297, 66, 9, 18	887.27	4.70
1-Feb-06	978	1882 M6.6 RMNP Routt	6.6	Routt	CEUS Event	0h2m	4, 1, 0, 0	16.48	0.53
15-May-06		1882 M6.6 State Npark 30km Depth	6.6	State	CEUS Event	4h20m	164, 20, 1, 3	470.35	0.13
19-May-06		1882 M7.2 State Npark 30km Depth	7.2	State	CEUS Event	4h24m	725, 113, 13, 21	1,948.92	0.54

Random EQ

Run Date	#	Scenario Name	Mag.	Q Function	Casualties	Total Damage ($M)	Loss Ratio (%)	Inventory ($M)
7-Feb-06	1008	Adams County Random EQ	6.5	CEUS Event	343, 75, 16, 20	853.52	4.06	21,025.00
7-Feb-06	1009	Alamosa County Random EQ WUS	6.5	WUS - Ext.	50, 11, 2, 3	152.22	8.28	1,839.50
7-Feb-06	1010	Alamosa County Random EQ CEUS	6.5	CEUS Event	101, 24, 4, 6	327.84	17.82	1,839.50
7-Feb-06	1011	Arapahoe County Random EQ	6.5	CEUS Event	978, 224, 47, 61	2,350.41	7.29	32,232.30
7-Feb-06	1012	Archuleta County Random EQ	6.5	CEUS Event	45, 11, 2, 3	341.25	17.51	1,948.70
7-Feb-06	1013	Baca County Random EQ	6.5	CEUS Event	26, 6, 1, 1	119.80	6.54	1,831.70
7-Feb-06	1014	Bent County Random EQ	6.5	CEUS Event	23, 5, 1, 1	72.32	6.69	1,081.00
7-Feb-06	1015	Boulder County Random EQ	6.5	CEUS Event	1143, 298, 84, 89	3,282.58	15.83	20,737.40
7-Feb-06	1016	Chaffee County Random EQ	6.5	CEUS Event	55, 12, 2, 3	288.32	12.25	2,354.10
7-Feb-06	1017	Cheyenne County Random EQ	6.5	CEUS Event	9, 2, 0, 0	51.12	3.52	1,450.80
7-Feb-06	1018	Clear Creek County Random EQ	6.5	CEUS Event	23, 6, 3, 2	175.44	10.74	1,632.90
7-Feb-06	1019	Conejos County Random EQ WUS	6.5	WUS - Ext.	8, 1, 0, 0	26.37	2.27	1,162.40
7-Feb-06	1020	Conejos County Random EQ CEUS	6.5	CEUS Event	28, 6, 1, 1	76.42	6.57	1,162.40
7-Feb-06	1021	Costilla County Random EQ WUS	6.5	WUS - Ext.	9, 2, 0, 0	20.66	2.04	1,013.40
7-Feb-06	1022	Costilla County Random EQ CEUS	6.5	CEUS Event	18, 4, 1, 1	46.92	4.63	1,013.40
7-Feb-06	1023	Crowley County Random EQ	6.5	CEUS Event	76, 20, 3, 5	91.11	13.66	666.90
8-Feb-06	1024	Custer County Random EQ	6.5	CEUS Event	28, 7, 1, 2	148.28	16.90	877.60
8-Feb-06	1025	Delta County Random EQ	6.5	CEUS Event	77, 16, 4, 4	287.66	10.12	2,841.30
8-Feb-06	1026	Denver County Random EQ	6.5	CEUS Event	12284, 3873, 749, 1302	14,227.75	36.44	39,039.40
8-Feb-06	1027	Dolores County Random EQ	6.5	CEUS Event	7, 1, 0, 0	26.18	5.08	515.70
8-Feb-06	1028	Douglas County Random EQ	6.5	CEUS Event	629, 183, 90, 53	2,036.54	14.87	13,697.50
8-Feb-06	1029	Eagle County Random EQ	6.5	CEUS Event	185, 48, 11, 14	599.67	11.96	5,014.90
8-Feb-06	1030	El Paso County Random EQ	6.5	CEUS Event	2193, 612, 155, 191	4,254.96	13.06	32,570.60
8-Feb-06	1031	Elbert County Random EQ	6.5	CEUS Event	14, 3, 2, 1	72.84	3.00	2,431.60
8-Feb-06	1032	Fremont County Random EQ	6.5	CEUS Event	86, 22, 4, 6	299.14	7.96	3,759.70
8-Feb-06	1033	Garfield County Random EQ	6.5	CEUS Event	67, 15, 8, 4	252.92	5.34	4,735.50
8-Feb-06	1034	Gilpin County Random EQ	6.5	CEUS Event	24, 6, 1, 2	133.28	18.38	725.30
8-Feb-06	1035	Grand County Random EQ	6.5	CEUS Event	32, 7, 2, 2	194.88	6.22	3,131.50
8-Feb-06	1036	Gunnison County Random EQ	6.5	CEUS Event	61, 16, 3, 5	164.33	6.13	2,681.30
8-Feb-06	1037	Hinsdale County Random EQ	6.5	CEUS Event	7, 2, 0, 1	45.10	12.99	347.30
8-Feb-06	1038	Huerfano County Random EQ	6.5	CEUS Event	17, 3, 1, 1	146.52	7.55	1,939.50
8-Feb-06	1039	Jackson County Random EQ	6.5	CEUS Event	13, 3, 1, 1	88.91	9.36	949.70
8-Feb-06	1040	Jefferson County Random EQ	6.5	CEUS Event	1589, 414, 92, 124	5,111.00	14.27	35,828.60
8-Feb-06	1041	Kiowa County Random EQ	6.5	CEUS Event	20, 5, 1, 1	45.31	3.97	1,141.60
8-Feb-06	1042	Kit Carson County Random EQ	6.5	CEUS Event	34, 7, 1, 2	100.24	4.45	2,252.00
8-Feb-06	1043	La Plata County Random EQ	6.5	CEUS Event	163, 42, 10, 12	640.28	14.86	4,309.40
9-Feb-06	1044	Lake County Random EQ	6.5	CEUS Event	85, 24, 8, 7	274.37	24.97	1,098.70
9-Feb-06	1045	Larimer County Random EQ	6.5	CEUS Event	534, 121, 18, 33	1,357.50	7.18	18,896.00
9-Feb-06	1046	Las Animas County Random EQ	6.5	CEUS Event	4, 1, 0, 0	33.82	0.91	3,705.50
9-Feb-06	1047	Lincoln County Random EQ	6.5	CEUS Event	46, 13, 2, 4	118.13	6.33	1,866.40

Random EQ

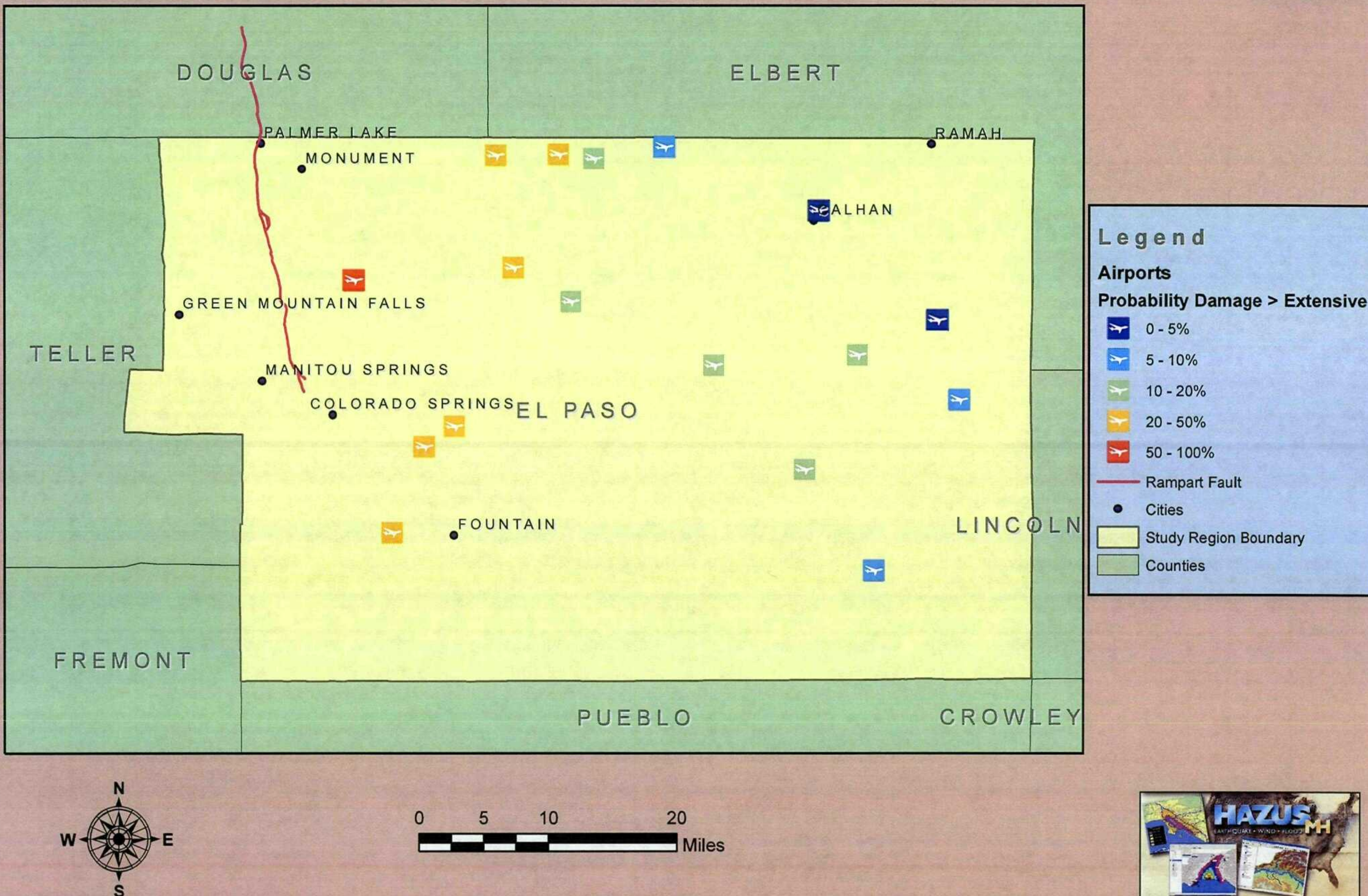
9-Feb-06	1048	Logan County Random EQ	6.5	CEUS Event	202, 61, 12, 20	346.75	11.34	3,057.30
9-Feb-06	1049	Mesa County Random EQ	6.5	CEUS Event	1241, 367, 80, 117	2,122.40	23.47	9,044.60
2-May-06		Mesa County Random M7.0 EQ	7	CEUS Event	1914, 590, 131, 192	2,960.92	32.74	9,044.60
9-Feb-06	1050	Mineral County Random EQ	6.5	CEUS Event	11, 3, 1, 1	74.41	11.15	667.40
9-Feb-06	1051	Moffat County Random EQ	6.5	CEUS Event	5, 1, 0, 0	36.09	1.30	2,778.00
10-Feb-06	1052	Montezuma County Random EQ	6.5	CEUS Event	57, 12, 3, 3	259.84	8.45	3,074.20
10-Feb-06	1053	Montrose County Random EQ	6.5	CEUS Event	74, 17, 3, 5	256.99	6.81	3,773.90
10-Feb-06	1054	Morgan County Random EQ	6.5	CEUS Event	297, 89, 20, 28	1,384.96	25.63	5,404.70
10-Feb-06	1055	Otero County Random EQ	6.5	CEUS Event	107, 26, 7, 7	334.00	11.38	2,935.40
10-Feb-06	1056	Ouray County Random EQ	6.5	CEUS Event	16, 4, 1, 1	147.27	18.84	781.70
10-Feb-06	1057	Park County Random EQ	6.5	CEUS Event	24, 5, 1, 1	152.72	5.44	2,806.30
10-Feb-06	1058	Phillips County Random EQ	6.5	CEUS Event	21, 5, 1, 1	74.10	6.44	1,151.20
10-Feb-06	1059	Pitkin County Random EQ	6.5	CEUS Event	63, 14, 3, 4	375.02	16.86	2,224.30
10-Feb-06	1060	Prowers County Random EQ	6.5	CEUS Event	100, 28, 5, 9	209.69	9.09	2,306.40
10-Feb-06	1061	Pueblo County Random EQ	6.5	CEUS Event	1165, 346, 68, 111	2,315.75	21.99	10,530.10
10-Feb-06	1062	Rio Blanco County Random EQ	6.5	CEUS Event	12, 3, 1, 1	51.43	3.28	1,567.20
10-Feb-06	1063	Rio Grande County Random EQ	6.5	CEUS Event	89, 22, 5, 6	199.08	11.16	1,783.20
10-Feb-06	1067	Rio Grande County Random EQ WUS	6.5	WUS - Ext.	54, 13, 3, 4	88.75	4.98	1,783.20
10-Feb-06	1064	Routt County Random EQ	6.5	CEUS Event	164, 47, 9, 15	461.55	14.82	3,114.00
10-Feb-06	1065	Saguache County Random EQ WUS	6.5	WUS - Ext.	27, 6, 1, 1	53.11	3.50	1,517.10
10-Feb-06	1066	Saguache County Random EQ CEUS	6.5	CEUS Event	42, 9, 1, 2	94.02	6.20	1,517.10
10-Feb-06	1068	San Juan County Random EQ	6.5	CEUS Event	3, 1, 0, 0	20.06	5.43	369.20
10-Feb-06	1069	San Miguel County Random EQ	6.5	CEUS Event	4, 1, 0, 0	32.62	2.40	1,361.60
10-Feb-06	1070	Sedgwick County Random EQ	6.5	CEUS Event	21, 5, 1, 1	62.77	5.86	1,071.60
10-Feb-06	1071	Summit County Random EQ	6.5	CEUS Event	167, 46, 10, 14	829.99	19.84	4,184.10
10-Feb-06	1072	Teller County Random EQ	6.5	CEUS Event	44, 9, 2, 2	255.40	13.08	1,952.20
10-Feb-06	1073	Washington County Random EQ	6.5	CEUS Event	21, 5, 1, 1	71.76	3.34	2,148.70
10-Feb-06	1074	Weld County Random EQ	6.5	CEUS Event	389, 88, 18, 24	944.83	6.61	14,295.20
10-Feb-06	1075	Yuma County Random EQ	6.5	CEUS Event	104, 28, 5, 8	201.22	7.64	2,633.00

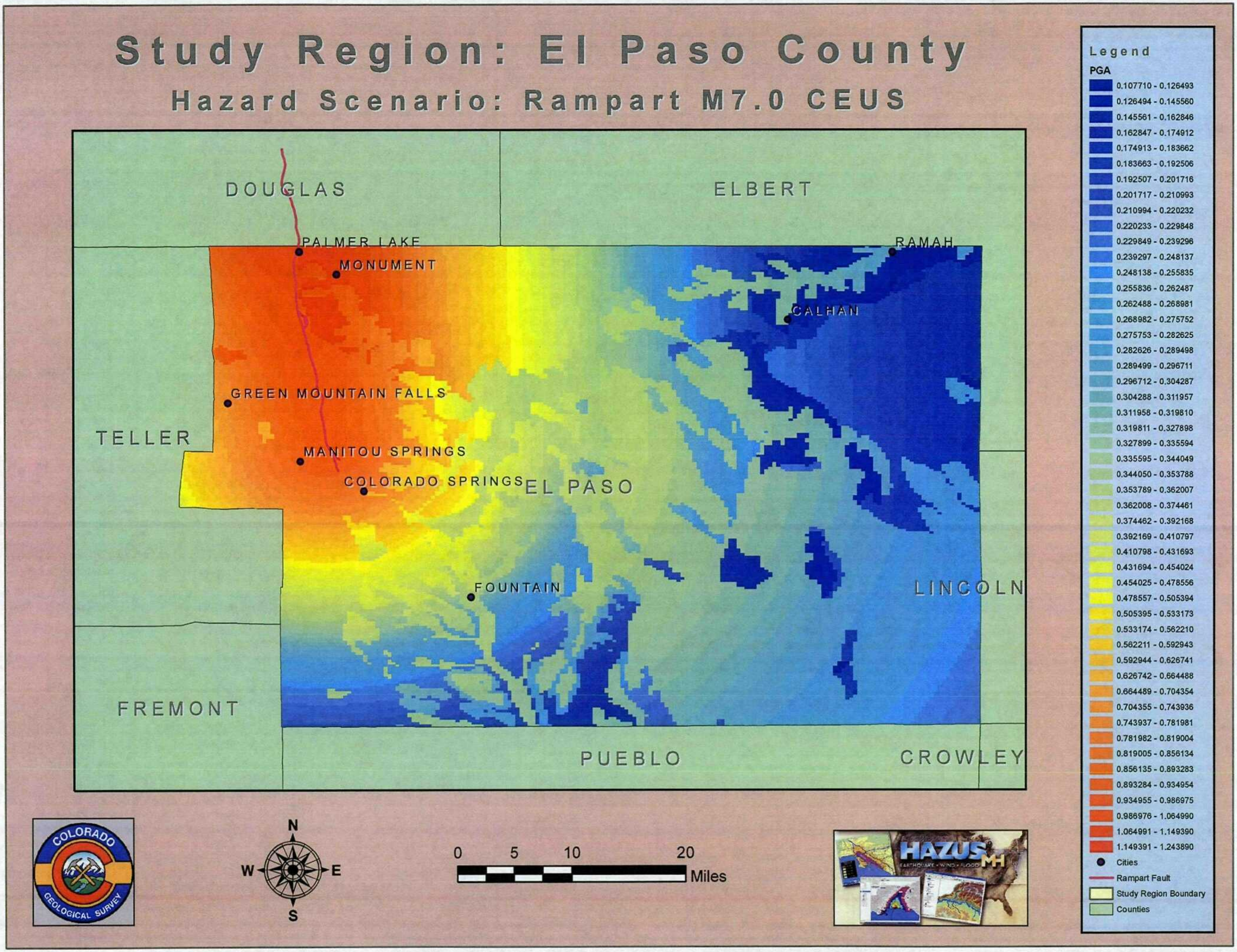
County Results Maps

El Paso County Rampart M7.0
Mesa County Random M7.0 - Schools

Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS

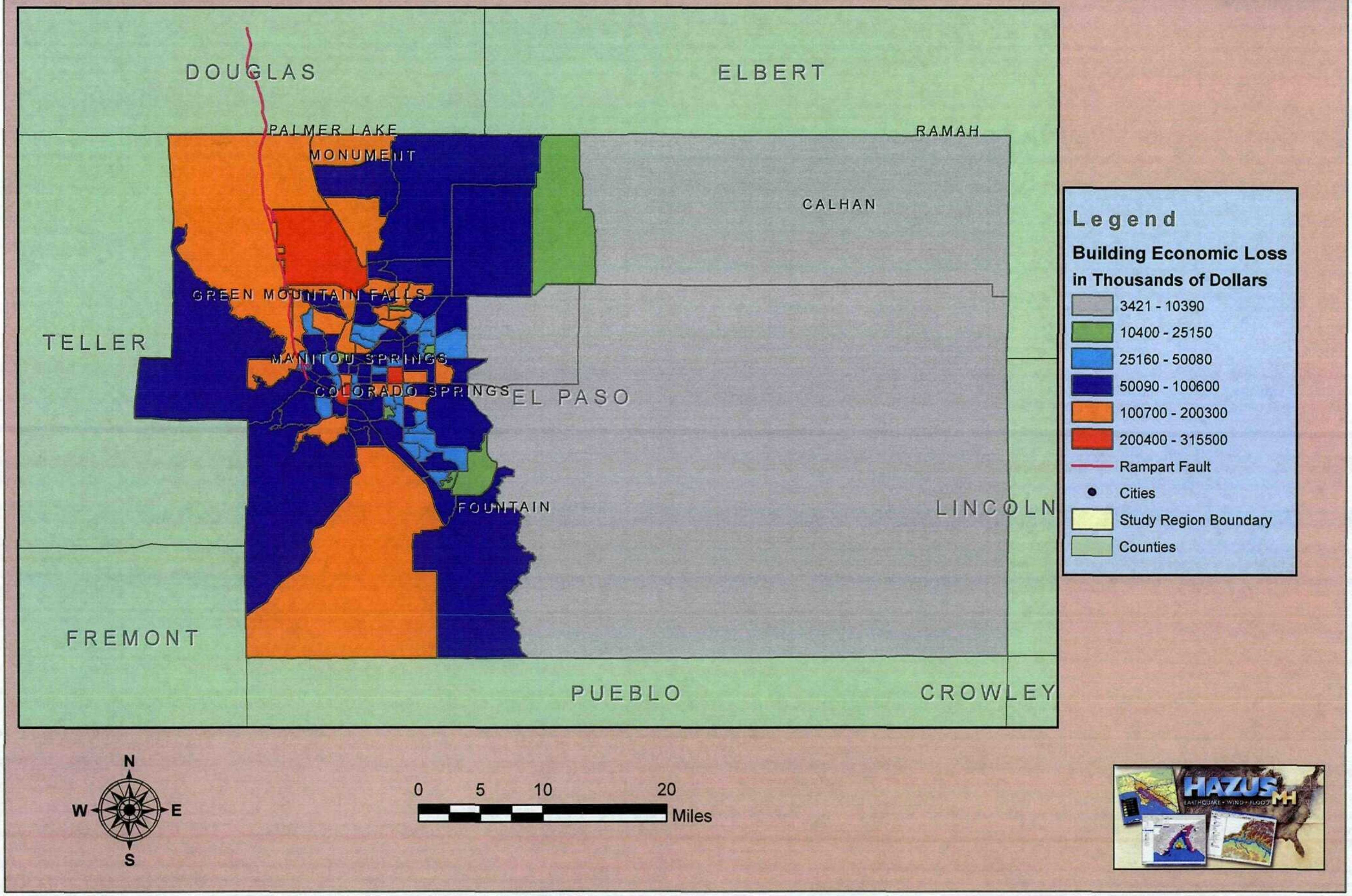



Study Region: El Paso County
Hazard Scenario: Rampart M7.0 CEUS
DOUGLAS
ELBERT
PALMER LAKE
MONUMENT
RAMAH
CALHAN
GREEN MOUNTAIN FALLS
TELLER
MANITOU SPRINGS
COLORADO SPRINGS
EL PASO
FOUNTAIN
LINCOLN
FREMONT
PUEBLO
CROWLEY
Legend
PGA
0.107710 - 0.126493
0.126494 - 0.145560
0.145561 - 0.162846
0.162847 - 0.174912
0.174913 - 0.183662
0.183663 - 0.192506
0.192507 - 0.201716
0.201717 - 0.210993
0.210994 - 0.220232
0.220233 - 0.229848
0.229849 - 0.239296
0.239297 - 0.248137
0.248138 - 0.255835
0.255836 - 0.262487
0.262488 - 0.268981
0.268982 - 0.275752
0.275753 - 0.282625
0.282626 - 0.289498
0.289499 - 0.296711
0.296712 - 0.304287
0.304288 - 0.311957
0.311958 - 0.319810
0.319811 - 0.327898
0.327899 - 0.335594
0.335595 - 0.344049
0.344050 - 0.353788
0.353789 - 0.362007
0.362008 - 0.374461
0.374462 - 0.392168
0.392169 - 0.410797
0.410798 - 0.431693
0.431694 - 0.454024
0.454025 - 0.478556
0.478557 - 0.505394
0.505395 - 0.533173
0.533174 - 0.562210
0.562211 - 0.592943
0.592944 - 0.626741
0.626742 - 0.664488
0.664489 - 0.704354
0.704355 - 0.743936
0.743937 - 0.781981
0.781982 - 0.819004
0.819005 - 0.856134
0.856135 - 0.893283
0.893284 - 0.934954
0.934955 - 0.986975
0.986976 - 1.064990
1.064991 - 1.149390
1.149391 - 1.243890
Cities
Rampart Fault
Study Region Boundary
Counties
COLORADO
GEOLOGICAL SURVEY
N
W
E
S
0 5 10 20
Miles
HAZUS MH

"At least" moderate includes moderate, extensive, & complete.

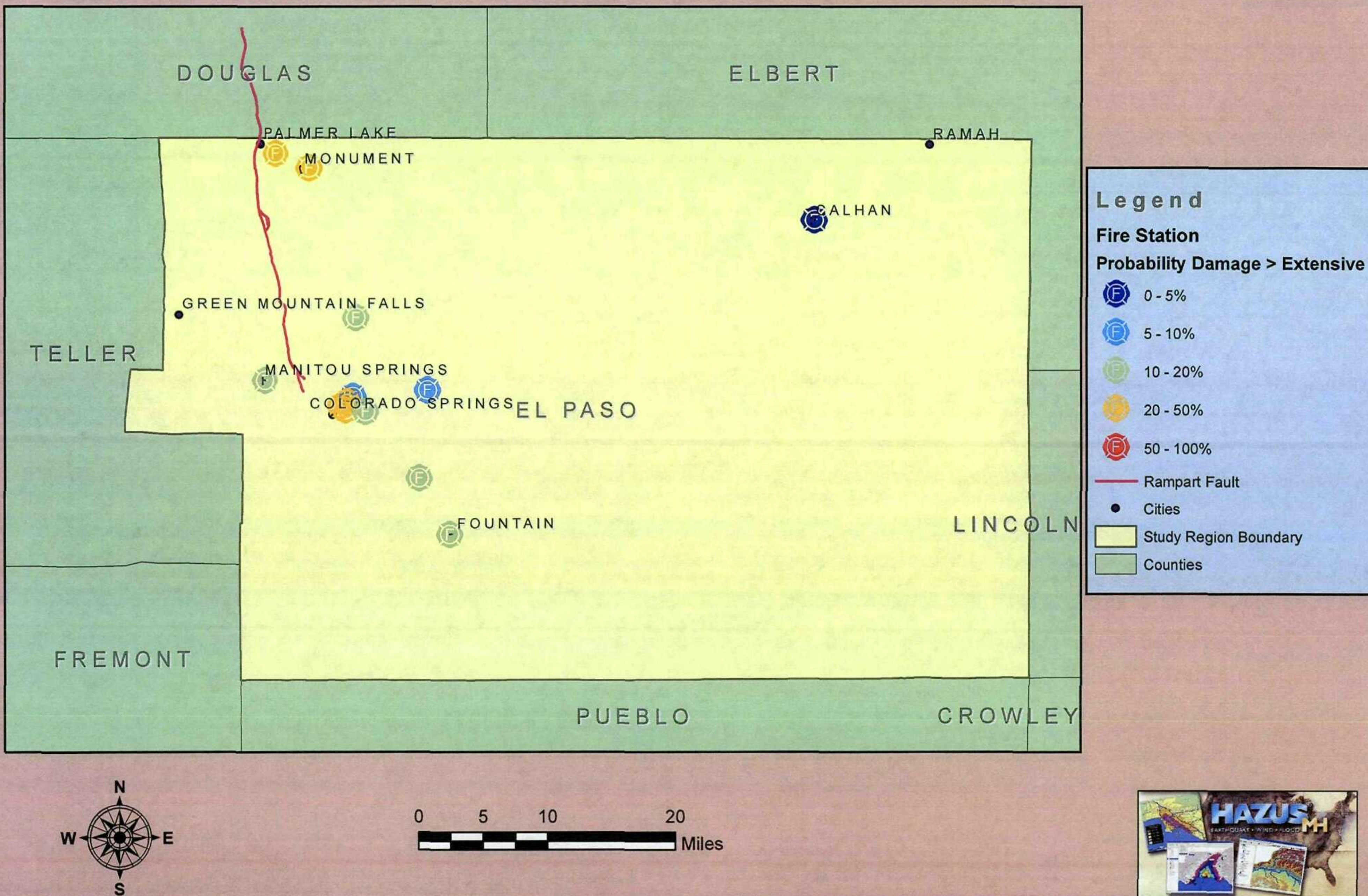
Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS



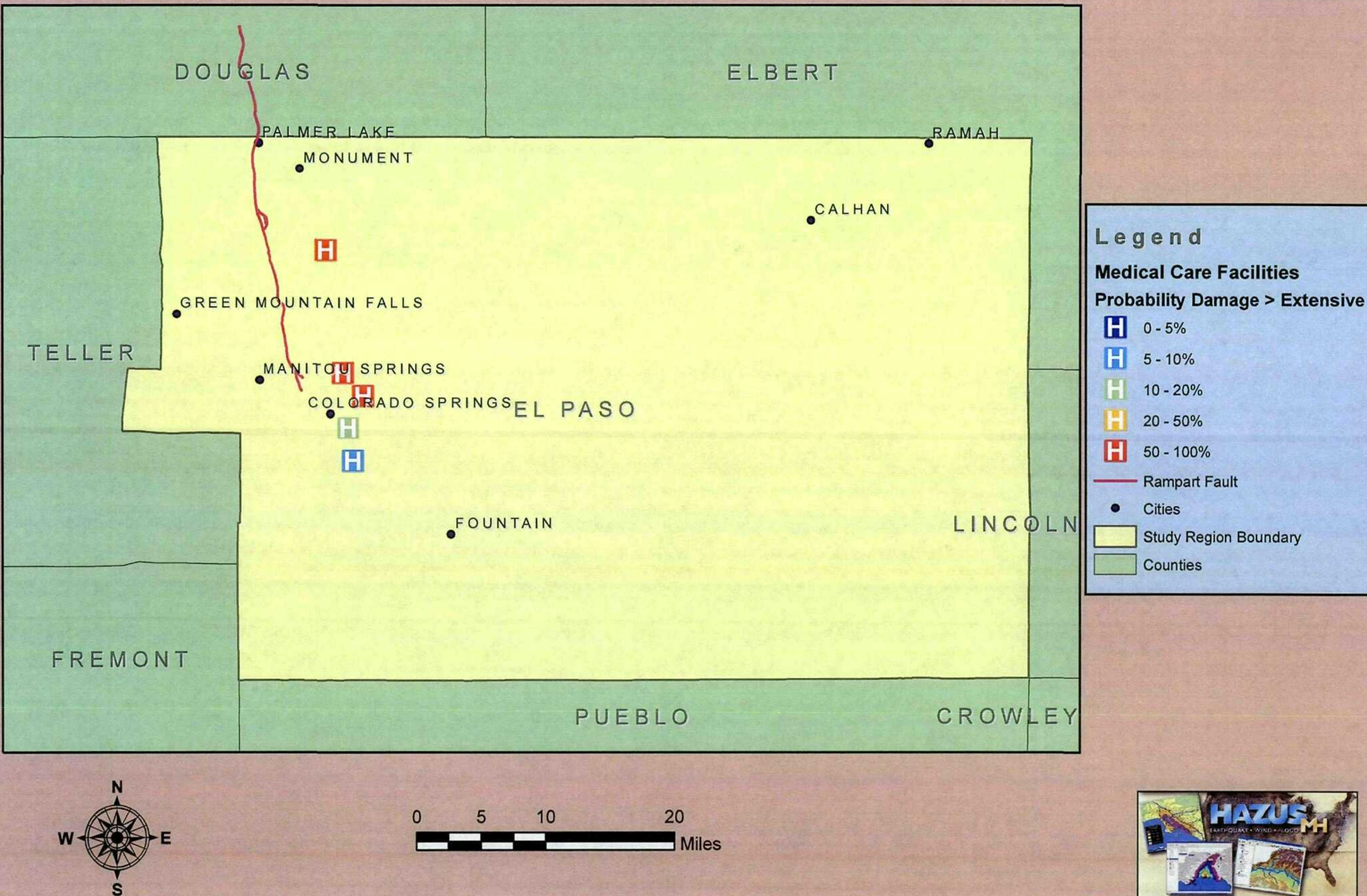
Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS



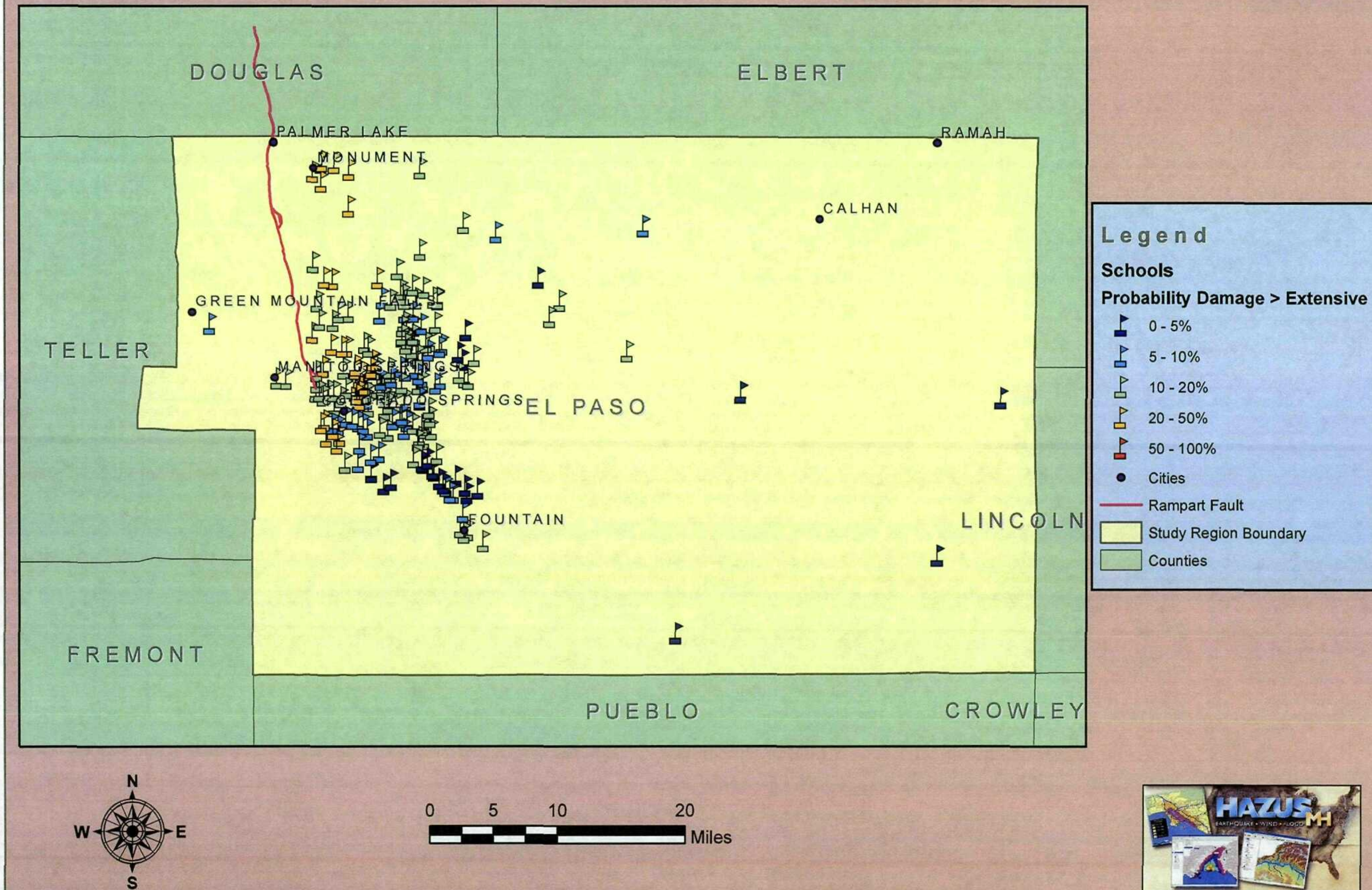
Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS



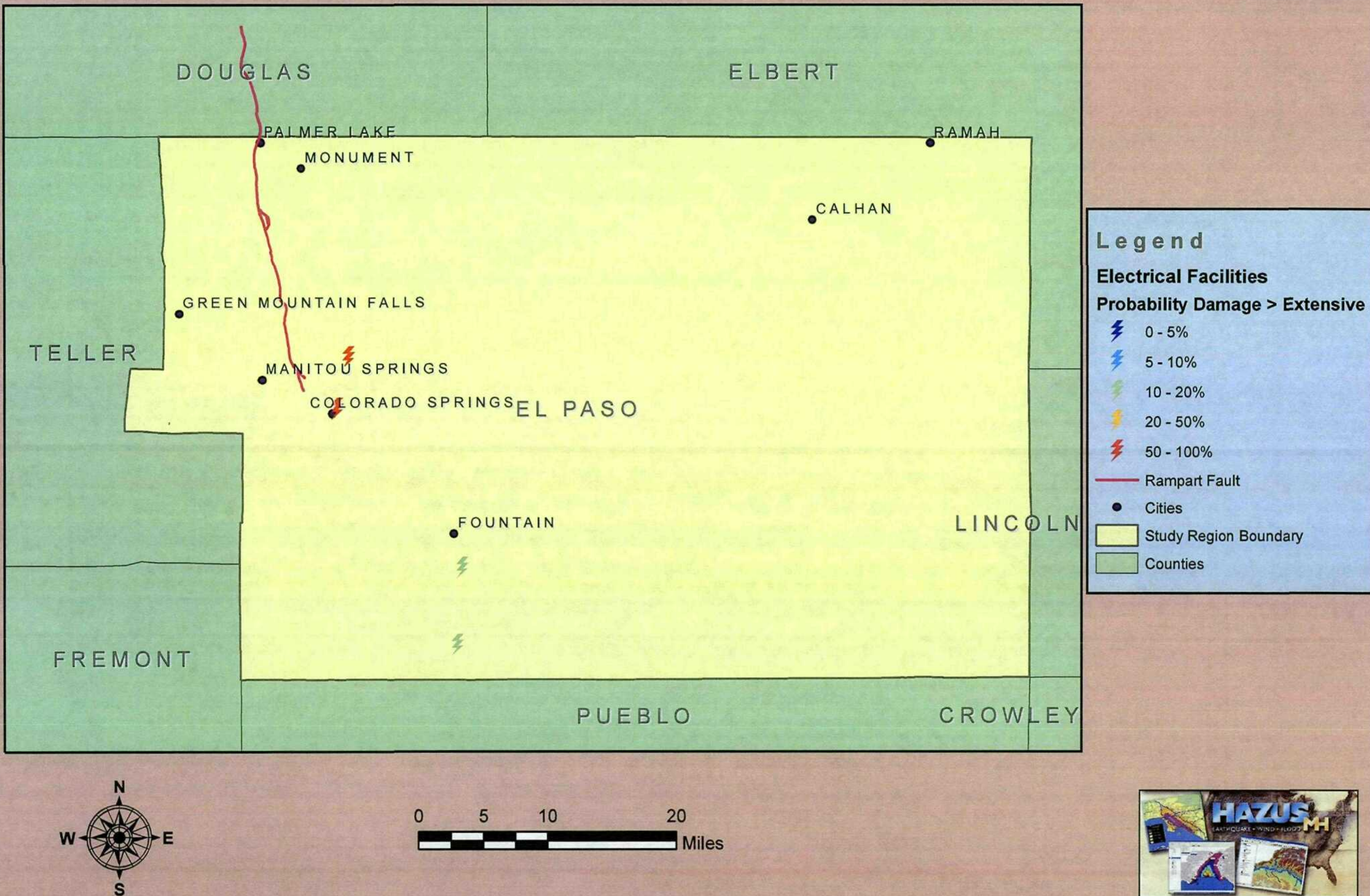
Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS



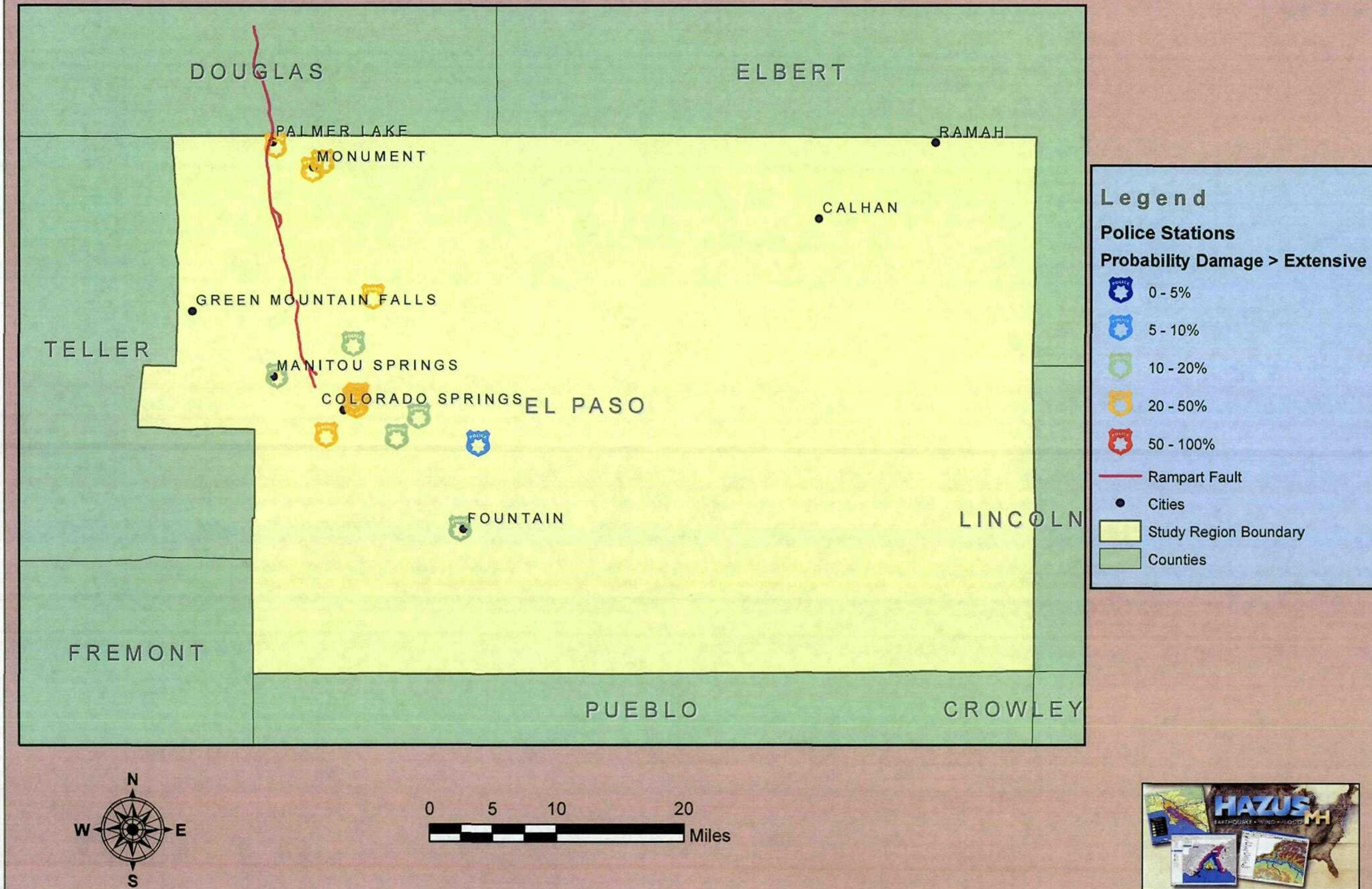
Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS



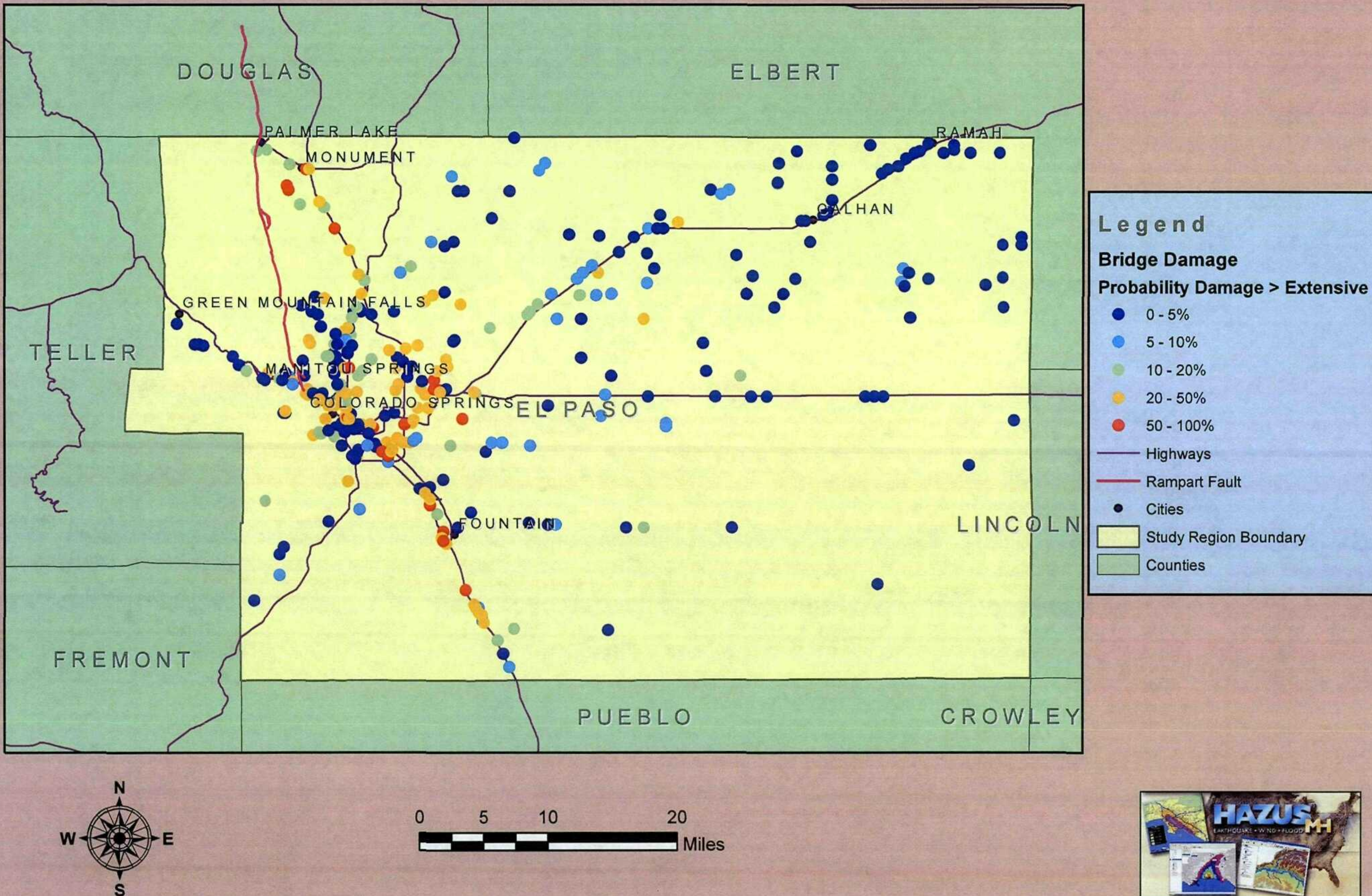
Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS



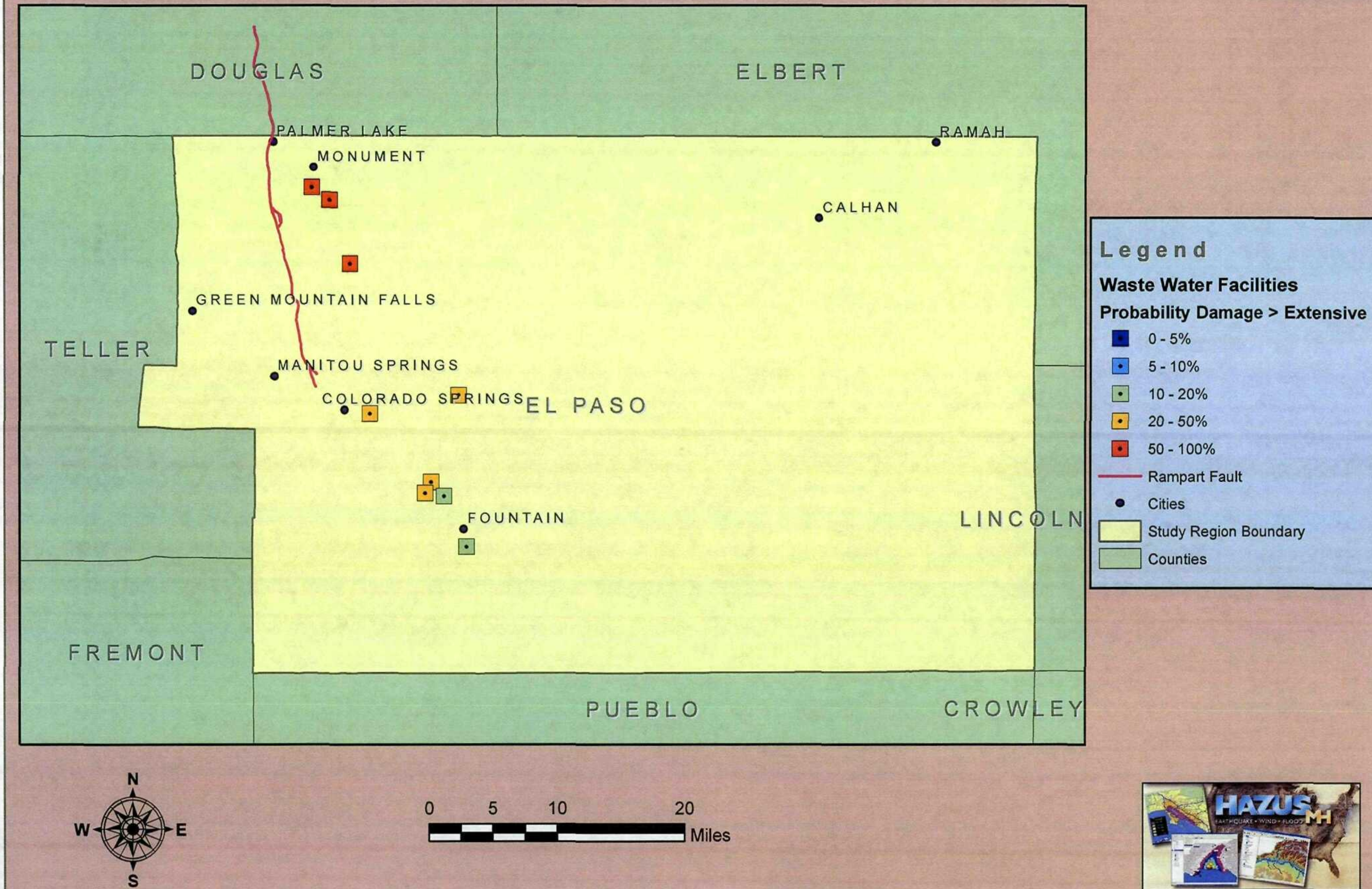
Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS



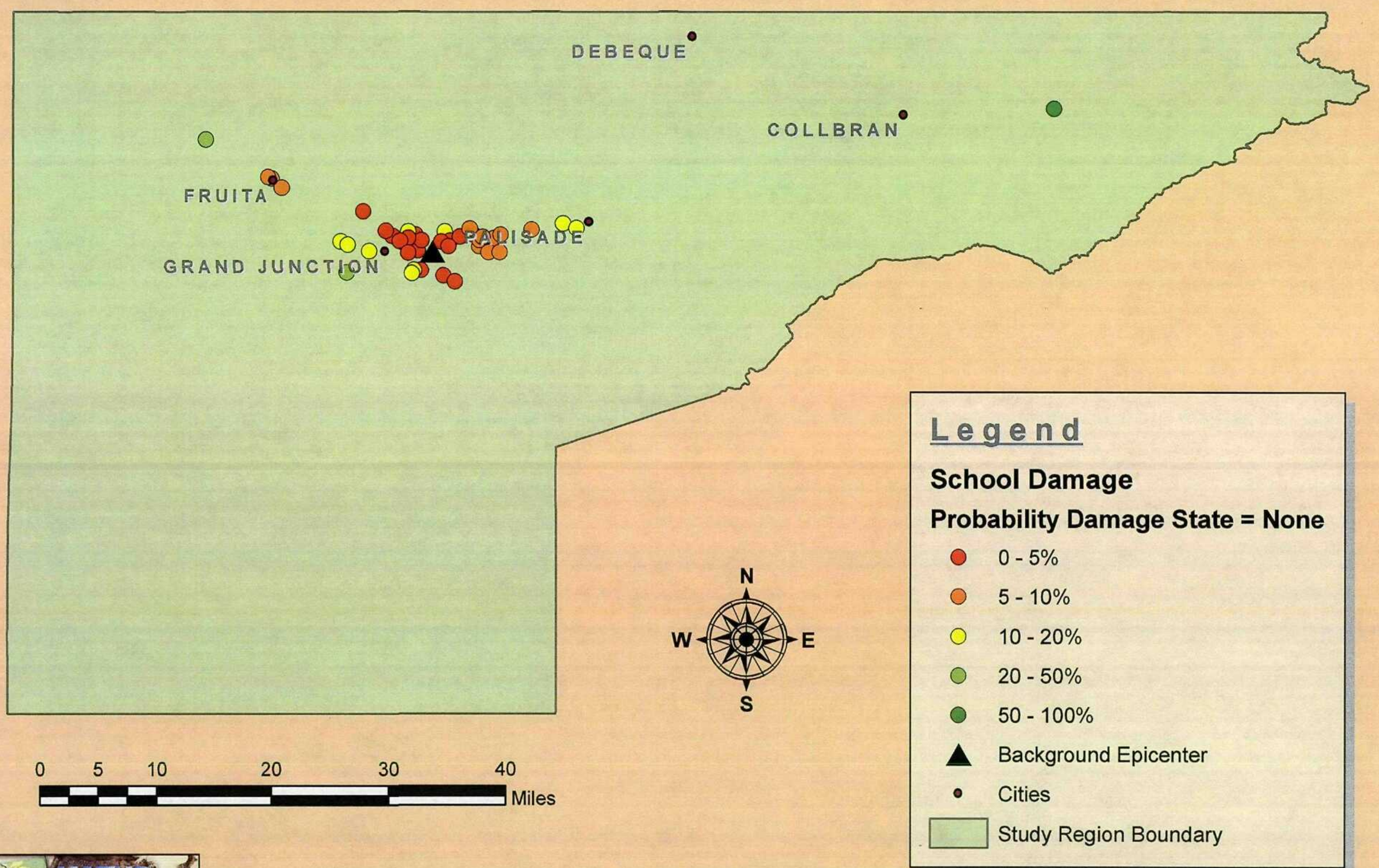
Study Region: El Paso County

Hazard Scenario: Rampart M7.0 CEUS



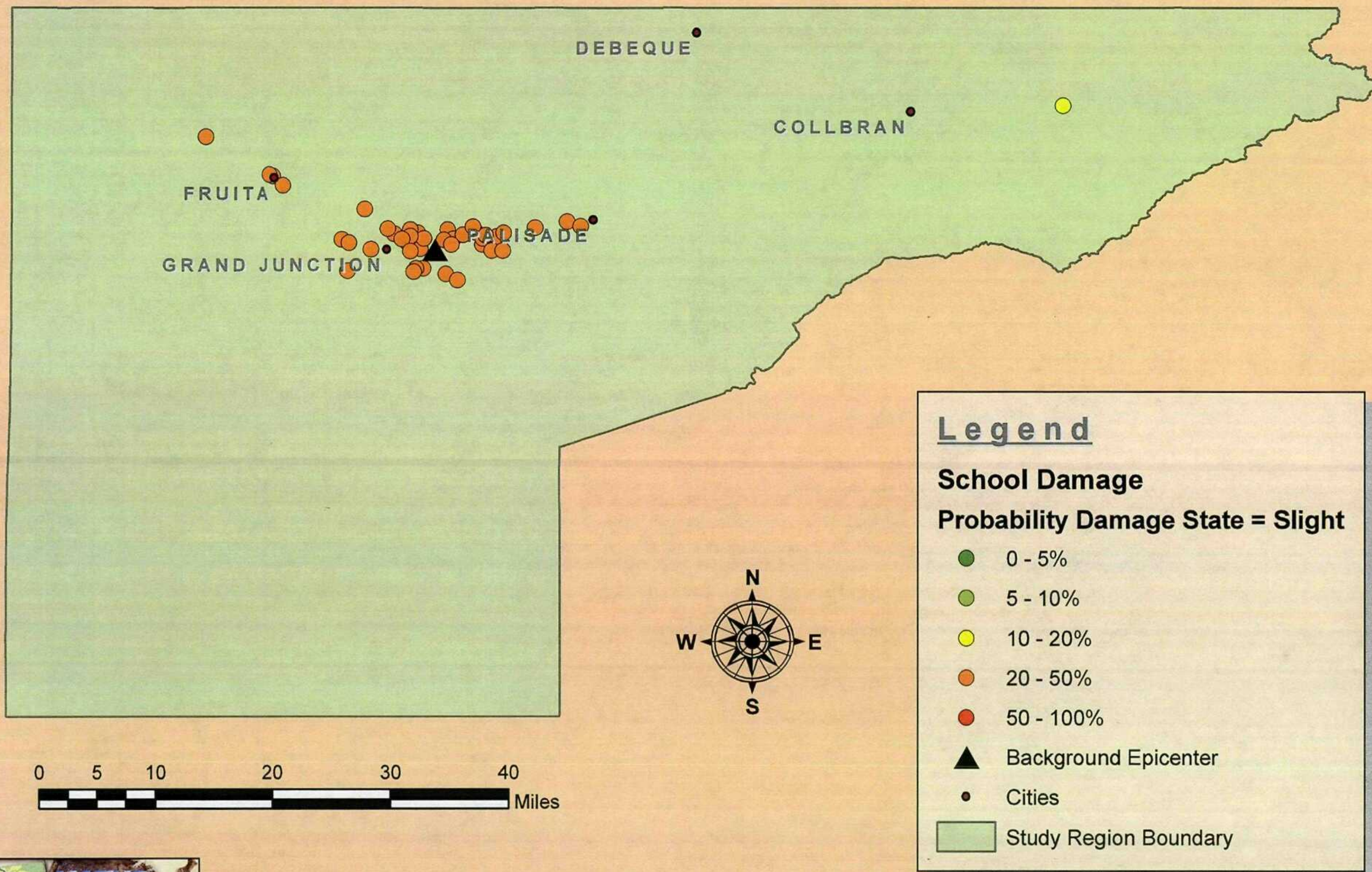
MESA COUNTY HAZUS SCENARIOS

Random Earthquake M 7.0



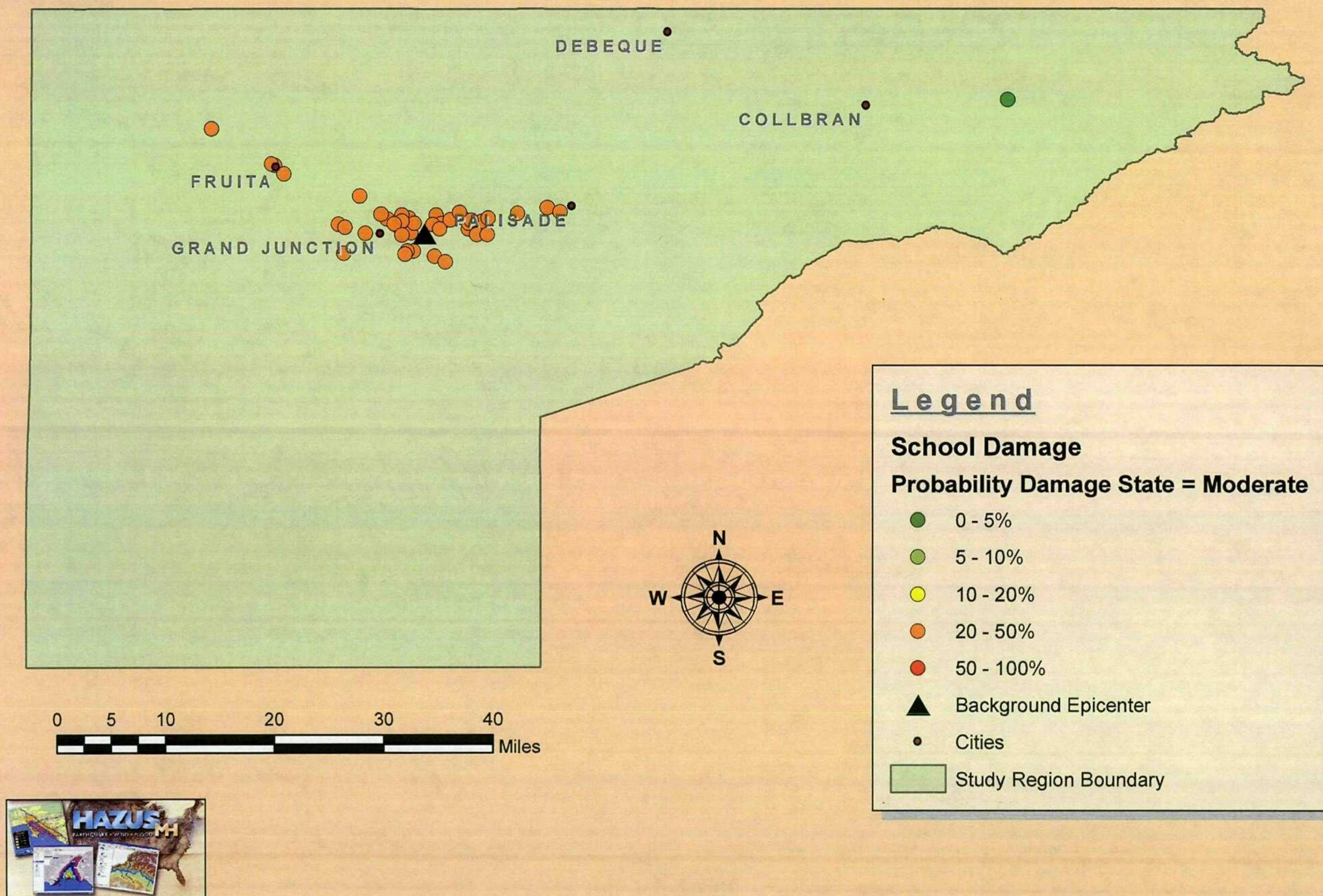
MESA COUNTY HAZUS SCENARIOS

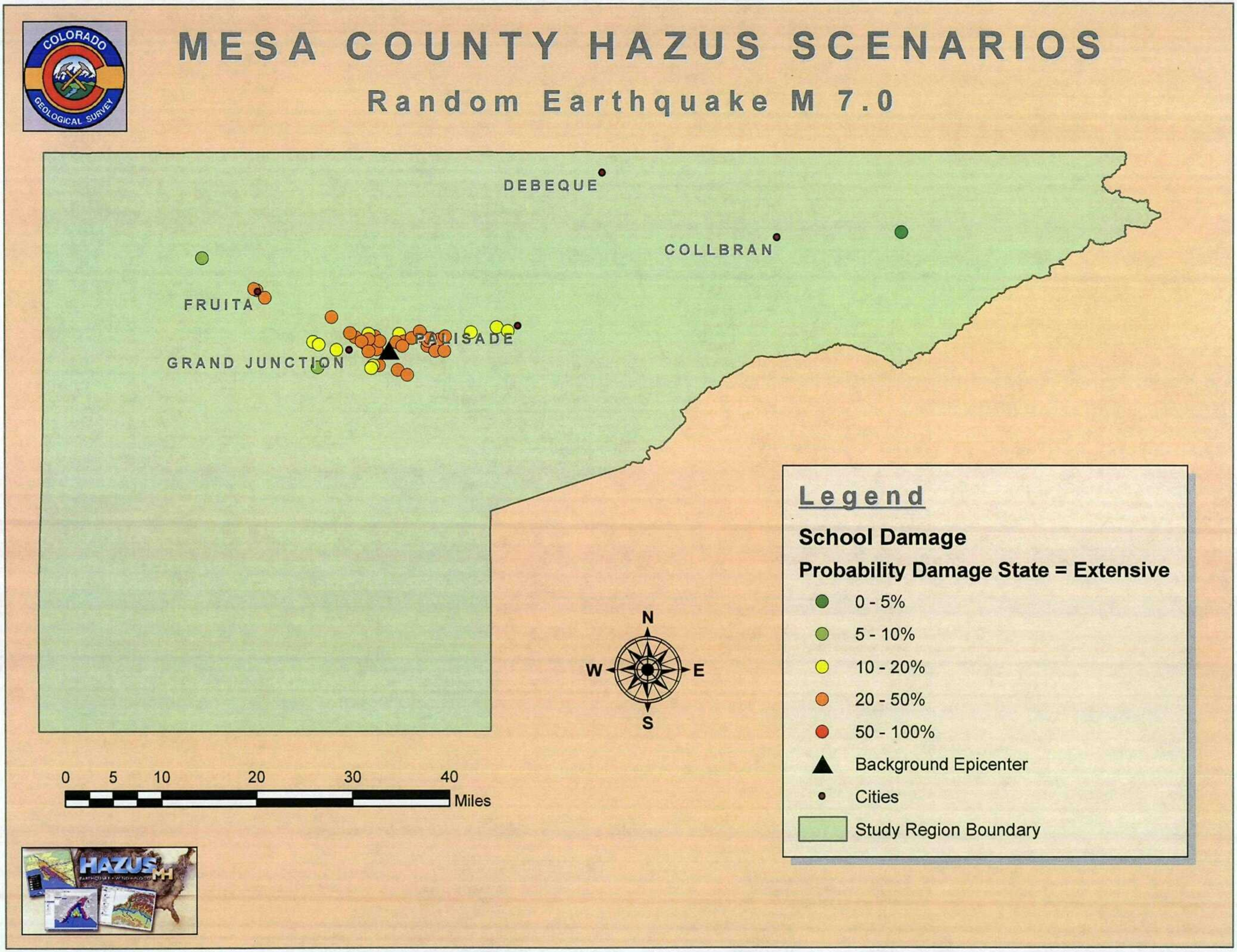
Random Earthquake M 7.0



MESA COUNTY HAZUS SCENARIOS

Random Earthquake M 7.0

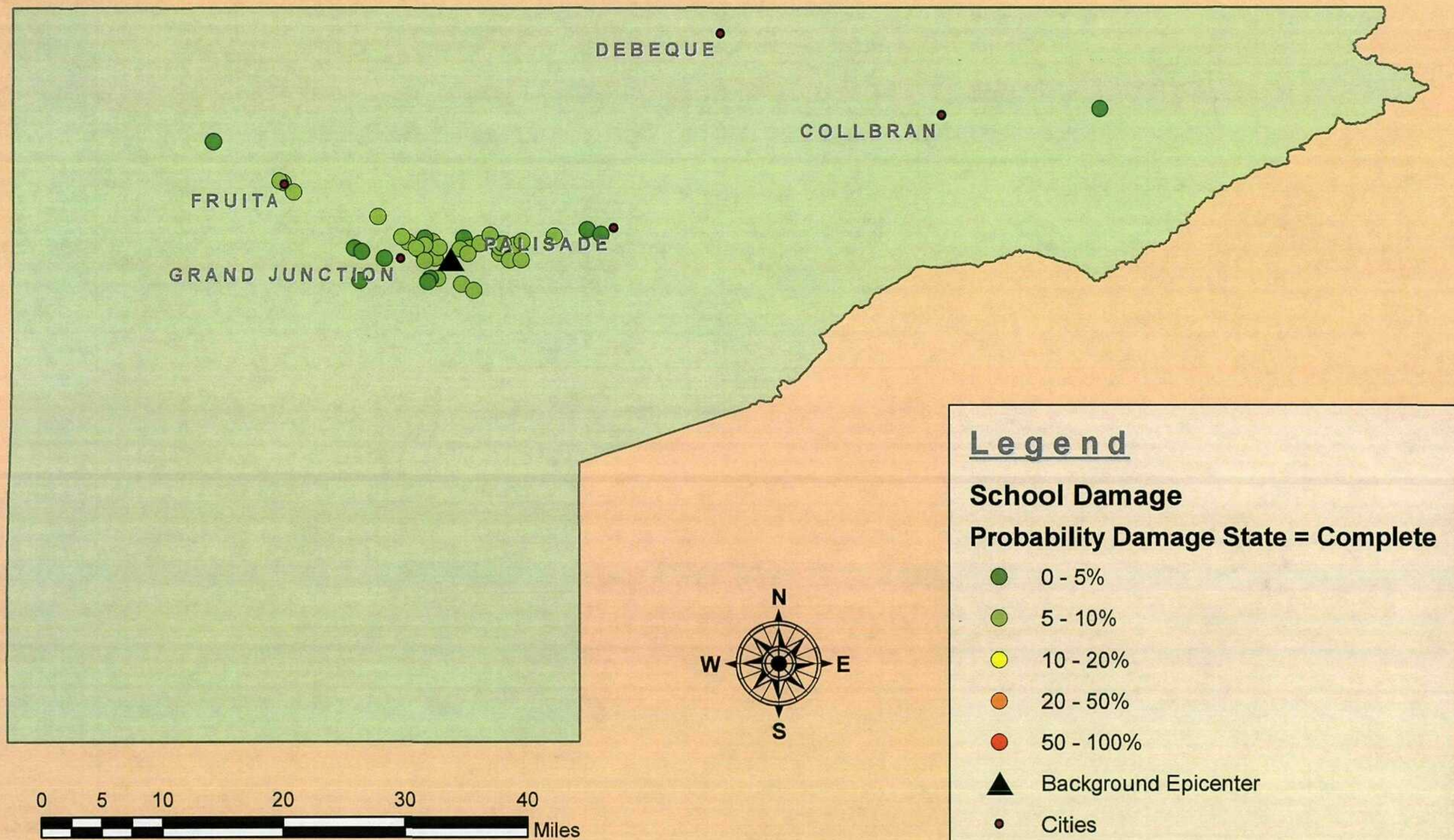




COLORADO GEOLOGICAL SURVEY
MESA COUNTY HAZUS SCENARIOS
Random Earthquake M 7.0
DEBEQUE
COLLBRAN
FRUITA
PALISADE
GRAND JUNCTION
N
W
E
S
0
5
10
20
30
40
Miles
Legend
School Damage
Probability Damage State = Extensive
0 - 5%
5 - 10%
10 - 20%
20 - 50%
50 - 100%
Background Epicenter
Cities
Study Region Boundary
HAZUS MH

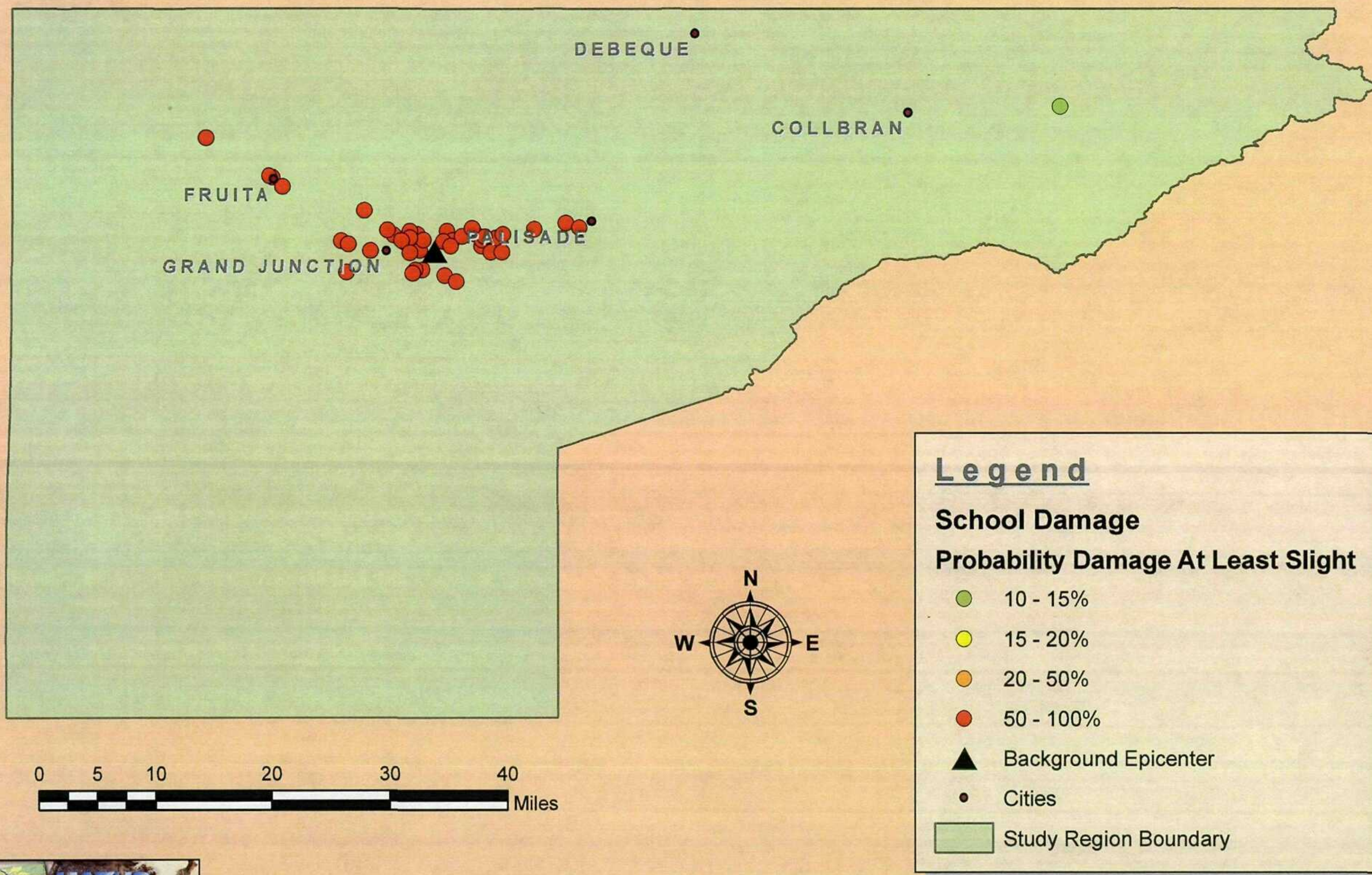
MESA COUNTY HAZUS SCENARIOS

Random Earthquake M 7.0



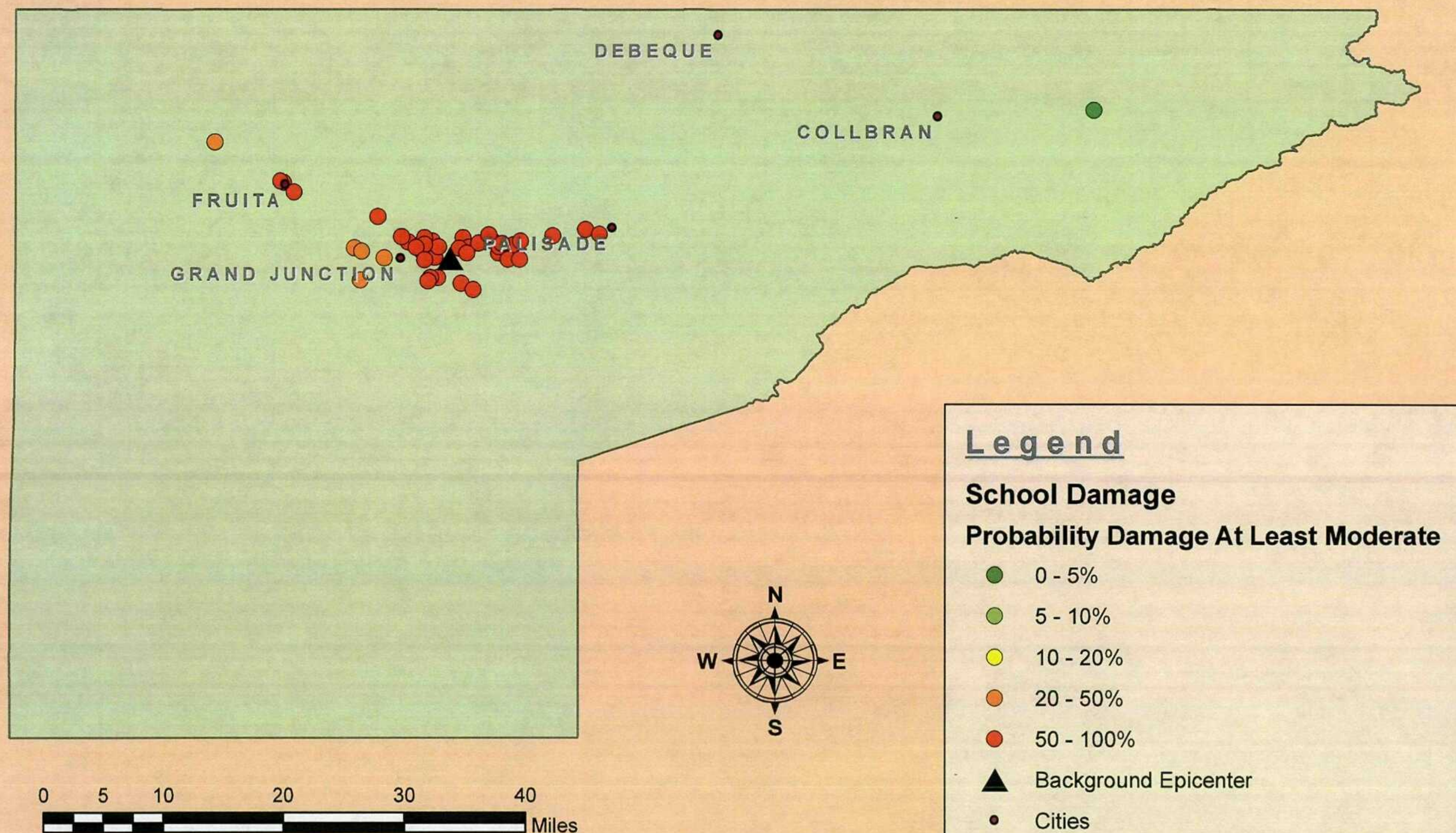
MESA COUNTY HAZUS SCENARIOS

Random Earthquake M 7.0



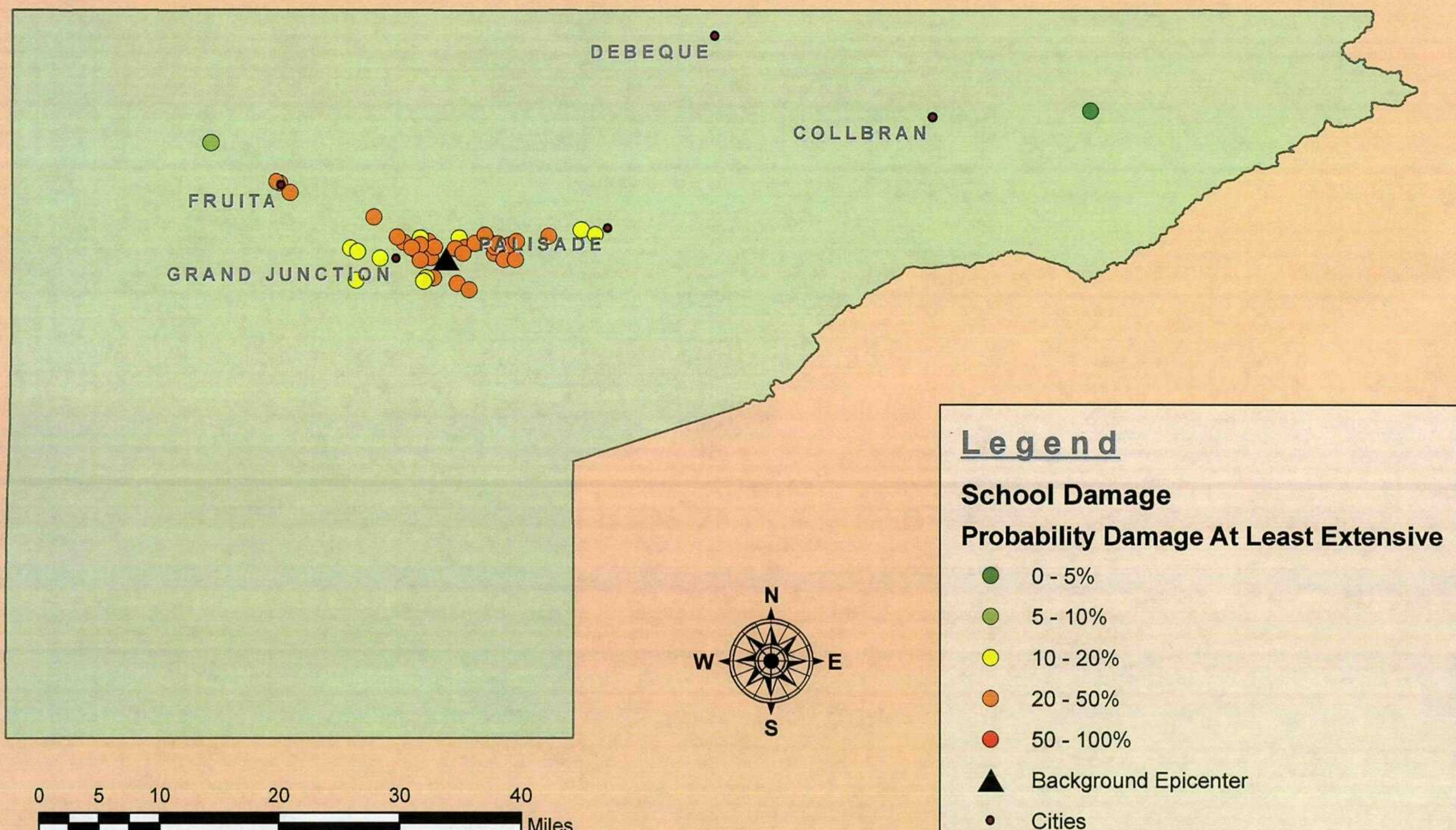
MESA COUNTY HAZUS SCENARIOS

Random Earthquake M 7.0



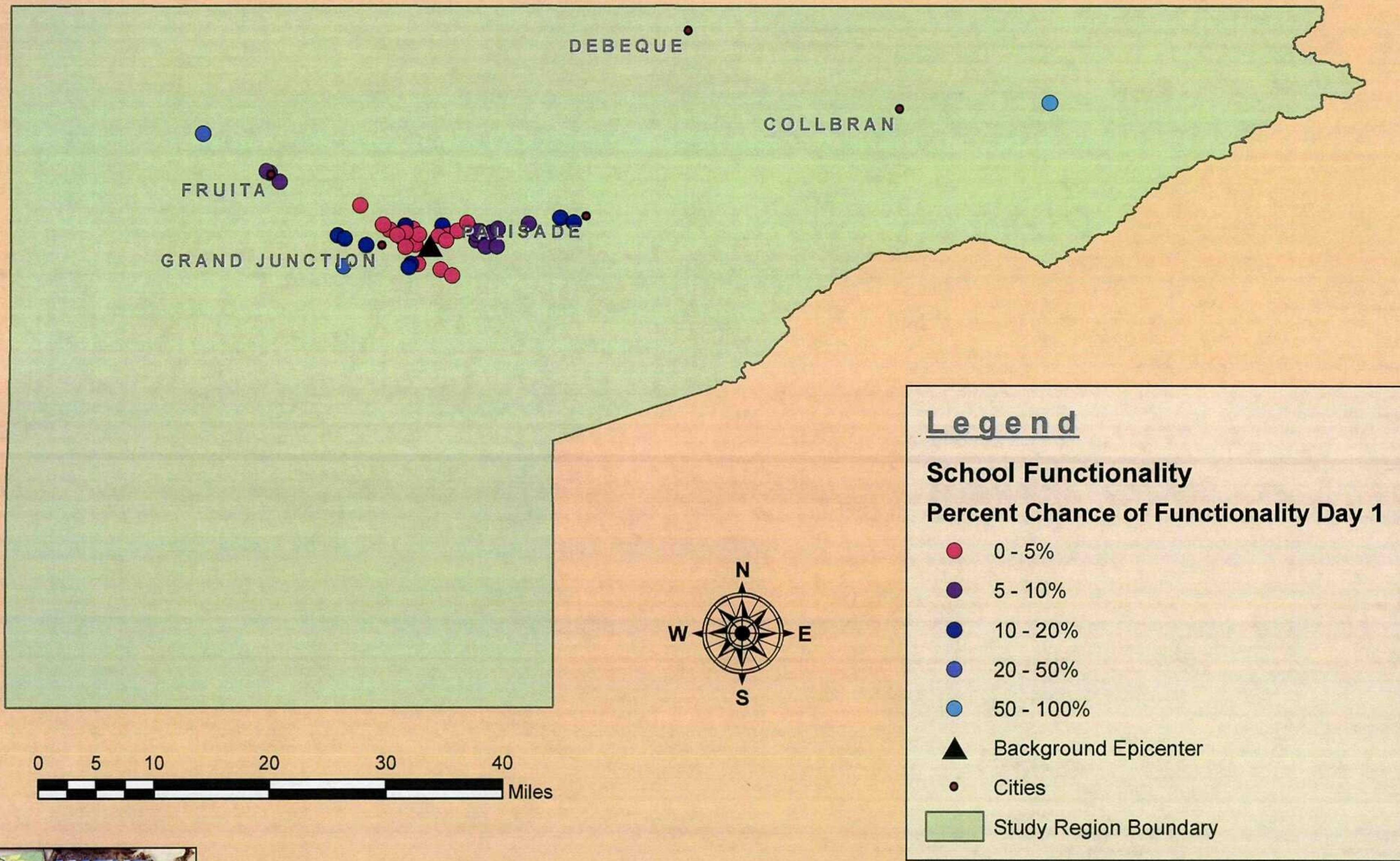
MESA COUNTY HAZUS SCENARIOS

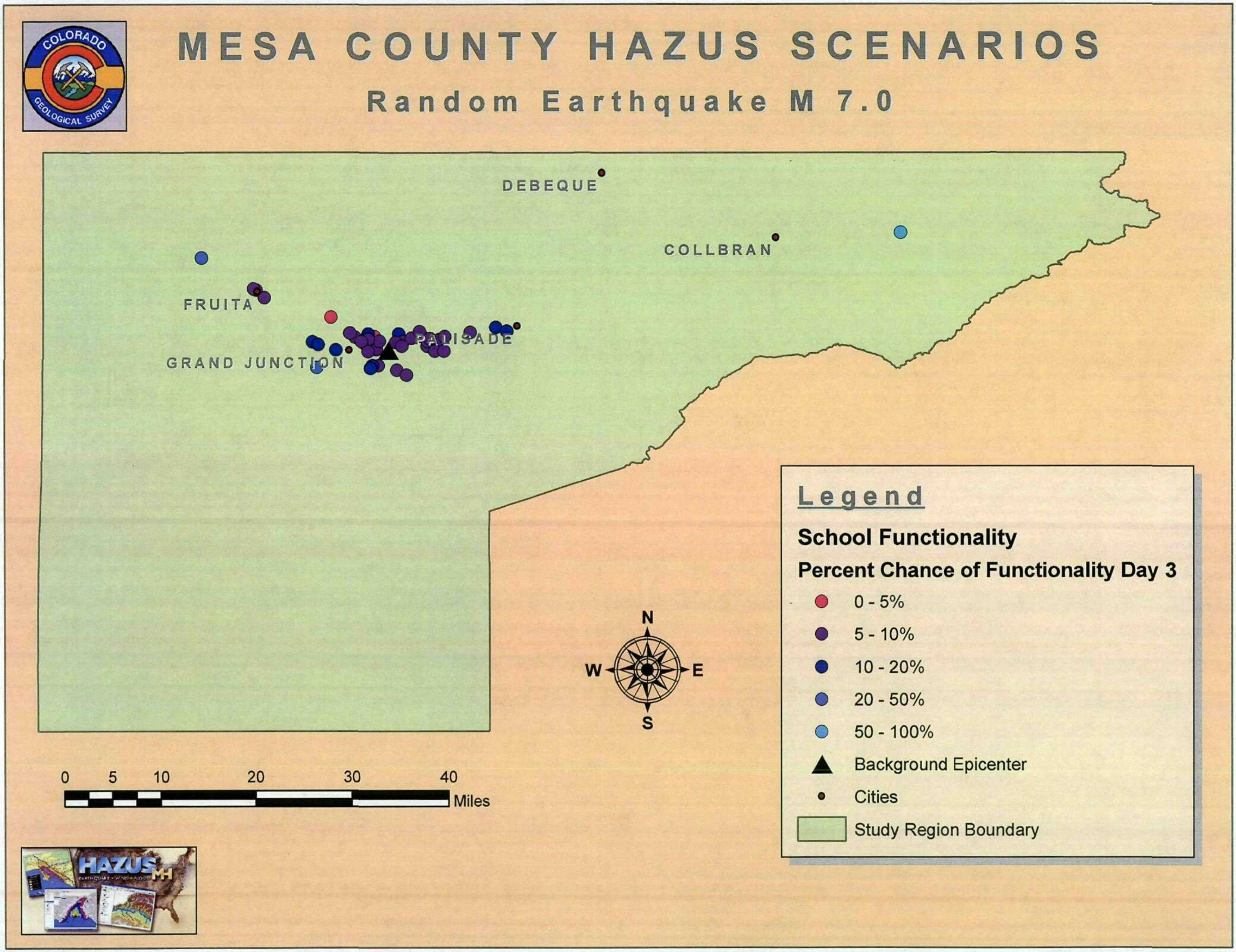
Random Earthquake M 7.0



MESA COUNTY HAZUS SCENARIOS

Random Earthquake M 7.0

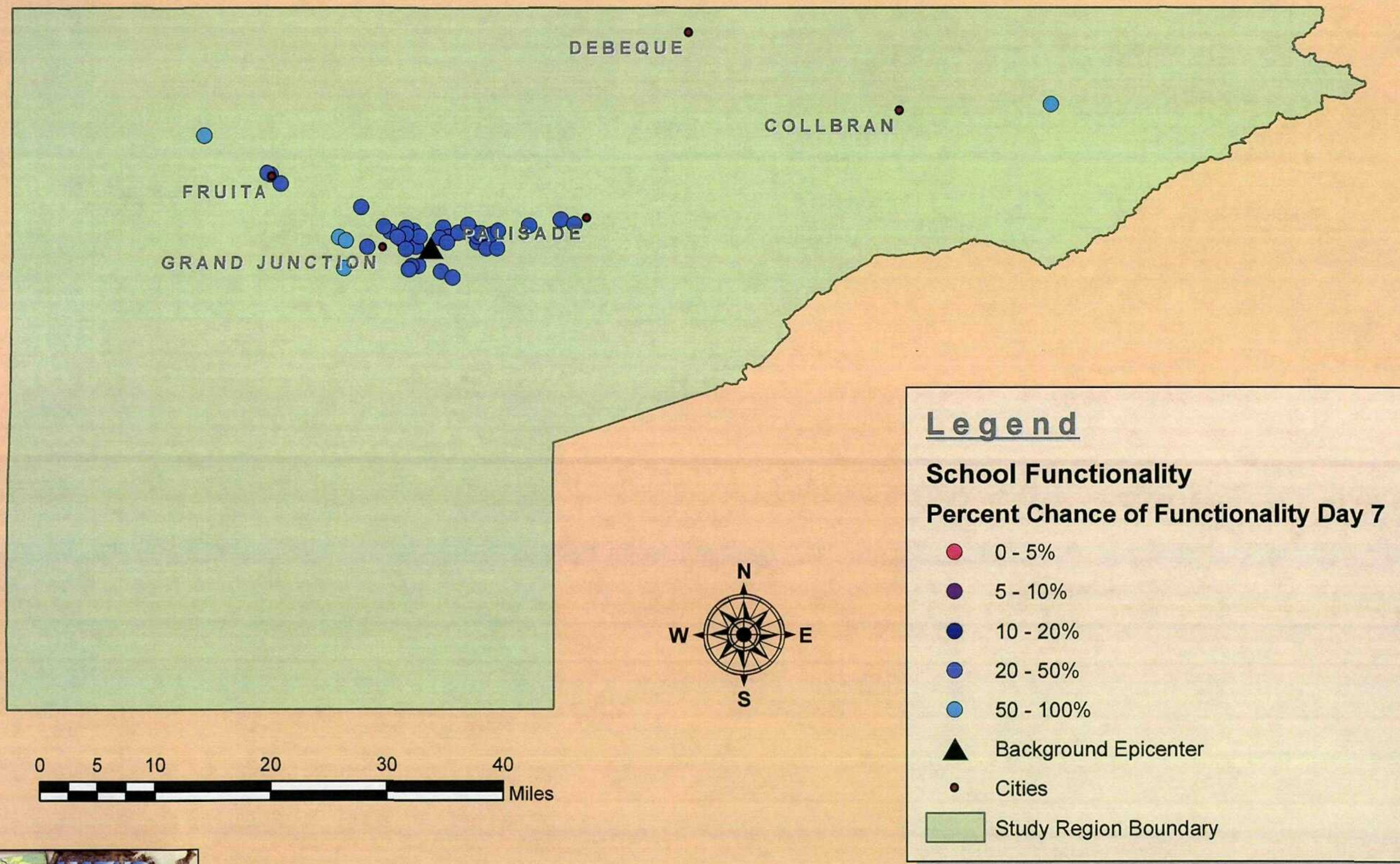




MESA COUNTY HAZUS SCENARIOS
Random Earthquake M 7.0
COLORADO GEOLOGICAL SURVEY
DEBEQUE
COLLBRAN
FRUITA
PALISADE
GRAND JUNCTION
N
W
E
S
0 5 10 20 30 40
Miles
Legend
School Functionality
Percent Chance of Functionality Day 3
0 - 5%
5 - 10%
10 - 20%
20 - 50%
50 - 100%
Background Epicenter
Cities
Study Region Boundary
HAZUS MH

MESA COUNTY HAZUS SCENARIOS

Random Earthquake M 7.0



MESA COUNTY HAZUS SCENARIOS

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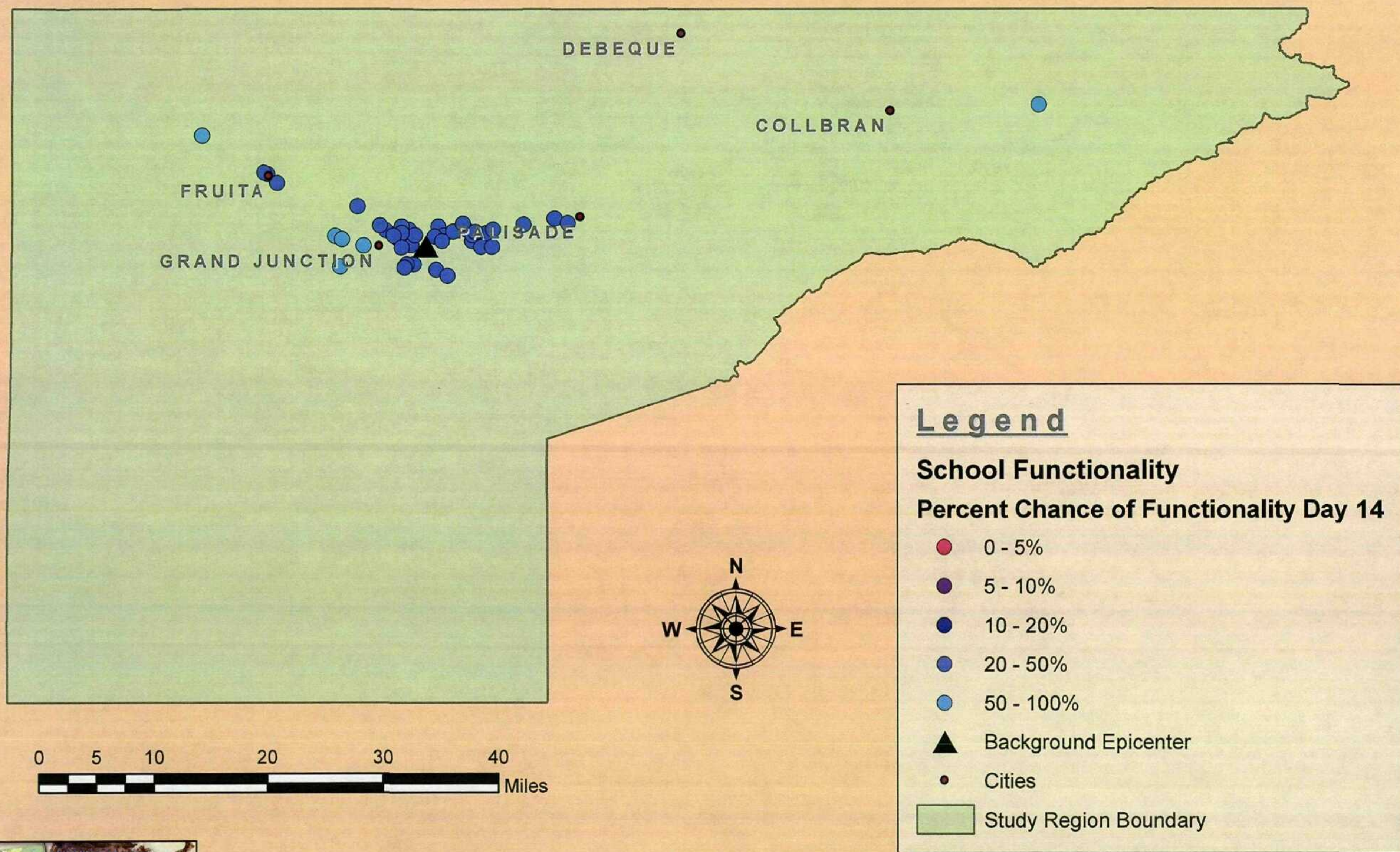
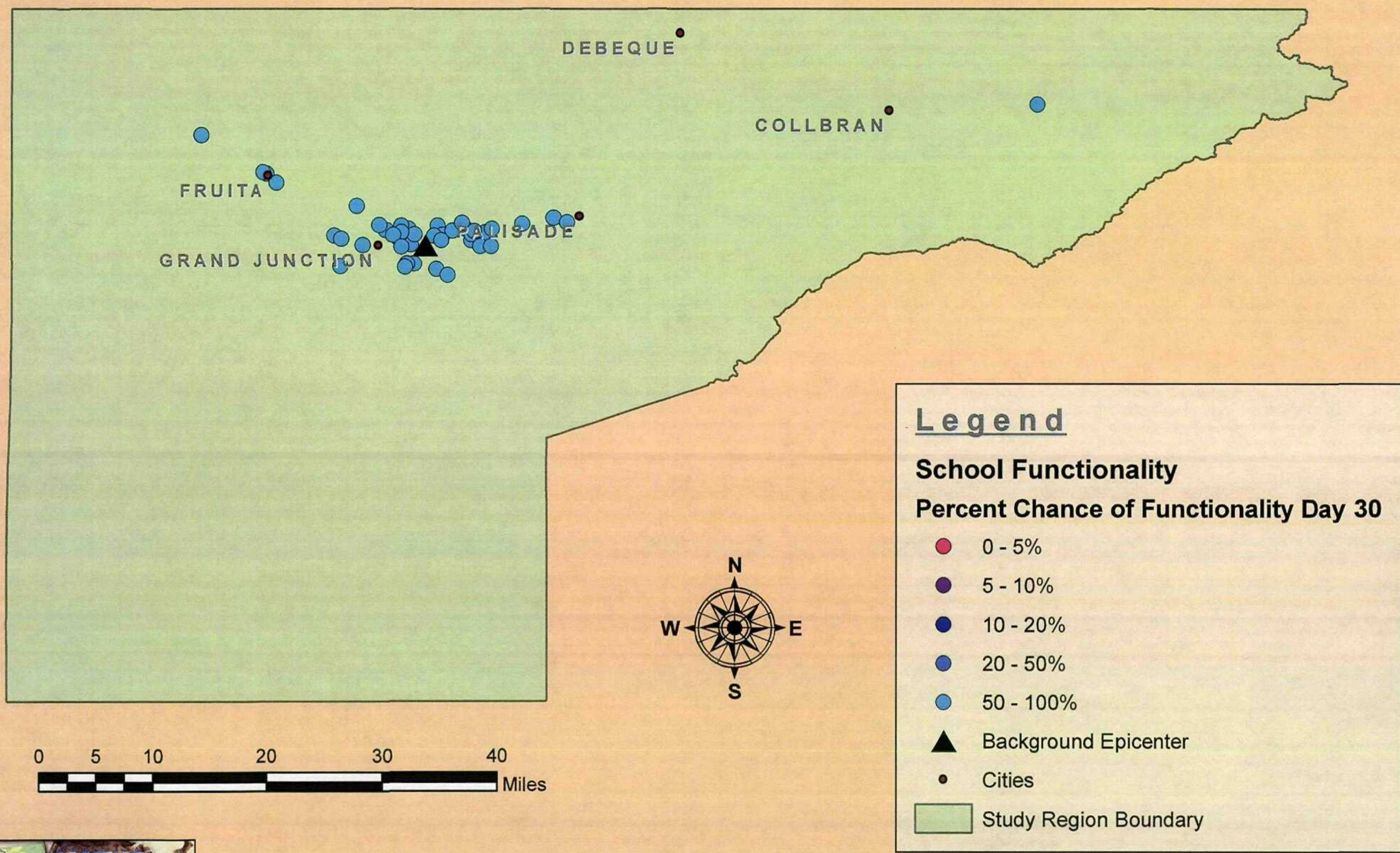


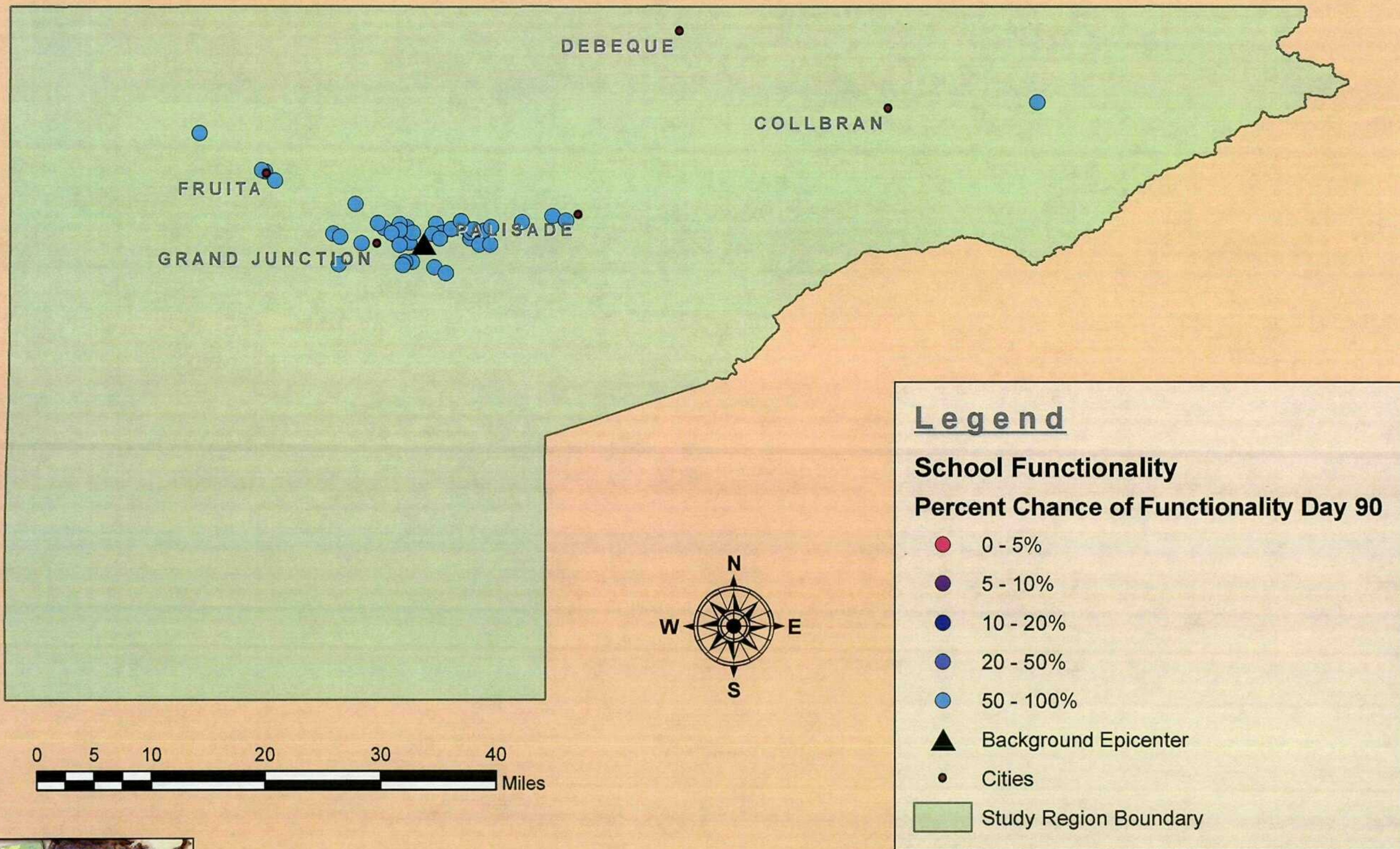
MESA COUNTY HAZUS SCENARIOS

Random Earthquake M 7.0

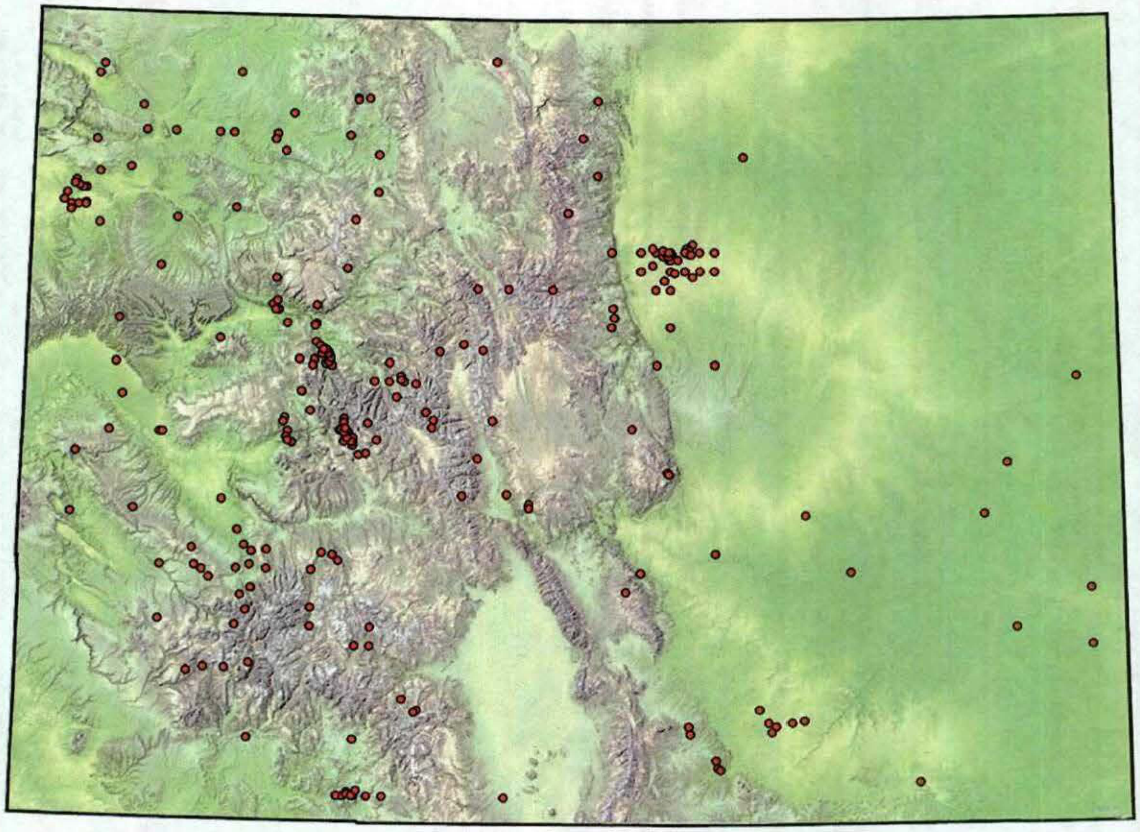


MESA COUNTY HAZUS SCENARIOS

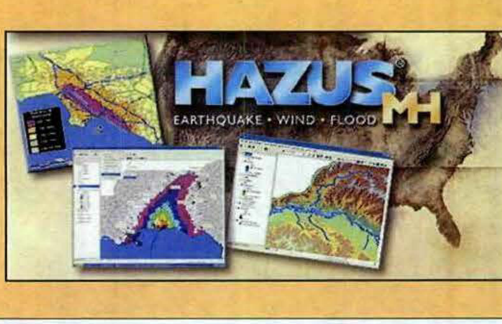
Random Earthquake M 7.0



HAZUS Supplementary Information



COLORADO GEOLOGICAL SURVEY



Earthquake Loss Estimates for Colorado using HAZUS-MH

Project Goal: Increase awareness of seismic consequences in Colorado by conducting numerous "what-if" scenarios throughout the state.

Participants: Lauren Heerschap, Matt Morgan, Jennifer McHarge, Trevor Burr (Metro State), Doug Bausch (FEMA), Vince Matthews

What is HAZUS-MH?

- Stands for Hazards U.S. – Multi-Hazard
- GIS-based loss estimation software developed by FEMA and NIBS (National Institute of Building Sciences) since 1990
- Can analyze potential losses from floods, hurricane winds, and earthquakes
- Considers physical damage, economic losses, social impacts, and indirect effects
- See http://www.fema.gov/plan/prevent/hazus/index.shtm and http://www.hazus.org/ for more information

How do HAZUS scenarios work?

- Run in ArcView 9.0 with latest HAZUS software
- Methodology draws from national inventory of demographic and built environment information and from USGS Hazard Map parameters
- CGS added soil maps, which increase accuracy of local ground shaking amplification
- User Input:
    - Scenario type – Deterministic or Probabilistic
    - Attenuation function and fault type
    - Epicenter coordinates, Magnitude, Fault orientation
    - Choice of analysis modules
- HAZUS Results:
    - Automatically-generated reports with summary tables
    - Mappable layers for physical damage, functionality, and economic loss
    - Casualties, shelter needs, displaced households
    - Contour maps showing ground shaking (Peak Ground Acceleration)

Other states doing HAZUS earthquake scenarios:

- Nevada Bureau of Mines and Geology, Open-File Report 06-1: http://www.nbmg.unr.edu/dox/of061/of061.htm
- California Geological Survey: http://www.consrv.ca.gov/CGS/rghm/loss/index.htm

Statewide Scenarios Ranked by Severity

Rank	Fault	Earthquake Magnitude	Economic Loss in State
1	Rampart Range	7	$23.1 Billion
2	Golden	6.5	$21.9 Billion
3	Ute Pass	7	$16.8 Billion
4	Rocky Mountain Arsenal	6.25	$14.9 Billion
5	Walnut Creek	6	$9.70 Billion
6	N Sangre de Cristo	7.5 CEUS	$8.02 Billion
7	Frontal	7	$6.73 Billion
8	Mosquito	7	$6.19 Billion
9	South Sawatch	7.25	$4.74 Billion
10	Chase Gulch (East-Side)	6.75	$3.76 Billion
11	North Sawatch	7	$3.62 Billion
12	Williams Fork	6.75	$3.48 Billion
13	1882 Rocky Mtn National Park	6.6	$2.76 Billion
14	Cheraw	7	$1.26 Billion
15	Cimarron	6.75	$808 Million
16	N Sangre de Cristo	7.5 WUS	$767 Million
17	Valmont	5	$712 Million
18	Busted Boiler	6.5	$694 Million
19	Cannibal	7	$675 Million
20	Goodpasture	6	$479 Million
21	Roubideau Creek East	5.5	$94.2 Million

CEUS = Central-Eastern U.S. Attenuation Function
WUS = Western U.S. Attenuation Function

These results show how important attenuation is for accurate ground shaking models. Colorado is in the boundary zone between the two functions, with only the San Luis Valley placed in the WUS zone by the USGS. The rest of Colorado lies in the CEUS zone and was analyzed in HAZUS based on this assumption.

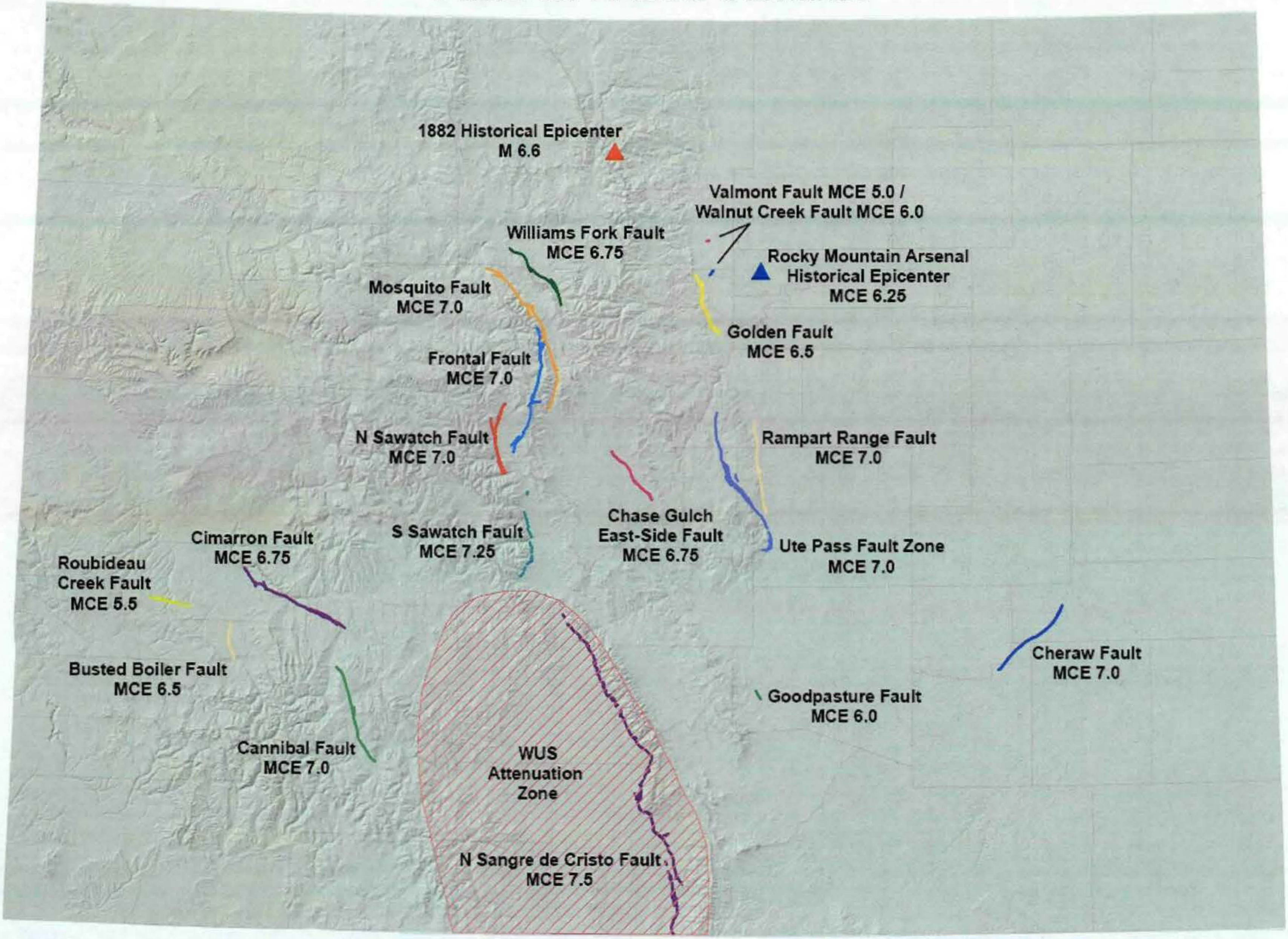
County Worst-Case Scenarios Ranked by Loss Ratio

Rank	County	Fault	Earthquake Magnitude	Economic Loss in County ($ Million)	Economic Loss Ratio (% total inventory)
1	Summit	Frontal	7.00	1,345.36	32.15%
2	Chaffee	S Sawatch	7.25	665.16	28.26%
3	El Paso	Rampart	7.00	9,013.76	27.67%
4	Lake	N Sawatch	7.00	302.50	27.53%
5	Lake	Mosquito	7.00	298.86	27.20%
6	Teller	Ute Pass	7.00	523.85	26.83%
7	Summit	Mosquito	7.00	1,056.71	25.26%
8	El Paso	Ute Pass	7.00	8,216.92	25.23%
9	Alamosa	N Sangre de Cristo	7.5 CEUS	433.09	23.54%
10	Denver	Golden	6.50	7,510.48	19.24%
11	Chaffee	N Sangre de Cristo	7.5 CEUS	425.76	18.09%
12	Jefferson	Golden	6.50	5,881.32	16.42%
13	Custer	N Sangre de Cristo	7.5 CEUS	138.38	15.77%
14	Adams	Rocky Mtn Arsenal	6.25	3,148.06	14.97%
15	Denver	Rocky Mtn Arsenal	6.25	5,557.58	14.24%
16	Otero	Cheraw	7.00	415.54	14.16%
17	Douglas	Rampart	7.00	1,848.03	13.49%
18	Ouray	Busted Boiler	6.50	104.19	13.33%
19	Montrose	Cimarron	6.75	497.40	13.18%
20	Arapahoe	Golden	6.50	3,900.99	12.10%
21	Denver	Rampart	7.00	4,652.06	11.92%
22	Arapahoe	Rampart	7.00	3,835.78	11.90%
23	Eagle	Frontal	7.00	571.47	11.40%
24	Fremont	N Sangre de Cristo	7.5 CEUS	393.64	10.47%
25	Hinsdale	Cannibal	7.00	35.15	10.12%

Loss Ratio = Scenario Economic Loss / Region's Total Inventory x 100

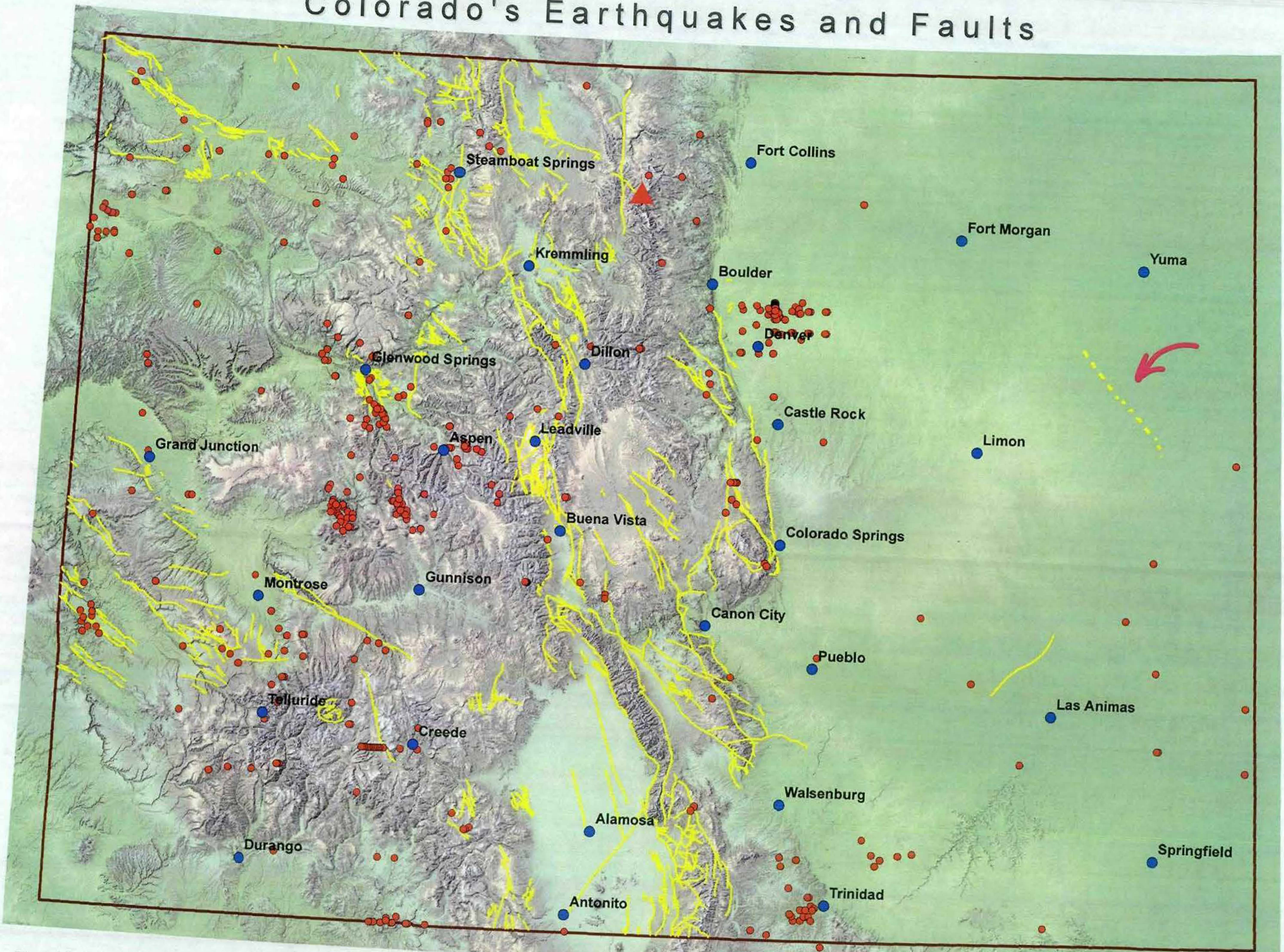
Loss Ratio presents a more *relative* view of a disaster's impact upon a community than dollar amounts alone. $500 Million loss in Denver County is a very different situation than $500 Million loss in Ouray County...

Faults for HAZUS Scenarios



MCE = Maximum Credible Earthquake Magnitude, determined by rupture length-magnitude relationships

Colorado's Earthquakes and Faults



Red Dots = Historical Earthquake Locations

Yellow Lines = Known Faults

Dashed Yellow Line = Anton Suspect Scarp

HAZUS-MH: Earthquake Event Report

Region Name: ***State of Colorado Probabilistic***

Earthquake Scenario: ***2500-yr Probabilistic Statewide***

Print Date: ***April 26, 2006***

Disclaimer:

The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

Table of Contents

General Description of the Region

HAZUS is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of HAZUS is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 63 county(ies) from the following state(s):

Colorado

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 103,979.78 square miles and contains 1,062 census tracts. There are over 1,658 thousand households in the region and has a total population of 4,301,261 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 1,373 thousand buildings in the region with a total building replacement value (excluding contents) of 253,527 (millions of dollars). Approximately 99.00 % of the buildings (and 0.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 77,869 and 19,265 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 1,373 thousand buildings in the region which have an aggregate total replacement value of 253,527 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 70% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilities into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 81 hospitals in the region with a total bed capacity of 11,042 beds. There are 1,695 schools, 206 fire stations, 275 police stations and 10 emergency operation facilities. With respect to HPL facilities, there are 1,633 dams identified within the region. Of these, 320 of the dams are classified as 'high hazard'. The inventory also includes 613 hazardous material sites, 0 military installations and 1 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within HAZUS, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 2 and 3.

The total value of the lifeline inventory is over 97,134.00 (millions of dollars). This inventory includes over 14,981 kilometers of highways, 7,750 bridges, 461,345 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	7,750	7,441.40
	Segments	1,782	56,078.90
	Tunnels	30	123.70
		Subtotal	**63,644.00**
Railways	Bridges	132	17.30
	Facilities	30	63.40
	Segments	2,682	4,133.20
	Tunnels	0	0.00
		Subtotal	**4,214.00**
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
		Subtotal	**7.20**
Bus	Facilities	34	35.90
		Subtotal	**35.90**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	249	1,316.30
	Runways	287	8,652.40
		Subtotal	**9,968.70**
		Total	**77,869.80**

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	4,613.50
	Facilities	29	936.70
	Pipelines	0	0.00
		Subtotal	**5,550.20**
Waste Water	Distribution Lines	NA	2,768.10
	Facilities	189	12,209.80
	Pipelines	0	0.00
		Subtotal	**14,977.80**
Natural Gas	Distribution Lines	NA	1,845.40
	Facilities	311	328.80
	Pipelines	0	0.00
		Subtotal	**2,174.20**
Oil Systems	Facilities	38	3.70
	Pipelines	0	0.00
		Subtotal	**3.70**
Electrical Power	Facilities	54	5,761.80
		Subtotal	**5,761.80**
Communication	Facilities	250	24.30
		Subtotal	**24.30**
		Total	**28,492.00**

Earthquake Scenario

HAZUS uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	2500-yr Probabilistic Statewide
Type of Earthquake	Probabilistic
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	2,500.00
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	6.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

HAZUS estimates that about 123,087 buildings will be at least moderately damaged. This is over 9.00 % of the total number of buildings in the region. There are an estimated 2,402 buildings that will be damaged beyond repair. The definition of the ' damage states' is provided in Volume 1: Chapter 5 of the HAZUS technical manual. Table 4 below summaries the expected damage by general occupancy for the buildings in the region. Table 5 summaries the expected damage by general building type.

Table 4: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	57	0.01	15	0.01	13	0.01	5	0.02	1	0.03
Commercial	10,641	1.00	2,515	1.32	2,387	2.49	870	3.51	125	5.21
Education	52	0.00	8	0.00	7	0.01	2	0.01	0	0.01
Government	421	0.04	112	0.06	114	0.12	41	0.16	6	0.23
Industrial	987	0.09	224	0.12	231	0.24	88	0.35	12	0.50
Other Residential	86,400	8.15	26,402	13.88	22,909	23.88	5,624	22.71	631	26.27
Religion	525	0.05	111	0.06	94	0.10	32	0.13	4	0.17
Single Family	961,056	90.65	160,784	84.55	70,162	73.15	18,107	73.10	1,624	67.58
Total	**1,060,139**		**190,171**		**95,916**		**24,770**		**2,402**	

Table 5: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	781,126	73.68	133246	70.07	36,186	37.73	3,783	15.27	198	8.25
Steel	4,423	0.42	922	0.48	1,104	1.15	392	1.58	66	2.76
Concrete	4,160	0.39	1095	0.58	987	1.03	321	1.30	32	1.35
Precast	1,744	0.16	401	0.21	556	0.58	300	1.21	35	1.44
RM	190,344	17.95	27157	14.28	31,180	32.51	12,756	51.50	738	30.73
URM	22,205	2.09	7350	3.86	6,024	6.28	2,407	9.72	790	32.90
MH	56,136	5.30	20000	10.52	19,880	20.73	4,811	19.42	542	22.58
Total	**1,060,139**		**190,171**		**95,916**		**24,770**		**2,402**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 11,042 hospital beds available for use. On the day of the earthquake, the model estimates that only 6,527 hospital beds (59.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 84.00% of the beds will be back in service. By 30 days, 98.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	81	0	0	46
Schools	1,695	0	0	1,673
EOCs	10	0	0	10
PoliceStations	275	0	0	246
FireStations	206	0	0	194

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Locations/ Segments	Number of Locations With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Segments	1,782	0	0	1,782	1,782
	Bridges	7,750	3	0	7,748	7,750
	Tunnels	30	0	0	30	30
Railways	Segments	2,682	0	0	2,682	2,682
	Bridges	132	0	0	132	132
	Tunnels	0	0	0	0	0
	Facilities	30	0	0	30	30
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	34	0	0	34	34
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	249	0	0	249	249
	Runways	287	0	0	287	287

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	29	1	0	26	29
Waste Water	189	14	0	98	189
Natural Gas	311	12	0	299	311
Oil Systems	38	0	0	23	38
Electrical Power	54	1	0	40	54
Communication	250	9	0	250	250

Table 9 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	230,673	2593	648
Waste Water	138,404	2051	513
Natural Gas	92,269	2192	548
Oil	0	0	0

Table 10: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	1,658,238	0	0	0	0	0
Electric Power		0	0	0	0	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 41 ignitions that will burn about 0.22 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 73 people and burn about 4 (millions of dollars) of building value.

Debris Generation

HAZUS estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 1.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 35.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 40,000 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

HAZUS estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates (11, 482 households to be displaced due to the earthquake. Of these, 2,946 people (out of a total population of 4,301,261 will seek temporary shelter in public shelters.

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1:Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2:Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3:Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4:Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 11 provides a summary of the casualties estimated for this earthquake

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	39	8	1	2
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	32	6	1	1
	Industrial	43	8	1	2
	Other-Residential	834	131	11	21
	Single Family	1,641	264	28	54
	Total	**2,590**	**417**	**41**	**80**
2 PM	Commercial	2,247	450	57	112
	Commuting	0	0	1	0
	Educational	292	56	7	13
	Hotels	6	1	0	0
	Industrial	319	62	8	15
	Other-Residential	148	23	2	4
	Single Family	293	48	5	10
	Total	**3,305**	**641**	**80**	**154**
5 PM	Commercial	1,639	329	42	81
	Commuting	14	17	30	6
	Educational	47	9	1	2
	Hotels	10	2	0	0
	Industrial	199	39	5	9
	Other-Residential	312	50	4	8
	Single Family	637	105	11	21
	Total	**2,857**	**549**	**94**	**127**

Economic Loss

The total economic loss estimated for the earthquake is 9,873.20 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 8,244.28 (millions of dollars); 15 % 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. Table 12 below provides a summary of the losses associated with the building damage.

Table 12: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Loses							
	Wage	0.00	22.88	355.86	9.09	11.90	399.73
	Capital-Related	0.00	9.76	315.45	5.57	2.83	333.61
	Rental	134.97	147.95	181.08	3.68	6.10	473.79
	Relocation	14.01	3.58	10.16	0.41	1.60	29.77
	Subtotal	**148.98**	**184.17**	**862.55**	**18.75**	**22.43**	**1,236.89**
Capital Stock Loses							
	Structural	664.03	201.16	347.16	45.54	39.39	1,297.28
	Non_Structural	2,189.03	966.63	760.49	125.36	90.24	4,131.75
	Content	759.64	256.00	395.11	83.18	49.23	1,543.16
	Inventory	0.00	0.00	15.41	18.59	1.20	35.19
	Subtotal	**3,612.71**	**1,423.79**	**1,518.16**	**272.67**	**180.06**	**7,007.39**
	Total	**3,761.69**	**1,607.95**	**2,380.72**	**291.43**	**202.49**	**8,244.28**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, HAZUS computes the direct repair cost for each component only. There are no losses computed by HAZUS for business interruption due to lifeline outages. Tables 13 & 14 provide a detailed breakdown in the expected lifeline losses.

HAZUS estimates the long-term economic impacts to the region for 15 years after the earthquake. The model quantifies this information in terms of income and employment changes within the region. Table 15 presents the results of the region for the given earthquake.

Table 13: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	56,078.87	$0.00	0.00
	Bridges	7,441.42	$34.12	0.46
	Tunnels	123.75	$0.36	0.29
	Subtotal	**63644.00**	**34.50**	
Railways	Segments	4,133.19	$0.00	0.00
	Bridges	17.32	$0.01	0.04
	Tunnels	0.00	$0.00	0.00
	Facilities	63.44	$8.47	13.35
	Subtotal	**4214.00**	**8.50**	
Light Rail	Segments	6.87	$0.00	0.00
	Bridges	0.32	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**7.20**	**0.00**	
Bus	Facilities	35.95	$4.75	13.22
	Subtotal	**35.90**	**4.80**	
Ferry	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Port	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Airport	Facilities	1,316.34	$159.09	12.09
	Runways	8,652.36	$0.00	0.00
	Subtotal	**9968.70**	**159.10**	
	Total	**77869.80**	**206.80**	

Table 14: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	936.70	$64.76	6.91
	Distribution Line	4,613.50	$11.67	0.25
	Subtotal	**5,550.18**	**$76.43**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	12,209.80	$949.22	7.77
	Distribution Line	2,768.10	$9.23	0.33
	Subtotal	**14,977.85**	**$958.45**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	328.80	$13.52	4.11
	Distribution Line	1,845.40	$9.86	0.53
	Subtotal	**2,174.20**	**$23.38**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	3.70	$0.29	7.92
	Subtotal	**3.69**	**$0.29**	
Electrical Power	Facilities	5,761.80	$362.20	6.29
	Subtotal	**5,761.80**	**$362.20**	
Communication	Facilities	24.30	$1.39	5.72
	Subtotal	**24.25**	**$1.39**	
	Total	**28,491.97**	**$1,422.13**	

Table 15. Indirect Economic Impact with outside aid
(Employment as # of people and Income in millions of $)

	LOSS	Total	%
First Year			
	Employment Impact	1,137,015	72.15
	Income Impact	3,686	4.67
Second Year			
	Employment Impact	446,008	28.30
	Income Impact	1,955	2.48
Third Year			
	Employment Impact	10,527	0.67
	Income Impact	354	0.45
Fourth Year			
	Employment Impact	594	0.04
	Income Impact	(221)	-0.28
Fifth Year			
	Employment Impact	30	0.00
	Income Impact	(253)	-0.32
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(255)	-0.32

Appendix A: County Listing for the Region

Adams,CO

Alamosa,CO

Arapahoe,CO

Archuleta,CO

Baca,CO

Bent,CO

Boulder,CO

Chaffee,CO

Cheyenne,CO

Clear Creek,CO

Conejos,CO

Costilla,CO

Crowley,CO

Custer,CO

Delta,CO

Denver,CO

Dolores,CO

Douglas,CO

Eagle,CO

Elbert,CO

El Paso,CO

Fremont,CO

Garfield,CO

Gilpin,CO

Grand,CO

Gunnison,CO

Hinsdale,CO

Huerfano,CO

Jackson,CO

Jefferson,CO

Kiowa,CO

Kit Carson,CO

Lake,CO

La Plata,CO

Larimer,CO

Las Animas,CO

Lincoln,CO

Logan,CO

Mesa,CO

Mineral,CO

Moffat,CO

Montezuma,CO

Montrose,CO

Morgan,CO

Otero,CO

Ouray,CO

Park,CO

Phillips,CO

Pitkin,CO

Prowers,CO

Pueblo,CO

Rio Blanco,CO

Rio Grande,CO

Routt,CO

Saguache,CO

San-Juan,CO

San-Miguel,CO

Sedgwick,CO

Summit,CO

Teller,CO

Washington,CO

Weld,CO

Yuma,CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado					
	Adams	363,857	14,434	2,435	16,869
	Alamosa	14,966	570	308	878
	Arapahoe	487,967	24,792	5,126	29,919
	Archuleta	9,898	589	110	700
	Baca	4,517	222	28	251
	Bent	5,998	237	25	262
	Boulder	291,288	14,239	3,523	17,762
	Chaffee	16,242	831	179	1,011
	Cheyenne	2,231	106	25	131
	Clear Creek	9,322	615	92	708
	Conejos	8,400	330	23	353
	Costilla	3,663	151	23	174
	Crowley	5,518	169	13	182
	Custer	3,503	295	28	323
	Delta	27,834	1,172	186	1,359
	Denver	554,636	28,051	8,182	36,233
	Dolores	1,844	107	13	120
	Douglas	175,766	10,657	1,135	11,792
	Eagle	41,659	2,328	675	3,003
	Elbert	19,872	944	85	1,029
	El Paso	516,929	23,988	4,117	28,105
	Fremont	46,145	1,727	221	1,948
	Garfield	43,791	1,793	467	2,260
	Gilpin	4,757	391	34	426
	Grand	12,442	1,183	187	1,371
	Gunnison	13,956	940	181	1,122
	Hinsdale	790	140	6	146
	Huerfano	7,862	440	56	496
	Jackson	1,577	111	13	124
	Jefferson	527,056	28,329	4,126	32,456
	Kiowa	1,622	77	6	83
	Kit Carson	8,011	336	62	399
	Lake	7,812	373	38	411
	La Plata	43,941	2,036	526	2,563
	Larimer	251,494	12,774	2,441	15,215
	Las Animas	15,207	738	125	863
	Lincoln	6,087	253	37	290
	Logan	20,504	859	139	999
	Mesa	116,255	4,746	1,069	5,816
	Mineral	831	115	10	125
	Moffat	13,184	544	86	631
	Montezuma	23,830	929	218	1,148
	Montrose	33,432	1,306	319	1,626
	Morgan	27,171	1,011	2,438	3,450

	Otero	20,311	880	128	1,009
	Ouray	3,742	236	56	292
	Park	14,523	1,165	73	1,238
	Phillips	4,480	210	32	243
	Pitkin	14,872	1,150	348	1,499
	Prowers	14,483	565	103	669
	Pueblo	141,472	6,109	990	7,100
	Rio Blanco	5,986	306	73	379
	Rio Grande	12,413	580	85	666
	Routt	19,690	1,205	310	1,515
	Saguache	5,917	243	22	265
	San Juan	558	68	13	82
	San Miguel	6,594	521	125	646
	Sedgwick	2,747	144	18	162
	Summit	23,548	2,399	405	2,805
	Teller	20,555	1,164	180	1,345
	Washington	4,926	224	18	243
	Weld	180,936	6,699	1,005	7,704
	Yuma	9,841	437	62	500
Total State		**4,301,261**	**210,283**	**43,182**	**253,494**
Total Region		**4,301,261**	**210,283**	**43,182**	**253,494**

HAZUS:
County EQ Information

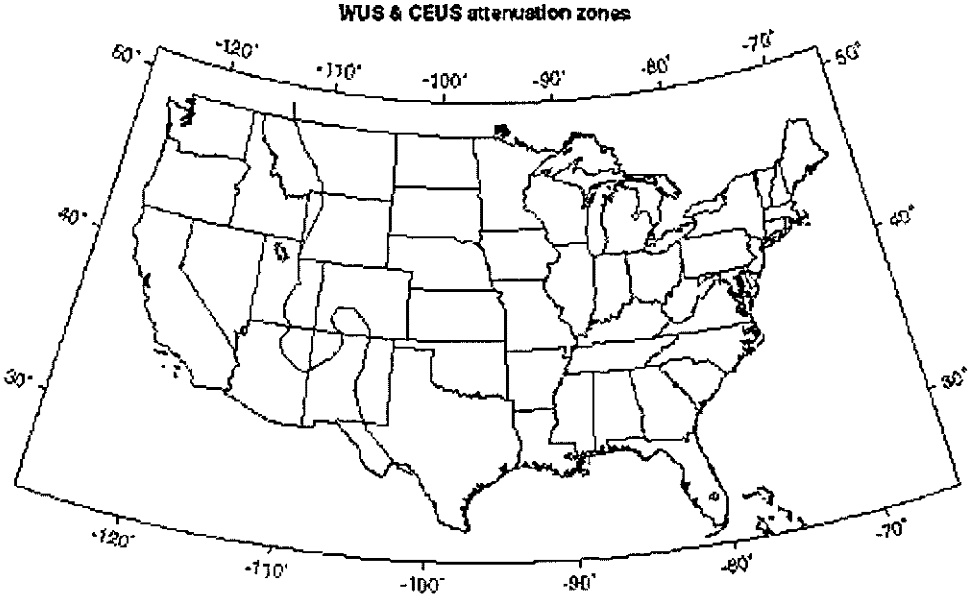
Earthquake Susceptibility by Colorado Counties

Demographic data is from the 2000 U.S. Census or updated county websites and Northeastern Colorado Emergency Managers hazard analysis (www.ncem10.org/pdf/Local%20Hazards.pdf).

Fault information and historical seismicity data is from the Colorado Earthquake Map Server (http://geosurvey.state.co.us/Default.aspx?tabid=270) and Colorado Late Cenozoic Fault and Fold Database and Internet Map Server (http://geosurvey.state.co.us/Default.aspx?tabid=453). Time of most recent fault activity is in parentheses after the fault name: H = Holocene, LQ = Late Quaternary, MLQ = Middle to Late Quaternary, Q = Quaternary, LC = Late Cenozoic. Earthquake event identification numbers can be found in the earthquake database table.

Inventory and HAZUS loss estimates are from deterministic scenarios performed in FEMA's Hazus-MH software. Deterministic scenarios were run for faults and counties to assess potential economic and social losses due to earthquake activity in Colorado. County inventories are the sum of building, transportation, and utility replacement default values in the Hazus data tables.

WUS & CEUS attenuation zones



Adams County

Population: 374,891 Growth since 1990: 37.3%

County Size: 1,198 square miles Inventory: $21,025.00 M

Contact:

Adams County Office of Emergency Management
4201 E. 72nd Ave.
Commerce City, CO 80022
(303)289-5441

Faults within County: Rocky Mountain Arsenal (uncertain)

Historical Earthquakes: 1962 to 1972 Rocky Mountain Arsenal Earthquakes (#98-99, 103-105, 107-143, 145-147, 150-152, 154-188, 190-209, 219, 228-229, 233, 237, 239-241, 246-247, 251, 253-303, 305-306, 308-309, 311-327, 330-334, 336, 339-340, 342, 344-346, 348-350); June 10, 1978 NE of Denver (#363); Mar.-Sept. 1981 NE of Denver (#369-371); Mar.-Sept. 1982 NE of Denver (#374-375); Feb. 25, 1984 NE of Denver (#380); Nov. 8, 1989 NE Denver (#446)

Faults analyzed for County: Golden (Q), Rampart (MLQ), RM Arsenal, Ute Pass (MLQ), Valmont (MLQ), Walnut Creek (Q), 1882 Historical Epicenter

HAZUS Loss Estimates:

Golden Fault:	M6.5 – 51 fatal, $1.59 Billion (-7.6%)
Rampart Fault:	M7.0 – 26 fatal, $774 Million (-3.7%)
RM Arsenal:	M6.25 – 130 fatal, $3.15 Billion (-15.0%)
Ute Pass:	M7.0 – 12 fatal, $496 Million (-2.4%)
Valmont:	M5.0 – 0 fatal, $64.1 Million (-0.3%)
Walnut Creek:	M6.0 – 20 fatal, $1.28 Billion (-6.1%)
1882 RMNP epc:	M6.6 – 1 fatal, $150 Million (-0.7%)

Alamosa County

Population: 15,336 Growth since 1990: 9.9%

County Size: 723 square miles Inventory: $1,839.50 M

Contact:

Alamosa County Office
PO Box 178
Alamosa, CO 81101
(719)589-4848

Faults within County: Alamosa Horst Fault Zone East (LC), Alamosa Horst Fault Zone West (LC), Manassa (LC), North Sangre de Cristo (H)

Historical Earthquakes: Dec. 28, 2003 Blanca-Ft. Garland (#562-563)

Faults analyzed for County: N Sangre de Cristo (H)

HAZUS Loss Estimates:

N Sangre de Cristo:	M7.5 WUS – 4 fatal, $142 Million (-7.7%)
	M7.5 CEUS – 18 fatal, $433 Million (-23.5%)

Arapahoe County

Population: 524,414 Growth since 1990: 24.6%

County Size: 818 square miles Inventory: $32,232.30 M

Contact:

Arapahoe County Government
5334 S. Prince Street
Littleton, CO 80166
(303)795-4400

Faults within County: None known

Historical Earthquakes: None

Faults analyzed for County: Chase Gulch (LQ), Cheraw (H), Golden (Q), Rampart (MLQ), RM Arsenal, Ute Pass (MLQ), Walnut Creek (Q)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 9 fatal, $678 Million (-2.1%)
Cheraw:	M7.0 – 0 fatal, $57.9 Million (-0.2%)
Golden:	M6.5 – 185 fatal, $3.90 Billion (-12.1%)
Rampart:	M7.0 – 186 fatal, $3.84 Billion (-11.9%)
RM Arsenal:	M6.25 – 74 fatal, $2.63 Billion (-8.2%)
Ute Pass:	M7.0 – 67 fatal, $2.11 Billion (-6.5%)
Walnut Creek:	M6.0 – 17 fatal, $1.25 Billion (-3.9%)

Archuleta County

Population: 9,898 Growth since 1990: 85.2%

County Size: 1,364 square miles Inventory: $1,948.70 M

Contact:

Department of Emergency Management
449 San Juan St. or PO Box 1507
Pagosa Springs, CO 81147
(970)264-8300

Faults within County: None

Historical Earthquakes: Feb. 12, 1882 Pagosa Springs (#6); May 12, 1882 Pagosa Springs (#7); Jan. 23, 1966 Dulce, NM (#210, 212-218, 220, 222-227)

Faults analyzed for County: Cannibal Fault (LQ), N Sangre de Cristo (H)

HAZUS Loss Estimates:

Cannibal:	M7.0 – 0 fatal, $42.1 Million (-2.2%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $1.04 Million (-0.0%)
	M7.5 CEUS – 1 fatal, $28.1 Million (-1.4%)

Baca County

Population: 4,517 Growth since 1990: -0.9%

County Size: 2,559 square miles Inventory: $1,831.70 M

Contact:

Baca County Courthouse
741 Main Street
Springfield, CO 81073
(719)523-6532

Faults within County: None

Historical Earthquakes: None

Faults analyzed for County: Cheraw (H)

HAZUS Loss Estimates:

Cheraw: M7.0 – 0 fatal, $2.14 Million (-0.1%)

Bent County

Population: 9,898 Growth since 1990: 85.2%

County Size: 1,517 square miles Inventory: $1,081.00 M

Contact:

Bent County Courthouse
725 Carson Avenue or PO Box 350
Las Animas, CO 81054
(719)456-1600

Faults within County: None

Historical Earthquakes: None

Faults analyzed for County: Cheraw (H)

HAZUS Loss Estimates:

Cheraw: M7.0 – 0 fatal, $18.1 Million (-1.7%)

Boulder County

Population: 214,978 Growth since 1990: 29.3%

County Size: 741 square miles Inventory: $20,737.40 M

Contact:

Boulder Office of Emergency Management
1805 33rd Street
Boulder, CO 80301
(303)441-3390

Faults within County: Rock Creek (Q), Valmont (MLQ)

Historical Earthquakes: Oct. 12, 1916 Boulder (#29)

Faults analyzed for County: Frontal (LQ), Golden (Q), Mosquito (LQ), Rocky Mountain Arsenal Epicenter, Ute Pass (MLQ), Valmont (MLQ), Walnut Creek (Q), Williams Fork (H), 1882 Historical Epicenter

HAZUS Loss Estimates:

Frontal:	M7.0 – 3 fatal, $330 Million (-1.6%)
Golden:	M6.5 – 24 fatal, $ 1.49 Billion (-7.2%)
Mosquito:	M7.0 – 2 fatal, $252 Million (-1.2%)
Rocky Mtn Arsenal:	M6.25 – 11 fatal, $1.10 Billion (-5.3%)
Ute Pass:	M7.0 – 2 fatal, $245 Million (-1.2%)
Valmont:	M5.0 – 0 fatal, $411 Million (-2.0%)
Walnut Creek:	M6.0 – 10 fatal, $1.21 Billion (-5.8%)
Williams Fork:	M6.75 – 1 fatal, $233 Million (-1.1%)
1882 Earthquake:	M6.6 RMNP – 2 fatal, $328 Million (-1.6%)

Chaffee County

Population: 16,242 Growth since 1990: 28.1%

County Size: 1,039 square miles Inventory: $2,354.10 M

Contact:

Chaffee County Commissioners
PO Box 699 or 104 Crestone Ave.
Salida, CO 81201
(719)539-2218

Faults within County: Buena Vista (Q), Missouri Park (LQ), North Sawatch (LQ), Northeastern Boundary Faults (MLQ), Poncha Pass (LC), Shavano Peak (Q), South Sawatch (H), Twin Lakes Faults (Q), Upper Arkansas Valley Faults (LC)

Historical Earthquakes: Nov. 15, 1901 Buena Vista (#20); Feb.-July, 1921 Garfield (#34-47); Dec. 19, 1966 Aspen (#242); July 20, 1987 Taylor Park (#435); Sept. 14, 1987 Winfield (#437); Aug. 4, 1994 Poncha Springs (#473)

Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Mosquito (LQ), N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 0 fatal, $33.9 Million (-1.4%)
Frontal:	M7.0 – 0 fatal, $17.5 Million (-0.7%)
Mosquito:	M7.0 – 0 fatal, $65.8 Million (-2.8%)
N Sangre de Cristo:	M7.5 WUS – 9 fatal, $133 Million (-5.7%)
	M7.5 CEUS – 29 fatal, $426 Million (-18.1%)
N Sawatch:	M7.0 – 2 fatal, $153 Million (-6.5%)
S Sawatch:	M7.25 WUS – 21 fatal, $426 Million (-18.1%)
	M7.25 CEUS – 26 fatal, $665 Million (-28.3%)

Cheyenne County

Population: 2,088 Growth since 1990: -6.9%
County Size: 1,782 square miles Inventory: $1,450.80 M
Contact:

Cheyenne County Courthouse
51 South 1st St. or PO Box 567
Cheyenne, CO 80810
(719)767-5872

Faults within County: High Plains Grabens (Anton scarp) under investigation

Historical Earthquakes: July 6, 1989 Kit Carson (#445)

Faults analyzed for County: Anton Scarp, Cheraw (H)

HAZUS Loss Estimates:

Anton Scarp:	M7.6 – 0 fatal, $27.1 Million (-1.9%)
Cheraw:	M7.0 – 0 fatal, $8.57 Million (-0.6%)

Clear Creek County

Population: 9,322 Growth since 1990: 22.4%
County Size: 396 square miles Inventory: $1,632.90 M
Contact:

Clear Creek County Offices
405 Argentine St. or PO Box 2000
Georgetown, CO 80444
(303)679-2300

Faults within County: Floyd Hill (LC), Kennedy Gulch (LC)

Historical Earthquakes: Nov. 9, 1871 Georgetown (#3); 1881 Georgetown (#5); Aug. 5, 1894 Georgetown (#16)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Golden (Q), Mosquito (LQ), N Sawatch (LQ), Ute Pass (MLQ), Williams Fork (H)
HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 0 fatal, $9.71 Million (-0.6%)
Frontal:	M7.0 – 0 fatal, $38.0 Million (-2.3%)
Golden:	M6.5 – 0 fatal, $42.9 Million (-2.6%)
Mosquito:	M7.0 – 0 fatal, $31.8 Million (-2.0%)
N Sawatch:	M7.0 – 0 fatal, $8.96 Million (-0.6%)
Ute Pass:	M7.0 – 0 fatal, $10.6 Million (-0.7%)
Williams Fork:	M6.75 – 0 fatal, $31.9 Million (-2.0%)

Conejos County
Population: 8,407 Growth since 1990: 12.7%
County Size: 1,290 square miles Inventory: $1,162.40 M
Contact:

Conejos County Courthouse
PO Box 157
Conejos, CO 81129
(719)376-5772

Faults within County: Conejos River Faults (LC), Cumbres (LC), La Jara Reservoir (LC), Los Mogotes Volcano Faults (LC)
Historical Earthquakes: Oct. 7, 1952 Antonito (#82)
Faults analyzed for County: N Sangre de Cristo (H)
HAZUS Loss Estimates:

N Sangre de Cristo:	M7.5 WUS – 0 fatal, $9.9 Million (-0.9%)
	M7.5 CEUS – 3 fatal, $56.3 Million (-4.8%)

Costilla County
Population: 3,688 Growth since 1990: 14.8%
County Size: 1,229 square miles Inventory: $1,013.40 M
Contact:

Costilla County Courthouse
352 Main St. or PO Box 100
San Luis, CO 81152
(719)672-3372

Faults within County: Alvarado (LC), Culebra Range Faults (LC), Garcia (LQ), La Veta Faults (LC), Mesita (LQ), N Basaltic Hills Faults (Q), N Sangre de Cristo (H), S Sangre de Cristo-San Pedro Mesa Section (LQ)
Historical Earthquakes: Dec. 28, 2003 Blanca-Ft. Garland (#562-563)
Faults analyzed for County: N Sangre de Cristo (H)
HAZUS Loss Estimates:

N Sangre de Cristo:	M7.5 WUS – 2 fatal, $51.6 Million (-5.1%)
	M7.5 CEUS – 4 fatal, $85.2 Million (-8.4%)

Crowley County
Population: 5,838 Growth since 1990: 39.8%
County Size: 803 square miles Inventory: $666.90 M
Contact:

Crowley County Courthouse
603 Main #2
Ordway, CO 81063
(719)267-5555

Faults within County: Cheraw (H)
Historical Earthquakes: Dec. 4, 1870 Pueblo-Ft. Reynolds (#1); Nov. 28, 1955 Fowler-Sugar City (#88)
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:

Cheraw: M7.0 – 2 fatal, $55.2 Million (-8.3%)

Custer County
Population: 3,700 Growth since 1990: 81.9%
County Size: 737 square miles Inventory: $877.60 M
Contact:

Custer County Office of Emergency Management
PO Box 1351
Westcliffe, CO 81252
(719)783-2270

Faults within County: Alvarado (LC), Dead Mule Gulch (LC), Ilse (LC), Johnson Gulch (LC), Rosita (LC), Round Mountain (LC), Silver Cliff Graben (LC), Westcliffe (LC), Wet Mountain (LC)
Historical Earthquakes: Oct. 23, 1888 Wet Mountains (#12); Feb. 18, 1925 Wetmore (#52)
Faults analyzed for County: Goodpasture (Q), N Sangre de Cristo (H)
HAZUS Loss Estimates:

Goodpasture: M6.0 – 0 fatal, $6.2 Million (-0.7%)
N Sangre de Cristo M7.5 WUS – 1 fatal, $28.5 Million (-3.3%)
M7.5 CEUS – 4 fatal, $138 Million (-15.8%)

Delta County
Population: 27,834 Growth since 1990: 32.7%
County Size: 1,157 square miles Inventory: $2,841.30 M
Contact:

Delta County Office of Emergency Management
555 Palmer Street
Delta, CO 81416
(970)874-2004

Faults within County: Bridgeport (Q), Escalante (Q), Little Dominguez Creek (Q)
Historical Earthquakes: Sept. 9, 1944 Montrose-Basalt (#75-border); Jan. 12, 1967 Somerset (#243-border); Sept. 26, 1994 Somerset Coal Bump (#479); Nov. 2, 1994 Somerset Coal Bump (#480); Jan. 1, 1995 Somerset Coal Bump (#483); Mar. 14, 1995

Somerset Coal Bump (#485); Nov. 5, 2001 Paonia-Somerset (#533); Dec. 4, 2001 Paonia-Somerset (#534); Mar.-Apr. 2002 Paonia-Somerset (#538-540); June-Dec. 2002 Paonia-Somerset (#543, 546-549, 551-552); Jan.-Aug. 2003 Paonia-Somerset (#555, 557-558)

Faults analyzed for County: Cimarron (LQ, Q), Roubideau Creek (H)

HAZUS Loss Estimates:

Cimarron:	M6.75 – 0 fatal, $53.1 Million (-1.9%)
Roubideau:	M5.5 – 0 fatal, $5.93 Million (-0.2%)

Denver City and County

Population: 554,636 Growth since 1990: 18.6%

County Size: 155 square miles Inventory: $39,039.40 M

Contact:

Denver Office of Emergency Management
1437 Bannock Street, Room 3
Denver, CO
(720)865-7600

Faults within County: None

Historical Earthquakes: Dec. 29, 1901 Denver (#21); Jan. 27, 1923 Denver (#49); Jan. 4, 1924 Denver (#50); June 5, 1963 RM Arsenal (#140); Numerous 1960's RM Arsenal shocks NE of Denver

Faults analyzed for County: Anton Scarp, Chase Gulch (LQ), Cheraw (H), Frontal (LQ), Golden (Q), Mosquito (LQ), Rampart (MLQ), Rocky Mountain Arsenal Epicenter, N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H), Ute Pass (MLQ), Valmont (MLQ), Walnut Creek (Q), Williams Fork (H), 1882 Historical Epicenter

HAZUS Loss Estimates:

Anton Scarp:	M6.7 – 172 fatal, $3.05 Billion (-7.8%)
Chase Gulch:	M6.75 – 13 fatal, $1.01 Billion (-2.6%)
Cheraw:	M7.0 – 0 fatal, $8.02 Million (-0.0%)
Frontal:	M7.0 – 30 fatal, $1.48 Billion (-3.8%)
Golden:	M6.5 – 416 fatal, $7.51 Billion (-19.2%)
Mosquito:	M7.0 – 25 fatal, $1.32 Billion (-3.4%)
Rampart:	M7.0 – 203 fatal, $4.65 Billion (-11.9%)
RM Arsenal:	M6.25 – 262 fatal, $5.56 Billion (-14.2%)
	M6.0 – 126 fatal, $3.89 Billion (-10.0%)
	M5.5 – 10 fatal, $1.41 Billion (-3.6%)
	M5.0 – 1 fatal, $544 Million (-1.4%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $69.9 Million (-0.2%)
	M7.5 CEUS – 48 fatal, $1.47 Billion (-3.8%)
N Sawatch:	M7.0 – 7 fatal, $652 Million (-1.7%)
S Sawatch:	M7.25 – 12 fatal, $866 Million (-2.2%)
Ute Pass:	M7.0 – 84 fatal, $2.75 Billion (-7.0%)
Valmont:	M5.0 – 0 fatal, $98.4 Million (-0.3%)
Walnut Creek:	M6.0 – 75 fatal, $3.15 Billion (-8.1%)
Williams Fork:	M6.75 – 10 fatal, $850 Million (-2.2%)
1882 Earthquake:	M6.6 RMNP – 5 fatal, $527 Million (-1.4%)

Dolores County

Population: 1,848 | Growth since 1990: 22.6%

County Size: 1,077 square miles | Inventory: $515.70 M

Contact:

Dolores County Courthouse
409 N. Main St. or PO Box 608
Dove Creek, CO 81324
(970)677-2383

Faults within County: None

Historical Earthquakes: Feb. 12, 1967 Rico (#248); Sept. 9, 1987 Rico (#436)

Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ)

HAZUS Loss Estimates:

Busted Boiler:	M6.5 – 0 fatal, $0.85 Million (-0.2%)
Cannibal:	M7.0 – 0 fatal, $0.90 Million (-0.2%)

Douglas County

Population: 175,766 | Growth since 1990: 191%

County Size: 843 square miles | Inventory: $13,697.50 M

Contact:

Douglas County Office of Emergency Management
4000 Justice Way
Castle Rock, CO 80109
(303)660-7589

Faults within County: Kennedy Gulch (LC), Oil Creek (LC), Perry Park-Jarre Canyon (LC), Rampart Range (MLQ), Ute Pass (MLQ)

Historical Earthquakes: Sept. 14, 1965 S of Denver (#189); Dec. 25, 1994 Palmer Lake (#482)

Faults analyzed for County: Chase Gulch (LQ), Cheraw (H), Frontal (LQ), Golden (Q), Mosquito (LQ), Rampart (MLQ), N Sawatch (LQ), Ute Pass (MLQ)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 1 fatal, $117 Million (-0.9%)
Cheraw:	M7.0 – 0 fatal, $19.2 Million (-0.1%)
Frontal:	M7.0 – 1 fatal, $114 Million (-0.8%)
Golden:	M6.5 – 7 fatal, $578 Million (-4.2%)
Mosquito:	M7.0 – 1 fatal, $111 Million (-0.8%)
Rampart:	M7.0 – 79 fatal, $1.85 Billion (-13.5%)
N Sawatch:	M7.0 – 0 fatal, $64.1 Million (-0.5%)
Ute Pass:	M7.0 – 15 fatal, $652 Million (-4.8%)

Eagle County

Population: 47,990 | Growth since 1990: 90.0%

County Size: 1,694 square miles | Inventory: $5,014.90 M

Contact:

Eagle County Emergency Management
PO Box 850
Eagle, CO 81631
(970)328-8603

Faults within County: Basalt Mountain (LC), Burns Faults (MLQ), Dotsero Faults (LC), Frontal (LQ), Gore (LC), Greenhorn Mountain (Q), Gypsum Faults (LC), Leadville (Q), Red Hill Faults (Q)

Historical Earthquakes: Apr. 3, 1946 Riland (#80); May 30, 1965 Tennessee Pass (#161); Apr. 3, 1966 South Park Blast (#221-border); Sept. 12, 1990 Vail (#449)

Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Mosquito (LQ), N Sawatch (LQ), S Sawatch (H), Williams Fork (H)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 0 fatal, $33.9 Million (-0.7%)
Frontal:	M7.0 – 26 fatal, $572 Million (-11.4%)
Mosquito:	M7.0 – 15 fatal, $417 Million (-8.3%)
N Sawatch:	M7.0 – 9 fatal, $387 Million (-7.7%)
S Sawatch:	M7.25 – 2 fatal, $146 Million (-2.9%)
Williams Fork:	M6.75 – 5 fatal, $207 Million (-4.1%)

El Paso County

Population: 543,818 Growth since 1990: 30.2%
County Size: 2,158 square miles Inventory: $32,570.60 M

Contact:

El Paso Board of County Commissioners
27 E. Vermijo Ave.
Colorado Springs, CO 80903
(719)520-7276

Faults within County: Colorado Springs Faults (LC), Rampart Range (MLQ), Ute Pass (MLQ)

Historical Earthquakes: Dec. 23 and 31, 1995 Manitou Springs (#492, 493); Jan. 1997 Woodland Park (#497-499); Apr. 18, 1998 Woodland Park (#503); July 22, 2001 Woodland Park (#515); Feb. 19, 2003 Woodland Park (#556)

Faults analyzed for County: Chase Gulch (LQ), Cheraw (H), Goodpasture (Q), Rampart (MLQ), N Sangre de Cristo (H), S Sawatch (H), Ute Pass (MLQ)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 8 fatal, $636 Million (-2.0%)
Cheraw:	M7.0 – 4 fatal, $353 Million (-1.1%)
Goodpasture:	M6.0 – 0 fatal, $103 Million (-0.3%)
Rampart:	M7.0 – 545 fatal, $9.01 Billion (-27.7%)
	M6.0 – 20 fatal, $1.67 Billion (-5.1%)
N Sangre de Cristo:	M7.5 WUS – 1 fatal, $90.8 Million (-0.3%)
	M7.5 CEUS – 125 fatal, $2.12 Billion (-6.5%)
S Sawatch:	M7.25 – 11 fatal, $659 Million (-2.0%)
Ute Pass:	M7.0 – 477 fatal, $8.22 Billion (-25.2%)
	M6.0 – 27 fatal, $1.91 Billion (-5.9%)

Elbert County

Population: 19,872 — Growth since 1990: 106.0%

County Size: 1,865 square miles — Inventory: $2,431.60 M

Contact:

Elbert County Emergency Management
(303)621-2027

Faults within County: None

Historical Earthquakes: Oct. 13, 1966 E of Castle Rock (#236)

Faults analyzed for County: Cheraw (H), Golden (Q), Rampart (MLQ), Ute Pass (MLQ)

HAZUS Loss Estimates:

Cheraw:	M7.0 – 0 fatal, $5.3 Million (-0.2%)
Golden:	M6.5 – 0 fatal, $15.6 Million (-0.6%)
Rampart:	M7.0 – 3 fatal, $98.9 Million (-4.1%)
Ute Pass:	M7.0 – 1 fatal, $44.3 Million (-1.8%)

Fremont County

Population: 46,145 — Growth since 1990: 43.0%

County Size: 1,502 square miles — Inventory: $3,759.70 M

Contact:

Fremont County Emergency Services
615 Macon Ave., Rm. #204
Cañon City, CO 81212

Faults within County: Alvarado (LC), Bare Hills (LC), Box Canyon and Quarry Faults (LC), Coaldale-Wellsville (LC), Currant Creek (LC), Dead Mule Gulch (LC), Fourmile Creek (LC), High Park (LC), Iron Mountain (LC), Isle (LC), Parkdale Faults (LC), Pleasant Valley (LC), Rice Mountain (LC), Salida South (LC), Tanner Peak (LC), Texas Creek (LC), Thompson Mountain (LC), Westcliffe (LC), Wet Mountain (LC)

Historical Earthquakes: Mar. 16, 1985 Salida (#402); Apr. 16, 1987 Howard (#434)

Faults analyzed for County: Chase Gulch (LQ), Goodpasture (Q), Rampart (MLQ), N Sangre de Cristo (H), S Sawatch (H), Ute Pass (MLQ)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 1 fatal, $79.5 Million (-2.1%)
Goodpasture:	M6.0 – 0 fatal, $56.1 Million (-1.5%)
Rampart:	M7.0 – 2 fatal, $127 Million (-3.4%)
N Sangre de Cristo:	M7.5 WUS – 3 fatal, $89.6 Million (-2.4%)
	M7.5 CEUS – 19 fatal, $394 Million (-10.5%)
S Sawatch:	M7.25 – 2 fatal, $121 Million (-3.2%)
Ute Pass:	M7.0 – 3 fatal, $184 Million (-4.9%)

Garfield County

Population: 48,503 — Growth since 1990: 46.1%

County Size: 2,958 square miles — Inventory: $4,735.50 M

Contact:

Garfield County Department of Emergency Management
109 8th St. #307
Glenwood Springs, CO 81601
(970)945-9789

Faults within County: Canyon Creek (LC), Causeway (LC), Consolidated Reservoir (LC), Grand Hogback Faults-Freeman Creek (Q), Grand Hogback-Fourmile Creek (H), Grand Hogback-SW Glenwood (LQ), Grand Hogback Faults-SW Glenwood (LC), Heuschkel Park Faults (LC), Lookout Mountain Faults (LC), Missouri Heights Faults (LC), Possum Creek (LC), Red Canyon (LC), Spring Valley Faults (LC), West Coal Creek (LC)
Historical Earthquakes: Jan. 15, 1889 Glenwood Springs (#13); Dec. 21, 1906 New Castle (#24); Dec. 29-30, 1920 New Castle (#30-33); Jan. 31, 1946 Glenwood Springs (#79); Sept. 10, 1969 Rulison AEC Test (#329); Jan. 7, 1971 Glenwood Springs (#341); Nov. 22, 1982 Rifle (#376); Apr.-May 1984 Carbondale Earthquakes (#381-399); Oct. 19, 1990 New Castle (#450-451); Dec. 12, 1990 New Castle (#453); Mar. 8, 1994 Douglas Pass (#472); Dec. 5, 2000 Carbondale (#514); Aug. 2001 Glenwood Springs Earthquakes (#516-519); Mar. 19, 2002 Douglas Pass (#536)
Faults analyzed for County: Frontal (LQ), Mosquito (LQ), N Sawatch (LQ)
HAZUS Loss Estimates:

Frontal:	M7.0 – 0 fatal, $35.3 Million (-0.8%)
Mosquito:	M7.0 – 0 fatal, $35.3 Million (-0.8%)
N Sawatch:	M7.0 – 1 fatal, $76.6 Million (-1.6%)

Gilpin County

Population: 4,757 Growth since 1990: 55.0%
County Size: 149 square miles Inventory: $725.30 M
Contact:

Gilpin County Commissioners
203 Eureka St., 2nd Floor or PO Box 366
Central City, CO 80427
(303)582-5214

Faults within County: Floyd Hill Fault Zone (LC)
Historical Earthquakes: None
Faults analyzed for County: Frontal (LQ), Golden (Q), Williams Fork (H)
HAZUS Loss Estimates:

Frontal:	M7.0 – 0 fatal, $10.8 Million (-1.5%)
Golden:	M6.5 – 0 fatal, $40.1 Million (-5.5%)
Williams Fork:	M6.75 – 0 fatal, $9.96 Million (-1.4%)

Grand County

Population: 12,442 Growth since 1990: 56.2%
County Size: 1,840 square miles Inventory: $3,131.50 M
Contact:

Grand County Courthouse
308 Byers Ave. or PO Box 264
Hot Sulphur Springs, CO 80451
(970)725-3347

Faults within County: Antelope Pass (LC), Barger Gulch (LC), Gore (LC), Granby Basin Faults (LC), Granby Faults West (LC), Kremmling Faults West (LC), Laramie River (LC), Parshall (LC), Rabbit Ears Pass Faults (LC), Rabbit Ears Range (LC), Sheephorn Mountain Faults (LC), Trail Ridge (LC), Troublesome Creek (LC), Williams Fork

Mountains (H), Williams Fork Valley Faults (MLQ), Williams Fork Valley Faults East (LC)
Historical Earthquakes: Aug. 4, 1964 Dillon (#149)
Faults analyzed for County: Frontal (LQ), Mosquito (LQ), N Sawatch (LQ), Williams Fork (H), 1882 Historical Epicenter
HAZUS Loss Estimates:

Frontal:	M7.0 – 2 fatal, $157 Million (-5.0%)
Mosquito:	M7.0 – 0 fatal, $47.2 Million (-1.5%)
N Sawatch:	M7.0 – 0 fatal, $24.1 Million (-0.8%)
Williams Fork:	M6.75 – 2 fatal, $184 Million (-5.9%)
1882 RMNP:	M6.6 – 0 fatal, $110 Million (-3.5%)

Gunnison County
Population: 14,012 Growth since 1990: 35.9%
County Size: 3,238 square miles Inventory: $2,681.30 M
Contact:

Gunnison County Commissioners
200 East Virginia Ave.
Gunnison, CO 81230
(970)641-0248

Faults within County: Cimarron (Q, LQ, LC), Red Rocks (Q), Treasure Mountain (LC)
Historical Earthquakes: July 1886 Cimarron (#11); Sept. 9, 1944 Montrose-Basalt (#75); Oct. 12, 1960 Montrose-Ridgway (#93); Sept. 4, 1966 Cimarron Ridge (#234); Jan. 12, 1967 Somerset (#243); Aug. 14, 1983 Cimarron (#377); Apr.-Oct. 1986 Crested Butte Earthquakes (#404-430, 432-433); Dec. 26, 1991 Powderhorn (#460-461); Sept. 26, 1994 Somerset Coal Bump (#479); Nov. 2, 1994 Somerset Coal Bump (#480); Jan. 1, 1995 Somerset Coal Bump (#483); Mar. 14, 1995 Somerset Coal Bump (#485); Nov. 5, 2001 Paonia-Somerset (#533); Dec. 4, 2001 Paonia-Somerset (#534); Mar.-Apr. 2002 Paonia-Somerset (#538-540); June-Dec. 2002 Paonia-Somerset (#543, 546-549, 551-552); Jan.-Aug. 2003 Paonia-Somerset (#555, 557-558)
Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ), Cimarron (LQ,Q), Roubideau Creek (H), N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H)
HAZUS Loss Estimates:

Busted Boiler:	M6.5 – 0 fatal, $13.1 Million (-0.5%)
Cannibal:	M7.0 – 2 fatal, $70.1 Million (-2.6%)
Cimarron:	M6.75 – 1 fatal, $67.6 Million (-2.5%)
Mosquito:	M7.0 – 0 fatal, $32.4 Million (-1.2%)
Roubideau Cr.:	M5.5 – 0 fatal, $0.5 Million (-0.0%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $4.2 Million (-0.2%)
	M7.5 CEUS – 4 fatal, $100 Million (-3.7%)
N Sawatch:	M7.0 – 1 fatal, $46.2 Million (-1.7%)
S Sawatch:	M7.25 – 2 fatal, $88.3 Million (-3.3%)

Hinsdale County
Population: 790 Growth since 1990: 69.2%
County Size: 1,124 square miles Inventory: $347.30 M

Contact:

Hinsdale County Courthouse
PO Box 277
Lake City, CO 81235
(970)944-2225

Faults within County: Cannibal (LQ), Lake City Caldera Faults (LC)
Historical Earthquakes: Aug. 3, 1955 Lake City (#85-87)
Faults analyzed for County: Busted Boiler (H), Cannibal (LQ), Cimarron (LQ)
HAZUS Loss Estimates:

Busted Boiler: M6.5 – 0 fatal, $1.1 Million (-0.3%)
Cannibal: M7.0 – 0 fatal, $35.2 Million (-10.1%)
Cimarron: M6.75 – 0 fatal, $1.9 Million (-0.6%)

Huerfano County

Population: 7,960 Growth since 1990: 30.8%
County Size: 1,592 square miles Inventory: $1,939.50 M
Contact:

Huerfano County Courthouse
401 Main St.
Walsenburg, CO 81089
(719)738-2370

Faults within County: Alvarado (LC), Bear Creek (LC), Farista Faults (LC), Greenhorn (LC), Ilse (LC), La Veta Faults West (LC), Westcliffe (LC), Wet Mountains South (LC)
Historical Earthquakes: None
Faults analyzed for County: Cheraw (H), Goodpasture (Q), N Sangre de Cristo (H)
HAZUS Loss Estimates:

Cheraw: M7.0 – 0 fatal, $4.6 Million (-0.2%)
Goodpasture: M6.0 – 0 fatal, $10.1 Million (-0.5%)
N Sangre de Cristo: M7.5 WUS – 0 fatal, $19.0 Million (-1.0%)
M7.5 CEUS – 1 fatal, $84.0 Million (-4.3%)

Jackson County

Population: 1,557 Growth since 1990: -1.7%
County Size: 1,620 square miles Inventory: $949.70 M
Contact:

Jackson County Courthouse
404 4th St. or PO Box 1019
Walden, CO 80480
(970)723-4660

Faults within County: Arapahoe Ridge Faults (LC), East Independence Mountain (LC), North Park Faults NW and W (LC), Park Range Faults (LC), Rabbit Ears Range (LC), Sierra Madre Range Faults (LC), Spring Creek (LC), Trail Ridge (LC), Walden Faults (LC), West Independence Mountain (LC)
Historical Earthquakes: Oct. 3, 1948 Walden (#81)
Faults analyzed for County: Frontal (LQ), Williams Fork (H), 1882 Historical Epicenter

HAZUS Loss Estimates:

Frontal:	M7.0 – 0 fatal, $3.0 Million (-0.3%)
Williams Fork:	M6.75 – 0 fatal, $2.3 Million (-0.2%)
1882 RMNP:	M6.6 – 0 fatal, $3.7 Million (-0.4%)

Jefferson County

Population: 527,056 | Growth since 1990: 20.2%

County Size: 774 square miles | Inventory: $35,828.60 M

Contact:

Jefferson County Department of Emergency Management
800 Jefferson County Parkway
Golden, CO 80419
(303)271-4900

Faults within County: Floyd Hill (LC), Golden (Q), Ken Caryl (LC), Kennedy Gulch (LC), Rock Creek (Q), Walnut Creek (Q)

Historical Earthquakes: Jan. 5, 1965 Rocky Flats (#153); Feb. 16, 1965 N of Denver (#155); Sept. 29, 1965 N of Denver (#192); 1960's-70's RM Arsenal Earthquakes; Nov.-Dec. 1981 Conifer (#372-373); Sept. 21, 1986 Conifer (#431)

Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Golden (Q), Mosquito (LQ), Rampart (MLQ), Rocky Mountain Arsenal Epicenter, N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H), Ute Pass (MLQ), Valmont (MLQ), Walnut Creek (Q), Williams Fork (H)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 2 fatal, $307 Million (-0.9%)
Frontal:	M7.0 – 5 fatal, $460 Million (-1.3%)
Golden:	M6.5 – 174 fatal, $5.88 Billion (-16.4%)
	M5.5 – 3 fatal, $1.03 Billion (-2.9%)
Mosquito:	M7.0 – 4 fatal, $402 Million (-1.1%)
Rampart:	M7.0 – 25 fatal, $1.30 Billion (-3.6%)
RM Arsenal:	M6.25 – 23 fatal, $1.42 Billion (-4.0%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $15.6 Million (-0.0%)
	M7.5 CEUS – 5 fatal, $285 Million (-0.8%)
N Sawatch:	M7.0 – 1 fatal, $206 Million (-0.6%)
S Sawatch:	M7.25 – 2 fatal, $253 Million (-0.7%)
Ute Pass:	M7.0 – 11 fatal, $770 Million (-2.2%)
Valmont:	M5.0 – 0 fatal, $50.4 Million (-0.1%)
Walnut Creek:	M6.0 – 43 fatal, $2.31 Billion (-6.4%)
Williams Fork:	M6.75 – 2 fatal, $274 Million (-0.8%)

Kiowa County

Population: 1,622 | Growth since 1990: -3.9%

County Size: 1,872 square miles | Inventory: $1,141.60 M

Contact:

Kiowa County Commissioners Office
PO Box 100
Eads, CO 81036

(719)438-5810
Faults within County: Cheraw (H)
Historical Earthquakes: Oct. 15, 1921 Eads (#48); Jan. 10, 2003 Lamar (#554)
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:
Cheraw: M7.0 – 0 fatal, $11.4 Million (-1.0%)

Kit Carson County
Population: 7,987 Growth since 1990: 12.2%
County Size: 2,162 square miles Inventory: $2,252.00 M
Contact:
Kit Carson County Courthouse
PO Box 160
Burlington, CO 80807
(719)346-8139
Faults within County: High Plains Grabens (Anton Scarp) under investigation
Historical Earthquakes: May 27, 1984 Burlington (#400)
Faults analyzed for County: Anton Scarp
HAZUS Loss Estimates:
Anton Scarp: M7.6 – 17 fatal, $285 Million (-12.7%)

La Plata County
Population: 47,494 Growth since 1990: 36.1%
County Size: 1,690 square miles Inventory: $4,309.40 M
Contact:
La Plata County Office of Emergency Management
1060 E. 2nd Ave.
Durango, CO 81301
(970)382-6274
Faults within County: None
Historical Earthquakes: Aug. 29, 1941 Durango-Bayfield (#72)
Faults analyzed for County: Busted Boiler (H), Cannibal (LQ), Cimarron (LQ,Q)
HAZUS Loss Estimates:
Busted Boiler: M6.5 – 0 fatal, $14.4 Million (-0.3%)
Cannibal: M7.0 – 0 fatal, $53.1 Million (-1.2%)
Cimarron: M6.75 – 0 fatal, $12.3 Million (-0.3%)

Lake County
Population: 7,917 Growth since 1990: 30.0%
County Size: 384 square miles Inventory: $1,098.70 M
Contact:
Lake County Courthouse
505 Harrison Ave. or PO Box 964
Leadville, CO 80461
(719)486-0993

Faults within County: Leadville-NW and S (Q), Mosquito (LQ), North Sawatch (LQ), Northeastern Boundary Faults (MLQ), Sawatch Range Faults (LC), Twin Lakes Reservoir Faults (Q)
Historical Earthquakes: May 23, 1964 Blast at Climax (#148); May 30, 1965 Tennessee Pass (#161)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Mosquito (LQ), N Sawatch (LQ), S Sawatch (H), Williams Fork (H)
HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 0 fatal, $27.3 Million (-2.5%)
Frontal:	M7.0 – 1 fatal, $69.5 Million (-6.3%)
Mosquito:	M7.0 – 10 fatal, $299 Million (-27.2%)
N Sawatch:	M7.0 – 10 fatal, $303 Million (-27.5%)
S Sawatch:	M7.25 – 6 fatal, $183 Million (-16.7%)
Williams Fork:	M6.75 – 0 fatal, $17.2 Million (-1.6%)

Larimer County
Population: 283,000 Growth since 1990: 35.1%
County Size: 2,640 square miles Inventory: $18,896.00 M
Contact:

Larimer County Emergency Management Office
200 W. Oak St.
Fort Collins, CO 80521
(970)498-5310

Faults within County: Larimer River (LC), Larimer River Valley (LC), Trail Ridge (LC)
Historical Earthquakes: Nov. 8, 1882 North-Central Colorado (#8); Sept. 9, 1903 Estes Park (#22); Oct. 3, 1948 Walden (#81); Nov. 3, 1977 Poudre Canyon (#361)
Faults analyzed for County: Golden (Q), Valmont (MLQ), Williams Fork (H)
HAZUS Loss Estimates:

Golden:	M6.5 – 3 fatal, $237 Million (-1.3%)
Valmont:	M5.0 – 0 fatal, $11.4 Million (-0.0%)
Williams Fork:	M6.75 – 2 fatal, $178 Million (-0.9%)
1882 Historical:	M6.6 – 18 fatal, $887 Million (-4.7%)

Las Animas County
Population: 15,967 Growth since 1990: 10.5%
County Size: 4,773 square miles Inventory: $3,705.50 M
Contact:

Las Animas County Courthouse
200 E. 1st Street, Rm. 207
Trinidad, CO 81082
(719)845-2568

Faults within County: La Veta Faults West (LC)
Historical Earthquakes: Oct. 3, 1966 NE of Trinidad (#235); Sept. 1973 Valdez-Boncarbo (#352-356); May 30, 1976 Pinon Canyon Area (#359); Aug. 17, 1983 NE of Trinidad (#378); Mar. 24, 1989 Mesa de Maya (#442); Apr. 15, 1992 Aguilar (#462); May 2, 1992 Gulnare (#463); Aug. 1, 1996 Tyrone (#494-495); Nov. 1, 1996 Tyrone

(#496); Aug.-Sept. 2001 Trinidad Earthquakes (#520-532); Sept. 8, 2003 Aguilar (#559); Oct. 25, 2003 SW of Trinidad (#560); Jan. 14, 2004 SW of Trinidad (#564)
Faults analyzed for County: Cheraw (H), N Sangre de Cristo (H)
HAZUS Loss Estimates:

Cheraw: M7.0 – 0 fatal, $3.97 Million (-0.1%)
N Sangre de Cristo: M7.5 WUS – 0 fatal, $3.40 Million (-0.0%)
M7.5 CEUS – 0 fatal, $31.6 Million (-0.9%)

Lincoln County

Population: 6,099 Growth since 1990: 34.4%
County Size: 2,585 square miles Inventory: $1,866.40 M
Contact:

Lincoln County Courthouse
103 3rd Avenue or PO Box 39
Hugo, CO 80821
(719)743-2810

Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Anton Scarp, Cheraw (H)
HAZUS Loss Estimates:

Anton Scarp: M7.6 – 2 fatal, $59.2 Million (-3.2%)
Cheraw: M7.0 – 0 fatal, $22.5 Million (-1.2%)

Logan County

Population: 21,889 Growth since 1990: 16.7%
County Size: 1,845 square miles Inventory: $3,057.30 M
Contact:

Logan County Courthouse
315 Main St.
Sterling, CO 80751
((970)522-0888

Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Anton Scarp
HAZUS Loss Estimates:

Anton Scarp: M7.6 – 20 fatal, $300 Million (-9.8%)

Mesa County

Population: 116,255 Growth since 1990: 24.8%
County Size: 3,309 square miles Inventory: $9,044.60 M
Contact:

Mesa County Emergency Management
544 Rood Avenue or PO Box 20000
Grand Junction, CO 81502
(970)244-1763

Faults within County: Atkinson Mesa (Q), Bangs Canyon (Q), Big Dominguez Creek (Q), Bridgeport (Q), Cactus Park (Q), Glade Park (Q), Granite Creek (Q), Ladder Creek (Q), Little Dolores River (Q), Little Dominguez Creek (Q), Lost Horse Basin (Q), Monitor Creek (Q), Pine Mountain (Q), Redlands Fault Complex (Q), Ryan Creek (Q), Sinbad Valley Graben (Q), Whitewater (Q), Wolf Hill (Q)
Historical Earthquakes: Feb. 28, 1915 Grand Junction (#28); June 24, 1962 Uncompahgre Plateau (#106); Nov. 12, 1971 Grand Junction (#347); Jan. 30, 1975 N of Grand Junction (#358); Dec. 6, 1985 Gateway (#403); Oct. 21, 1990 Palisade (#452); Apr. 23, 1995 Grand Mesa (#491)
Faults analyzed for County: Cimarron (LQ,Q), Roubideau Creek (H)
HAZUS Loss Estimates:

Cimarron: M6.75 – 0 fatal, $55.4 Million (-0.6%)
Roubideau: M5.5 – 0 fatal, $4.71 Million (-0.0%)

Mineral County
Population: 891 Growth since 1990: 48.9%
County Size: 878 square miles Inventory: $667.40 M
Contact:

Mineral County Courthouse
PO Box 70
Creede, CO 81130
(719)658-2331

Faults within County: Cannibal (LQ)
Historical Earthquakes: Apr.-May 1928 Creede Earthquakes (#53-66); May 3, 1957 Creede Area (#91); Jan. 23, 1966 Creede (#211)
Faults analyzed for County: Cannibal (LQ), Cimarron (LQ,Q), N Sangre de Cristo (H)
HAZUS Loss Estimates:

Cannibal: M7.0 – 1 fatal, $43.1 Million (-6.5%)
Cimarron: M6.75 – 0 fatal, $2.75 Million (-0.4%)
N Sangre de Cristo: M7.5 CEUS – 0 fatal, $9.52 Million (-1.4%)

Moffat County
Population: 13,184 Growth since 1990: 16.1%
County Size: 4,754 square miles Inventory: $2,778.00 M
Contact:

Moffat County Courthouse
221 W. Victory Way, Suite 130
Craig, CO 81625

Faults within County: Bakers Peak (LC), Beaver Creek (LC), Browns Park Faults (LC), Craig Faults (LC), Cross Mountain (LC), East (LC), Elk Springs Faults (LC), Elkhead Mountains Faults (LC), Lay Faults (LC), Maybell Faults (LC), Mitten Park (LC), Sawmill Canyon (LC), Sparks Ranch-Uinta (LC), Teepee (LC), Wapiti Peak (LC), Yampa (LC)
Historical Earthquakes: Oct. 1871 Lily Park-Moffat (#2); Dec. 1891 Axial Basin (#14); 1899 Lay (#19); Apr. 1906 Maybell (#23); Summer 1924 Craig (#51); Jul.-Aug. 1942 W Moffat County (#73-74); Jan. 18, 1968 Dinosaur National Monument (#304); Nov. 30, 1978 Craig (#364); Jan. 20, 1979 NW of Craig (#366); Sept. 24, 1983 Browns Park

(#379); Feb. 14, 1988 Maybell (#439); Aug. 31, 1988 Cold Spring Mountain (#440); Nov. 15, 1991 Hamilton (#459); Feb. 14, 1994 Craig (#471); Jan. 31, 2002 Axial Basin (#535)
Faults analyzed for County: Frontal (LQ)
HAZUS Loss Estimates:
Frontal: M7.0 – 0 fatal, $5.11 Million (-0.2%)

Montezuma County
Population: 23,830 Growth since 1990: 27.6%
County Size: 2,094 square miles Inventory: $3,074.20 M
Contact:
Montezuma County Courthouse
109 West Main St.
Cortez, CO 81321
(970)565-8317
Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Cannibal (LQ)
HAZUS Loss Estimates:
Cannibal: M7.0 – 0 fatal, $9.8 Million (-0.3%)

Montrose County
Population: 35,971 Growth since 1990: 36.9%
County Size: 2,246 square miles Inventory: $3,773.90 M
Contact:
Montrose County Courthouse
161 S. Townsend Ave.
Montrose, CO 81401
(970)249-7755
Faults within County: Atkinson Mesa Faults (Q), Big Gypsum Valley Graben Faults (Q), Cimarron (Q, LQ), Clay Creek (Q), Cottonwood Creek Faults (Q), Ellison Gulch Scarp (H), Hanks Creek (Q), Horsefly Creek (Q), Johnson Spring (Q), Love Mesa (Q), Monitor Creek (Q), Montrose Faults SW (Q), Paradox Valley Graben Faults (Q), Pinto Mesa Faults (Q), Red Canyon (Q), Red Rocks (Q), Roubideau Creek (H), Roubideau Creek Faults East (Q), San Miguel Canyon Faults (Q), Sinbad Valley Graben (Q)
Historical Earthquakes: Jan. 13, 1962 Montrose (#97); May 13, 1989 Uravan (#443); May 15, 1992 Olathe (#464); Sept. 13-15, 1994 Norwood (#475-478); Apr. 10, 1998 Paradox Valley (#502); June-Nov. 1999 Paradox Valley (#504-508); Mar.-May 2000 Paradox Valley (#511-512); June 6, 2002 Paradox Valley (#544)
Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ), Cimarron (LQ,Q), Roubideau Creek (H)
HAZUS Loss Estimates:
Busted Boiler: M6.5 – 21 fatal, $432 Million (-11.5%)
Cannibal: M7.0 – 4 fatal, $174 Million (-4.6%)
Cimarron: M6.75 – 28 fatal, $497 Million (-13.2%)
Roubideau: M5.5 – 0 fatal, $78.2 Million (-2.1%)

Morgan County

Population: 28,183 Growth since 1990: 23.8%
County Size: 1,294 square miles Inventory: $5,404.70 M
Contact:

Morgan County Courthouse
PO Box 596
Fort Morgan, CO 80701
(970)542-3500

Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Anton Scarp, Rocky Mountain Arsenal Epicenter
HAZUS Loss Estimates:

Anton Scarp: M7.6 – 48 fatal, $2.44 Billion (-45.2%)
RM Arsenal: M6.25 – 0 fatal, $21.8 Million (-0.4%)

Otero County

Population: 19,681 Growth since 1990: 0.6%
County Size: 1,268 square miles Inventory: $2,935.40 M
Contact:

Otero County Courthouse
PO Box 511
La Junta, CO 81050
(719)383-3000

Faults within County: Cheraw (H)
Historical Earthquakes: None
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:

Cheraw: M7.0 – 15 fatal, $416 Million (-14.2%)

Ouray County

Population: 4,030 Growth since 1990: 63.1%
County Size: 542 square miles Inventory: $781.70 M
Contact:

Ouray County Courthouse
PO Bin C
Ouray, CO 81427
(970)325-7320

Faults within County: Busted Boiler (LQ), Cow Creek (LC), Log Hill Mesa Graben Faults (LQ), Montrose Faults SW (Q), Ridgway (Q), Ridgway Quarry Faults (LC)
Historical Earthquakes: Aug. 3, 1897 Ridgway (#18); Nov. 11, 1913 Ridgway Area (#25-27); Oct. 11, 1960 Montrose-Ridway (#92); Feb. 5, 1962 Ridgway-Montrose (#100); Apr. 4, 1967 Montrose (#252); Nov. 19, 1989 Ridgway (#447); Nov. 22, 1989 Ouray (#448); Jan. 17, 1994 Ridgway (#470)
Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ), Cimarron (LQ,Q), Roubideau Creek (H)

HAZUS Loss Estimates:

Busted Boiler:	M6.5 – 1 fatal, $104 Million (-13.3%)
Cannibal:	M7.0 – 0 fatal, $36.5 Million (-4.7%)
Cimarron:	M6.75 – 0 fatal, $32.7 Million (-4.2%)
Roubideau:	M5.5 – 0 fatal, $2.8 Million (-0.4%)

Park County

Population: 14,523 Growth since 1990: 102.4%

County Size: 2,166 square miles Inventory: $2,806.30 M

Contact:

Park County Commissioners Office
501 Main St. or PO Box 1373
Fairplay, CO 80440
(719)836-4201

Faults within County: Bare Hills (LC), Chase Gulch-East Side (LQ), Chase Gulch-West Side (LQ), Currant Creek Fault Zone (LC), Eleven Mile (LQ), Elevenmile Canyon Reservoir Faults (LC), Frontal (LQ), Hartsel Faults W (LC), High Park Fault Zone (LC), Ilse (LC), Kaufman Ridge (LC), Northeastern Boundary Faults (MLQ), Pulver Gulch-Rocky Gulch (LC), Schoolmarm Mountain (LC), Tarryall (LC), Thirty-nine Mile Mountain (LC),

Historical Earthquakes: Nov. 27, 1961 South Park (#95-96); Apr. 3, 1966 Blast in South Park (#221)

Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Golden (Q), Mosquito (LQ), Rampart (MLQ), N Sangre (H), N Sawatch (LQ), S Sawatch (H), Ute Pass (MLQ), Williams Fork (H)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 1 fatal, $166 Million (-5.9%)
Frontal:	M7.0 – 1 fatal, $75.9 Million (-2.7%)
Golden:	M6.5 – 0 fatal, $13.0 Million (-0.5%)
Mosquito:	M7.0 – 3 fatal, $169 Million (-6.0%)
Rampart:	M7.0 – 0 fatal, $25.9 Million (-0.9%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $4.17 Million (-0.2%)
N Sawatch:	M7.0 – 1 fatal, $66.9 Million (-2.4%)
S Sawatch:	M7.25 – 1 fatal, $72.2 Million (-2.6%)
Ute Pass:	M7.0 – 0 fatal, $34.5 Million (-1.2%)
Williams Fork:	M6.75 – 0 fatal, $18.5 Million (-0.7%)

Phillips County

Population: 4,505 Growth since 1990: 6.9%

County Size: 688 square miles Inventory: $1,151.20 M

Contact:

Phillips County Courthouse
221 S. Interocean Ave.
Holyoke, CO 80734
(970)854-2454

Faults within County: None

Historical Earthquakes: None

Faults analyzed for County: Anton Scarp
HAZUS Loss Estimates:
Anton Scarp: M7.6 – 0 fatal, $17.6 Million (-1.5%)

Pitkin County

Population: 14,872 Growth since 1990: 17.5%
County Size: 975 square miles Inventory: $2,224.30 M
Contact:
Pitkin County Emergency Management
506 E. Main Street
Aspen, CO 81611
(970)920-5234
Faults within County: Basalt Mountain Fault (Q), Sawatch Range Faults (LC)
Historical Earthquakes: Sept. 17, 1880 Aspen (#4); Apr. 8, 1940 Aspen (#68); Feb. 1941 Aspen (#69-71); Oct. 17, 1960 Aspen (#94); Mar. 5, 1962 Aspen (#101); June 23, 1968 SW of Carbondale (#310); Sept. 24, 1977 SW of Carbondale (#360); May 29, 1978 SW of Carbondale (#362); Apr.-May 1984 Carbondale Earthquakes (#381-399); Apr. 21, 1991 Aspen (#454); July 7-8, 1993 Aspen (#466-469); Oct. 13, 2002 Aspen (#550); Jan. 1, 2003 Aspen (#553); Nov. 6, 2003 Aspen (#561)
Faults analyzed for County: Chase Gulch (LQ), Cimarron (LQ,Q), Frontal (LQ), Mosquito (LQ), N Sawatch (LQ), S Sawatch (H), Williams Fork (H)
HAZUS Loss Estimates:
Chase Gulch: M6.75 – 0 fatal, $10.9 Million (-0.5%)
Cimarron: M6.75 – 0 fatal, $12.6 Million (-0.6%)
Frontal: M7.0 – 0 fatal, $32.5 Million (-1.5%)
Mosquito: M7.0 – 0 fatal, $61.4 Million (-2.8%)
N Sawatch: M7.0 – 3 fatal, $169 Million (-7.6%)
S Sawatch: M7.25 – 2 fatal, $115 Million (-5.2%)
Williams Fork: M6.75 – 0 fatal, $13.2 Million (-0.6%)

Prowers County

Population: 14,104 Growth since 1990: 8.5%
County Size: 1,645 square miles Inventory: $2,306.40 M
Contact:
Prowers County Courthouse
310 S. Main St., #215
Lamar, CO 81052
(719)336-8025
Faults within County: None
Historical Earthquakes: Sept. 29, 1928 Holly (#67); Jan. 14, 1956 Lamar (#89-90); Apr. 21, 1968 S of Holly (#307); Jan. 10, 2003 Lamar (#554)
Faults analyzed for County: Cheraw (H)
HAZUS Loss Estimates:
Cheraw: M7.0 – 1 fatal, $60.9 Million (-2.6%)

Pueblo County

Population: 141,472 Growth since 1990: 15.0%

County Size: 2,401 square miles Inventory: $10,530.10 M

Contact:

Pueblo County Department of Emergency Management
320 W. 10th St., B1
Pueblo, CO 81003
(719)583-6200

Faults within County: Goodpasture (Q), Greenhorn (LC), Ilse (LC), Wet Mountain (LC)

Historical Earthquakes: Dec. 4, 1870 Pueblo-Ft. Reynolds (#1); Nov. 13, 1963 Pueblo (#144)

Faults analyzed for County: Cheraw (H), Goodpasture (Q), Rampart (MLQ), N Sangre (H), Ute Pass (MLQ)

HAZUS Loss Estimates:

Cheraw:	M7.0 – 2 fatal, $171 Million (-1.6%)
Goodpasture:	M6.0 – 1 fatal, $243 Million (-2.3%)
Rampart:	M7.0 – 3 fatal, $203 Million (-1.9%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $25.6 Million (-0.2%)
	M7.5 CEUS – 26 fatal, $484 Million (-4.6%)
Ute Pass:	M7.0 – 5 fatal, $288 Million (-2.7%)

Rio Blanco County

Population: 6,033 Growth since 1990: -1.1%

County Size: 3,226 square miles Inventory: $1,567.20 M

Contact:

Rio Blanco County Courthouse
PO Box I
Meeker, CO 81641
(970)878-5001

Faults within County: Blue Lake-Heart Lake Faults (LC), Fish Creek Faults (LC), Killarney Faults (Q), West Coal Creek (LC)

Historical Earthquakes: Feb. 21, 1954 Rangely-Grand Junction (#83); July 5-6, 1966 Rangely (#230-232); Feb. 15, 1967 Rangely (#249-250); Apr. 21, 1970 Rangely (#337-338); May 17, 1973 Rio Blanco AEC Test (#351); Mar. 19, 1979 Rangely (#367); Mar. 29, 1979 Rangely (#368); June 30, 1989 Meeker (#444); Nov. 3, 1994 Meeker (#481); Mar.-Apr. 1995 Dinosaur National Monument (#486-490)

Faults analyzed for County: Frontal (LQ)

HAZUS Loss Estimates:

Frontal:	M7.0 – 0 fatal, $6.69 Million (-0.4%)

Rio Grande County

Population: 12,711 Growth since 1990: 15.3%

County Size: 913 square miles Inventory: $1,783.20 M

Contact:

Rio Grande County Courthouse

925 6th Street, Rm. 207
Del Norte, CO 81132
(719)657-2744

Faults within County: Del Norte Peak Faults (LC), Monte Vista Faults (Q), Monte Vista Faults West (LC), Summitville Faults (LC)

Historical Earthquakes: Jan. 15, 1988 Summitville (#438); May 10, 1991 Summitville (#455-458)

Faults analyzed for County: Cannibal (LQ), N Sangre de Cristo (H)

HAZUS Loss Estimates:

Cannibal:	M7.0 – 0 fatal, $36.6 Million (-2.1%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $16.3 Million (-0.9%)
	M7.5 CEUS – 7 fatal, $124 Million (-7.0%)

Routt County

Population: 19,690 Growth since 1990: 39.8%
County Size: 2,331 square miles Inventory: $3,114.00 M

Contact:

Routt County Office of Emergency Management
135 6th Street or PO Box 773598
Steamboat Springs, CO 80477
(970)870-5551

Faults within County: Blacktail Mountain Faults (LC), Brush Mountain (LC), Diamond Peak Faults (LC), Fish Creek Faults (LC), Gardner Reservoir Faults (LC), Green Ridge (LC), Grouse Mountain (LC), Hahns Peak Faults (LC), Hinman Creek (LC), King Solomon (LC), Kremmling Faults (LC), Lawson Creek (LC), Lester Creek Reservoir (LC), Little Rock Creek (LC), Lone Spring Faults (LC), Milner Faults (LC), Morrison Creek (LC), Newcomer Creek Faults (LC), Park Range Faults (LC), Rabbit Ears Pass Faults (LC), Reed Creek (LC), Sand Mountain (LC), Sierra Madre Range Faults (LC), Silver City Creek (LC), Silver Creek (LC), Spillway (LC), Steamboat Lake (LC), Steamboat Springs Fault Zone (LC), Trail Creek (LC), Twentymile Park Faults (LC), Wheeler Creek (LC), Willow Creek Structural Zone (LC), Yampa (LC)

Historical Earthquakes: Mar. 22, 1895 Steamboat Springs (#17); Feb. 10, 1955 Steamboat Springs (#84); Nov. 1, 1966 Yampa (#238); Jan. 18, 1967 Flat Tops (#245); Mar. 18, 1971 Clark (#343); Mar. 31, 1974 Clark (#357); Apr. 29, 1993 Clark (#465); Feb. 2000 E of Steamboat Springs (#509-510); July 30, 2000 Steamboat Springs (#513); Mar. 23, 2002 Steamboat Springs (#537); Apr. 2002 Steamboat Springs (#541-542)

Faults analyzed for County: Frontal (LQ), Mosquito (LQ), Williams Fork (H), 1882 Rocky Mountain Park Epicenter

HAZUS Loss Estimates:

Frontal:	M7.0 – 1 fatal, $56.0 Million (-1.8%)
Mosquito:	M7.0 – 0 fatal, $23.2 Million (-0.7%)
Williams Fork:	M6.75 – 0 fatal, $40.4 Million (-1.3%)
1882 RMNP:	M6.6 – 0 fatal, $16.5 Million (-0.5%)

Saguache County

Population: 6,425 Growth since 1990: 28.1%
County Size: 3,168 square miles Inventory: $1,517.10 M

Contact:

Saguache County Courthouse
PO Box 655
Saguache, CO 81149
(719)655-2231

Faults within County: Alamosa Horst Fault Zone-East (LC), Cimarron Fault-Powderhorn Section (LC), Houselog Creek Faults (LC), Kerber Creek (LC), Lucky Boy (LQ), Mineral Hot Springs (LQ), North Sangre de Cristo (H), Poncha Pass Faults (LC), Saguache Creek Faults (LC), Squaw Creek Faults (LC), Villa Grove Fault Zone (H), Western Boundary (LQ)

Historical Earthquakes: None

Faults analyzed for County: Cannibal (LQ), N Sangre de Cristo (H), S Sawatch (H)

HAZUS Loss Estimates:

Cannibal:	M7.0 – 0 fatal, $16.3 Million (-1.1%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $25.2 Million (-1.7%)
	M7.5 CEUS – 4 fatal, $104 Million (-6.9%)
S Sawatch:	M7.25 – 0 fatal, $28.6 Million (-1.9%)

San Juan County

Population: 570 Growth since 1990: -25.1%
County Size: 389 square miles Inventory: $369.20 M

Contact:

San Juan County Courthouse
PO Box 466
Silverton, CO 81433
(970)387-5766

Faults within County: None

Historical Earthquakes: Nov. 23, 1882 Silverton (#10); Apr. 29, 1945 Silverton (#77-78); Jan. 16, 1967 Silverton (#244); June 18, 2002 SE of Silverton (#545)

Faults analyzed for County: Busted Boiler (LQ), Cannibal (LQ)

HAZUS Loss Estimates:

Busted Boiler:	M6.5 – 0 fatal, $0.89 Million (-0.2%)
Cannibal:	M7.0 – 0 fatal, $2.36 Million (-0.6%)

San Miguel County

Population: 7,100 Growth since 1990: 80.5%
County Size: 1,291 square miles Inventory: $1,361.60 M

Contact:

San Miguel County
PO Box 1170
Telluride, CO 81435
(970)728-3844

Faults within County: Big Gypsum Valley Graben Faults (Q), Dolores Fault Zone (Q), San Miguel Canyon Faults (Q)

Historical Earthquakes: Jan. 1, 1894 Telluride (#15); Feb. 3, 1970 S of Norwood (#335); Sept. 13-15, 1994 Norwood (#475-478)

Faults analyzed for County: Busted Boiler (LQ), Cimarron (LQ,Q), Roubideau (H)
HAZUS Loss Estimates:

Busted Boiler: M6.5 – 0 fatal, $36.2 Million (-2.7%)
Cimarron: M6.75 – 0 fatal, $7.53 Million (-0.6%)
Roubideau: M5.5 – 0 fatal, $0.81 Million (-0.0%)

Sedgwick County

Population: 2,747
Growth since 1990: 2.1%
County Size: 544 square miles
Inventory: $1,071.60 M
Contact:

Sedgwick County Courthouse
315 Cedar St. or PO Box 50
Julesburg, CO 80737
(970)474-2485

Faults within County: None
Historical Earthquakes: None
Faults analyzed for County: Anton Scarp
HAZUS Loss Estimates:

Anton Scarp: M7.6 – 0 fatal, $4.01 Million (-0.4%)

Summit County

Population: 23,548
Growth since 1990: 82.8%
County Size: 612 square miles
Inventory: $4,184.10 M
Contact:

Summit County Commissioners Office
208 E. Lincoln Ave. or PO Box 68
Breckenridge, CO 80424
(970)453-3535

Faults within County: Blue River Graben Faults (LC), Blue River Fault West (LC), Frontal (LQ), Gore (LC), Green Mountain Reservoir Faults (LC), Mosquito (LQ), Mount Powell Faults (LC), Sheephorn Mountain Faults (LC)
Historical Earthquakes: Aug. 4, 1964 Dillon (#149); Sept. 12, 1990 Vail (#449)
Faults analyzed for County: Chase Gulch (LQ), Frontal (LQ), Golden (Q), Mosquito (LQ), N Sangre de Cristo (H), N Sawatch (LQ), S Sawatch (H), Ute Pass (MLQ), Williams Fork (H)
HAZUS Loss Estimates:

Chase Gulch: M6.75 – 0 fatal, $73.3 Million (-1.8%)
Frontal: M7.0 – 39 fatal, $1.35 Billion (-32.2%)
Golden: M6.5 – 0 fatal, $27.1 Million (-0.7%)
Mosquito: M7.0 – 25 fatal, $1.06 Billion (-25.3%)
N Sawatch: M7.0 – 3 fatal, $217 Million (-5.2%)
S Sawatch: M7.25 – 2 fatal, $141 Million (-3.4%)
Ute Pass: M7.0 – 0 fatal, $42.7 Million (-1.0%)
Williams Fork: M6.75 – 9 fatal, $436 Million (-10.4%)

Teller County

Population: 22,156 — Growth since 1990: 64.9%

County Size: 559 square miles — Inventory: $1,952.20 M

Contact:

Teller County Courthouse
PO Box 959
Cripple Creek, CO 80813
(719)689-2988

Faults within County: Bare Hills (LC), Colorado Springs Faults (LC), Fourmile Creek (LC), Hay Creek (LC), High Park Fault Zone (LC), Midland (LC), Oil Creek (LC), Raspberry Mountain (LC), Ute Pass Fault Zone (MLQ)

Historical Earthquakes: Jan. 6, 1979 Divide (#365); Dec. 23 and 31, 1995 Manitou Springs (#492-493); Jan. 1997 Woodland Park (#497-499); Apr. 18, 1998 Woodland Park (#503); July 22, 2001 Woodland Park (#515); Feb. 19, 2003 Woodland Park (#556)

Faults analyzed for County: Chase Gulch (LQ), Rampart Range (MLQ), N Sangre de Cristo (H), S Sawatch (H), Ute Pass (MLQ)

HAZUS Loss Estimates:

Chase Gulch:	M6.75 – 0 fatal, $50.0 Million (-2.6%)
Rampart:	M7.0 – 4 fatal, $260 Million (-13.3%)
N Sangre de Cristo:	M7.5 WUS – 0 fatal, $2.44 Million (-0.1%)
S Sawatch:	M7.25 – 0 fatal, $18.0 Million (-0.9%)
Ute Pass:	M7.0 – 14 fatal, $524 Million (-26.8%)

Washington County

Population: 5,048 — Growth since 1990: 2.4%

County Size: 2,523 square miles — Inventory: $2,148.70 M

Contact:

Washington County Courthouse
150 Ash Ave.
Akron, CO 80720
(970)345-2701

Faults within County: High Plains Grabens under investigation

Historical Earthquakes: None

Faults analyzed for County: Anton Scarp

HAZUS Loss Estimates:

Anton Scarp:	M7.6 – 10 fatal, $228 Million (-10.6%)

Weld County

Population: 180,936 — Growth since 1990: 37.3%

County Size: 3,999 square miles — Inventory: $14,295.20 M

Contact:

Weld County Commissioners
915 Tenth Street or PO Box 758
Greeley, CO 80632
(970)336-7204

Faults within County: None
Historical Earthquakes: May 26, 1969 E of Greeley (#328)
Faults analyzed for County: Golden (Q), Rocky Mountain Arsenal Epicenter, Valmont (MLQ), Walnut Creek (Q)
HAZUS Loss Estimates:

Golden:	M6.5 – 3 fatal, $299 Million (-2.1%)
RM Arsenal:	M6.25 – 7 fatal, $502 Million (-3.5%)
Valmont:	M5.0 – 0 fatal, $40.2 Million (-0.3%)
Walnut Creek:	M6.0 – 1 fatal, $212 Million (-1.5%)

Yuma County

Population: 10,018 Growth since 1990: 9.9%
County Size: 2,370 square miles Inventory: $2,633.00 M
Contact:

Yuma County Courthouse
310 Ash Suite A
Wray, CO 80758
(970)332-5796

Faults within County: High Plains Grabens under investigation
Historical Earthquakes: None
Faults analyzed for County: Anton Scarp
HAZUS Loss Estimates:

Anton Scarp:	M7.6 – 12 fatal, $214 Million (-8.1%)

HAZUS:
County Scenario Summaries

HAZUS County Summary

Alamosa County

Scenarios:

1. N Sangre de Cristo M7.5 CEUS, $433 Million Total Loss (23.5% Loss Ratio)
2. Random M6.5 CEUS, $328 Million Total Loss (17.8% Loss Ratio)
3. Random M6.5 WUS, $152 Million Total Loss (8.3% Loss Ratio)
4. N Sangre de Cristo M7.5 WUS, $142 Million Total Loss (7.7% Loss Ratio)

Maps:

- Random M6.5 WUS and CEUS
- N Sangre de Cristo M7.5 WUS and CEUS

HAZUS County Summary

Adams County

Scenarios:

1. Rocky Mountain Arsenal M6.25, $3.15 Billion Total Loss (15.0% Loss Ratio)
2. Golden Fault M6.5, $1.59 Billion Total Loss (7.6% Loss Ratio)
3. Walnut Creek Fault M6.0, $1.28 Billion Total Loss (6.1% Loss Ratio)
4. Random M6.5, $854 Million Total Loss (4.1% Loss Ratio)
5. Rampart Range Fault M7.0, $774 Million Total Loss (3.7% Loss Ratio)
6. Ute Pass Fault M7.0, $496 Million Total Loss (2.4% Loss Ratio)
7. 1882 Repeat RMNP M6.6, $150 Million Total Loss (0.7% Loss Ratio)
8. Valmont Fault M5.0, $64.1 Million Total Loss (0.3% Loss Ratio)

Maps:

- Random M6.5
- Golden M6.5
- Rocky Mountain Arsenal M6.25

HAZUS County Summary

Arapahoe County

Scenarios:

1. Golden Fault M6.5, $3.90 Billion Total Loss (12.1% Loss Ratio)
2. Rampart Fault M7.0, $3.84 Billion Total Loss (11.9% Loss Ratio)
3. Rocky Mountain Arsenal M6.25, $2.63 Billion Total Loss (8.2% Loss Ratio)
4. Random M6.5, $2.35 Billion Total Loss (7.3% Loss Ratio)
5. Ute Pass Fault M7.0, $2.11 Billion Total Loss (6.5% Loss Ratio)
6. Walnut Creek Fault M6.0, $1.25 Billion Total Loss (3.9% Loss Ratio)
7. Chase Gulch Fault M6.75, $678 Million Total Loss (2.1% Loss Ratio)
8. Cheraw Fault M7.0, $57.9 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- Golden Fault M6.5
- Rampart Fault M7.0

HAZUS County Summary

Archuleta County

Scenarios:

1. Random M6.5, $341 Million Total Loss (17.5% Loss Ratio)
2. Cannibal Fault M7.0, $42.1 Million Total Loss (2.2% Loss Ratio)
3. N Sangre Fault M7.5 CEUS, $28.1 Million Total Loss (1.4% Loss Ratio)
4. N Sangre Fault M7.5 WUS, $1.04 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Cannibal Fault M7.0

HAZUS County Summary

Baca County

Scenarios:

1. Random M6.5, $120 Million Total Loss (6.5% Loss Ratio)

2. Cheraw Fault M7.0, $2.14 Million Total Loss (0.1% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

Bent County

Scenarios:

1. Random M6.5, $72.3 Million Total Loss (6.7% Loss Ratio)

2. Cheraw Fault M7.0, $18.1 Million Total Loss (1.7% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

Boulder County

Scenarios:

1. Random M6.5, $3.28 Billion Total Loss (15.8% Loss Ratio)
2. Golden Fault M6.5, $1.49 Billion Total Loss (7.2% Loss Ratio)
3. Walnut Creek Fault M6.0, $1.21 Billion Total Loss (5.8% Loss Ratio)
4. Rocky Mountain Arsenal M6.25, $1.10 Billion Total Loss (5.3% Loss Ratio)
5. Valmont Fault M5.0, $411 Million Total Loss (2.0% Loss Ratio)
6. Frontal Fault M7.0, $330 Million Total Loss (1.6% Loss Ratio)
7. 1882 Repeat RMNP M6.6, $328 Million Total Loss (1.6% Loss Ratio)
8. Mosquito Fault M7.0, $252 Million Total Loss (1.2% Loss Ratio)
9. Ute Pass Fault M7.0, $245 Million Total Loss (1.2% Loss Ratio)
10. Williams Fork Fault M6.75, $233 Million Total Loss (1.1% Loss Ratio)

Maps:

- Random M6.5
- Golden Fault M6.5

HAZUS County Summary

Chaffee County

Scenarios:

1. S Sawatch Fault M7.25 CEUS, $665 Million Total Loss (28.3% Loss Ratio)
2. N Sangre Fault M7.5 CEUS, $426 Million Total Loss (18.1% Loss Ratio)
3. Random M6.5, $288 Million Total Loss (12.3% Loss Ratio)
4. N Sawatch Fault M7.0, $153 Million Total Loss (6.5% Loss Ratio)
5. N Sangre Fault M7.5 WUS, $133 Million Total Loss (5.7% Loss Ratio)
6. Mosquito Fault M7.0, $65.8 Million Total Loss (2.8% Loss Ratio)
7. Chase Gulch Fault M6.75, $33.9 Million Total Loss (1.4% Loss Ratio)
8. Frontal Fault M7.0, $17.5 Million Total Loss (0.7% Loss Ratio)

Maps:

- Random M6.5
- S Sawatch Fault M7.0
- N Sangre de Cristo Fault M7.5

HAZUS County Summary

Cheyenne County

Scenarios:

1. Random M6.5, $51.1 Million Total Loss (3.5% Loss Ratio)

2. Anton Scarp (suspect) M7.6, $27.1 Million Total Loss (1.9% Loss Ratio)

3. Cheraw Fault M7.0, $8.57 Million Total Loss (0.6% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

Clear Creek County

Scenarios:

1. Random M6.5, $175 Million Total Loss (10.7% Loss Ratio)
2. Golden Fault M6.5, $42.9 Million Total Loss (2.6% Loss Ratio)
3. Frontal Fault M7.0, $38.0 Million Total Loss (2.3% Loss Ratio)
4. Williams Fork Fault M6.75, $31.9 Million Total Loss (2.0% Loss Ratio)
5. Mosquito Fault M7.0, $31.8 Million Total Loss (2.0% Loss Ratio)
6. Ute Pass Fault M7.0, $10.6 Million Total Loss (0.7% Loss Ratio)
7. Chase Gulch Fault M6.75, $9.71 Million Total Loss (0.6% Loss Ratio)
8. N Sawatch Fault M7.0, $8.96 Million Total Loss (0.6% Loss Ratio)

Maps:

- Random M6.5
- Golden Fault M6.5

HAZUS County Summary

Conejos County

Scenarios:

1. Random M6.5 CEUS, $76.4 Million Total Loss (6.6% Loss Ratio)
2. N Sangre Fault M7.5 CEUS, $56.3 Million Total Loss (4.8% Loss Ratio)
3. Random M6.5 WUS, $26.4 Million Total Loss (2.3% Loss Ratio)
4. N Sangre Fault M7.5 WUS, $9.9 Million Total Loss (0.9% Loss Ratio)

Maps:

- Random M6.5 WUS and CEUS
- N Sangre Fault M7.5 WUS

HAZUS County Summary

Costilla County

Scenarios:

1. N Sangre Fault M7.5 CEUS, $85.2 Million Total Loss (8.4% Loss Ratio)
2. N Sangre Fault M7.5 WUS, $51.6 Million Total Loss (5.1% Loss Ratio)
3. Random M6.5 CEUS, $46.9 Million Total Loss (4.6% Loss Ratio)
4. Random M6.5, $20.7 Billion Total Loss (2.0% Loss Ratio)

Maps:

- N Sangre Fault M7.5 WUS
- Random M6.5 WUS and CEUS

HAZUS County Summary

Crowley County

Scenarios:

1. Random M6.5, $91.1 Million Total Loss (13.7% Loss Ratio)
2. Cheraw Fault M7.0, $55.2 Million Total Loss (8.3% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

Custer County

Scenarios:

1. Random M6.5, $148 Million Total Loss (16.9% Loss Ratio)
2. N Sangre Fault M7.5 CEUS, $138 Million Total Loss (15.8% Loss Ratio)
3. N Sangre Fault M7.5 WUS, $28.5 Million Total Loss (3.3% Loss Ratio)
4. Goodpasture Fault M6.0, $6.2 Million Total Loss (0.7% Loss Ratio)

Maps:

- Random M6.5
- N Sangre Fault M7.5 CEUS

HAZUS County Summary

Delta County

Scenarios:

1. Random M6.5, $288 Million Total Loss (10.1% Loss Ratio)

2. Cimarron Fault M6.75, $53.1 Million Total Loss (1.9% Loss Ratio)

3. Roubideau Creek Fault M5.5, $5.93 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- Cimarron Fault M6.75

HAZUS County Summary

Denver County

Scenarios:

1. Random M6.5, $14.23 Billion Total Loss (36.4% Loss Ratio)
2. Golden Fault M6.5, $7.51 Billion Total Loss (19.2% Loss Ratio)
3. Rocky Mountain Arsenal M6.25, $5.56 Billion Total Loss (14.2% Loss Ratio)
4. Rampart Fault M7.0, $4.65 Billion Total Loss (11.9% Loss Ratio)
5. Rocky Mountain Arsenal M6.0, $3.89 Billion Total Loss (10.0% Loss Ratio)
6. Walnut Creek Fault M6.0, $3.15 Billion Total Loss (8.1% Loss Ratio)
7. Anton Scarp (suspect) M7.6, $3.05 Billion Total Loss (7.8% Loss Ratio)
8. Ute Pass Fault M7.0, $2.75 Billion Total Loss (7.0% Loss Ratio)
9. Frontal Fault M7.0, $1.48 Billion Total Loss (3.8% Loss Ratio)
10. N Sangre Fault M7.5 CEUS, $1.47 Billion Total Loss (3.8% Loss Ratio)
11. Rocky Mountain Arsenal M5.5, $1.41 Billion Total Loss (3.6% Loss Ratio)
12. Mosquito Fault M7.0, $1.32 Billion Total Loss (3.4% Loss Ratio)
13. Chase Gulch Fault M6.75, $1.01 Billion Total Loss (2.6% Loss Ratio)
14. S Sawatch Fault M7.25, $866 Million Total Loss (2.2% Loss Ratio)
15. Williams Fork Fault M6.75, $850 Million Total Loss (2.2% Loss Ratio)
16. N Sawatch Fault M7.0, $652 Million Total Loss (1.7% Loss Ratio)
17. Rocky Mountain Arsenal M5.0, $544 Million Total Loss (1.4% Loss Ratio)
18. 1882 Repeat RMNP M6.6, $527 Million Total Loss (1.4% Loss Ratio)
19. Valmont Fault M5.0, $98.4 Million Total Loss (0.3% Loss Ratio)

20. N Sangre Fault M7.5 WUS, $69.9 Million Total Loss (0.2% Loss Ratio)

21. Cheraw Fault M7.0, $8.02 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Golden Fault M6.5
- Rampart Fault M7.0
- Rocky Mountain Arsenal M6.25
- Walnut Creek M6.0

HAZUS County Summary

Dolores County

Scenarios:

1. Random M6.5, $26.2 Million Total Loss (5.1% Loss Ratio)
2. Cannibal Fault M7.0, $0.9 Million Total Loss (0.2% Loss Ratio)
3. Busted Boiler Fault M6.5, $0.85 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- Cannibal Fault M7.0

HAZUS County Summary

Douglas County

Scenarios:

1. Random M6.5, $2.04 Billion Total Loss (14.9% Loss Ratio)
2. Rampart Fault M7.0, $1.85 Billion Total Loss (13.5% Loss Ratio)
3. Ute Pass Fault M7.0, $652 Million Total Loss (4.8% Loss Ratio)
4. Golden Fault M6.5, $578 Million Total Loss (4.2% Loss Ratio)
5. Chase Gulch Fault M6.75, $117 Million Total Loss (0.9% Loss Ratio)
6. Frontal Fault M7.0, $114 Million Total Loss (0.8% Loss Ratio)
7. Mosquito Fault M7.0, $111 Million Total Loss (0.8% Loss Ratio)
8. N Sawatch Fault M7.0, $64.1 Million Total Loss (0.5% Loss Ratio)
9. Cheraw Fault M7.0, $19.2 Million Total Loss (0.1% Loss Ratio)

Maps:

- Random M6.5
- Rampart Fault M7.0

HAZUS County Summary

Eagle County

Scenarios:

1. Random M6.5, $599.7 Million Total Loss (12.0% Loss Ratio)
2. Frontal Fault M7.0, $572 Million Total Loss (11.4% Loss Ratio)
3. Mosquito Fault M7.0, $417 Million Total Loss (8.3% Loss Ratio)
4. N Sawatch Fault M7.0, $387 Million Total Loss (7.7% Loss Ratio)
5. Williams Fork Fault M6.75, $207 Million Total Loss (4.1% Loss Ratio)
6. S Sawatch Fault M7.25, $146 Million Total Loss (2.9% Loss Ratio)
7. Chase Gulch Fault M6.75, $33.9 Million Total Loss (0.7% Loss Ratio)

Maps:

- Random M6.5
- Frontal Fault M7.0

HAZUS County Summary

El Paso County

Scenarios:

1. Rampart Fault M7.0, $9.01 Billion Total Loss (27.7% Loss Ratio)
2. Ute Pass Fault M7.0, $8.22 Billion Total Loss (25.2% Loss Ratio)
3. Random M6.5, $4.25 Billion Total Loss (13.1% Loss Ratio)
4. N Sangre Fault M7.5 CEUS, $2.12 Billion Total Loss (6.5% Loss Ratio)
5. Ute Pass Fault M6.0, $1.91 Billion Total Loss (5.9% Loss Ratio)
6. Rampart Fault M6.0, $1.67 Billion Total Loss (5.1% Loss Ratio)
7. S Sawatch Fault M7.25, $659 Million Total Loss (2.0% Loss Ratio)
8. Chase Gulch Fault M6.75, $636 Million Total Loss (2.0% Loss Ratio)
9. Cheraw Fault M7.0, $353 Million Total Loss (1.1% Loss Ratio)
10. Goodpasture Fault M6.0, $103 Million Total Loss (0.3% Loss Ratio)
11. N Sangre Fault M7.5 WUS, $90.8 Million Total Loss (0.3% Loss Ratio)

Maps:

- Random M6.5
- Rampart Fault M7.0
- Ute Pass Fault M7.0

HAZUS County Summary

Elbert County

Scenarios:

1. Rampart Fault M7.0, $98.9 Million Total Loss (4.1% Loss Ratio)
2. Random M6.5, $72.8 Million Total Loss (3.0% Loss Ratio)
3. Ute Pass Fault M7.0, $44.3 Million Total Loss (1.8% Loss Ratio)
4. Golden Fault M6.5, $15.6 Million Total Loss (0.6% Loss Ratio)
5. Cheraw Fault M7.0, $5.3 Million Total Loss (0.2% Loss Ratio)

Maps:

- Rampart Fault M7.0
- Random M6.5

HAZUS County Summary

Fremont County

Scenarios:

1. N Sangre Fault M7.5 CEUS, $393.6 Million Total Loss (10.5% Loss Ratio)
2. Random M6.5, $299.1 Million Total Loss (8.0% Loss Ratio)
3. Ute Pass Fault M7.0, $184 Million Total Loss (4.9% Loss Ratio)
4. Rampart Fault M7.0, $127 Million Total Loss (3.4% Loss Ratio)
5. S Sawatch Fault M7.25, $121 Million Total Loss (3.2% Loss Ratio)
6. N Sangre Fault M7.5 WUS, $89.6 Million Total Loss (2.4% Loss Ratio)
7. Chase Gulch Fault M6.75, $79.5 Million Total Loss (2.1% Loss Ratio)
8. Goodpasture Fault M6.0, $56.1 Million Total Loss (1.5% Loss Ratio)

Maps:

- N Sangre Fault M7.5 CEUS
- Random M6.5

HAZUS County Summary

Garfield County

Scenarios:

1. Random M6.5, $253 Million Total Loss (5.3% Loss Ratio)
2. N Sawatch Fault M7.0, $76.6 Million Total Loss (1.6% Loss Ratio)
3. Frontal Fault M7.0, $35.3 Million Total Loss (0.8% Loss Ratio)
4. Mosquito Fault M7.0, $35.3 Million Total Loss (0.8% Loss Ratio)

Maps:

- Random M6.5
- N Sawatch Fault M7.0

HAZUS County Summary

Gilpin County

Scenarios:

1. Random M6.5, $133 Million Total Loss (18.4% Loss Ratio)
2. Golden Fault M6.5, $40.1 Million Total Loss (5.5% Loss Ratio)
3. Frontal Fault M7.0, $10.8 Million Total Loss (1.5% Loss Ratio)
4. Williams Fork Fault M6.75, $9.96 Million Total Loss (1.4% Loss Ratio)

Maps:

- Random M6.5
- Golden Fault M6.5

HAZUS County Summary

Grand County

Scenarios:

1. Random M6.5, $195 Million Total Loss (6.2% Loss Ratio)
2. Williams Fork Fault M6.75, $184 Million Total Loss (5.9% Loss Ratio)
3. Frontal Fault M7.0, $157 Million Total Loss (5.0% Loss Ratio)
4. 1882 RMNP M6.6, $110 Million Total Loss (3.5% Loss Ratio)
5. Mosquito Fault M7.0, $47.2 Million Total Loss (1.5% Loss Ratio)
6. N Sawatch Fault M7.0, $24.1 Million Total Loss (0.8% Loss Ratio)

Maps:

- Random M6.5
- Williams Fork Fault M6.75

HAZUS County Summary

Gunnison County

Scenarios:

1. Random M6.5, $164 Million Total Loss (6.1% Loss Ratio)
2. N Sangre Fault M7.0 CEUS, $100 Million Total Loss (3.7% Loss Ratio)
3. S Sawatch Fault M7.25, $88.3 Million Total Loss (3.3% Loss Ratio)
4. Cannibal Fault M7.0, $70.1 Million Total Loss (2.6% Loss Ratio)
5. Cimarron Fault M6.75, $67.6 Million Total Loss (2.5% Loss Ratio)
6. N Sawatch Fault M7.0, $46.2 Million Total Loss (1.7% Loss Ratio)
7. Mosquito Fault M7.0, $32.4 Million Total Loss (1.2% Loss Ratio)
8. Busted Boiler Fault M6.5, $13.1 Million Total Loss (0.5% Loss Ratio)
9. N Sangre Fault M7.5 WUS, $4.2 Million Total Loss (0.2% Loss Ratio)
10. Roubideau Creek Fault M5.5, $0.5 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- N Sangre Fault M7.5
- Cimarron Fault M6.75

HAZUS County Summary

Hinsdale County

Scenarios:

1. Random M6.5, $45.1Million Total Loss (13.0% Loss Ratio)

2. Cannibal Fault M7.0, $35.2 Million Total Loss (10.1% Loss Ratio)

3. Cimarron Fault M6.75, $1.9 Million Total Loss (0.6% Loss Ratio)

4. Busted Boiler Fault M6.5, $1.1 Million Total Loss (0.3% Loss Ratio)

Maps:

- Random M6.5
- Cannibal Fault M7.0

HAZUS County Summary

Huerfano County

Scenarios:

1. Random M6.5, $147 Million Total Loss (7.6% Loss Ratio)
2. N Sangre Fault M7.5 CEUS, $84.0 Million Total Loss (4.3% Loss Ratio)
3. N Sangre Fault M7.5 WUS, $19.0 Million Total Loss (1.0% Loss Ratio)
4. Goodpasture Fault M6.0, $10.1 Million Total Loss (0.5% Loss Ratio)
5. Cheraw Fault M7.0, $4.6 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- N Sangre Fault M7.5 CEUS

HAZUS County Summary

Jackson County

Scenarios:

1. Random M6.5, $88.9 Million Total Loss (9.4% Loss Ratio)
2. 1882 RMNP M6.6, $3.7 Million Total Loss (0.4% Loss Ratio)
3. Frontal Fault M7.0, $3.0 Million Total Loss (0.3% Loss Ratio)
4. Williams Fork Fault M6.75, $2.3 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- 1882 RMNP Repeat M6.6

HAZUS County Summary

Jefferson County

Scenarios:

1. Golden Fault M6.5, $5.88 Billion Total Loss (16.4% Loss Ratio)
2. Random M6.5, $5.11 Billion Total Loss (14.3% Loss Ratio)
3. Walnut Creek Fault M6.0, $2.31 Billion Total Loss (6.4% Loss Ratio)
4. Rocky Mountain Arsenal M6.25, $1.42 Billion Total Loss (4.0% Loss Ratio)
5. Rampart Fault M7.0, $1.30 Billion Total Loss (3.6% Loss Ratio)
6. Golden Fault M5.5, $1.03 Billion Total Loss (2.9% Loss Ratio)
7. Ute Pass Fault M7.0, $770 Million Total Loss (2.2% Loss Ratio)
8. Frontal Fault M7.0, $460 Million Total Loss (1.3% Loss Ratio)
9. Mosquito Fault M7.0, $402 Million Total Loss (1.1% Loss Ratio)
10. Chase Gulch Fault M6.75, $307 Million Total Loss (0.9% Loss Ratio)
11. N Sangre Fault M7.5 CEUS, $285 Million Total Loss (0.8% Loss Ratio)
12. Williams Fork Fault M6.75, $274 Million Total Loss (0.8% Loss Ratio)
13. S Sawatch Fault M7.25, $253 Million Total Loss (0.7% Loss Ratio)
14. N Sawatch Fault M7.0, $206 Million Total Loss (1.6% Loss Ratio)
15. Valmont Fault M5.0, $50.4 Million Total Loss (0.1% Loss Ratio)
16. N Sangre Fault M7.5 WUS, $15.6 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Golden Fault M6.5

HAZUS County Summary

Kiowa County

Scenarios:

1. Random M6.5, $45.3 Million Total Loss (4.0% Loss Ratio)

2. Cheraw Fault M7.0, $11.4 Billion Total Loss (1.0% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

Kit Carson County

Scenarios:

1. Anton Scarp (suspect) M7.6, $285 Million Total Loss (12.7% Loss Ratio)

2. Random M6.5, $100 Billion Total Loss (4.5% Loss Ratio)

3. Cheraw Fault M7.0, $11.3 Million Total Loss (0.5% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

La Plata County

Scenarios:

1. Random M6.5, $640 Million Total Loss (14.9% Loss Ratio)
2. Cannibal Fault M7.0, $53.1 Million Total Loss (1.2% Loss Ratio)
3. Busted Boiler Fault M6.5, $14.4 Million Total Loss (0.3% Loss Ratio)
4. Cimarron Fault M6.75, $12.3 Million Total Loss (0.3% Loss Ratio)

Maps:

- Random M6.5
- Cannibal Fault M7.0

HAZUS County Summary

Lake County

Scenarios:

1. N Sawatch Fault M7.0, $303 Million Total Loss (27.5% Loss Ratio)
2. Mosquito Fault M7.0, $299 Million Total Loss (27.2% Loss Ratio)
3. Random M6.5, $274 Million Total Loss (25.0% Loss Ratio)
4. S Sawatch Fault M7.25, $183 Million Total Loss (16.7% Loss Ratio)
5. Frontal Fault M7.0, $69.5 Million Total Loss (6.3% Loss Ratio)
6. Chase Gulch Fault M6.75, $27.3 Million Total Loss (2.5% Loss Ratio)
7. Williams Fork Fault M6.75, $17.2 Million Total Loss (1.6% Loss Ratio)

Maps:

- Random M6.5
- Mosquito Fault M7.0
- N Sawatch Fault M7.0

HAZUS County Summary

Larimer County

Scenarios:

1. Random M6.5, $1.36 Billion Total Loss (7.2% Loss Ratio)
2. 1882 RMNP M6.6, $887 Million Total Loss (4.7% Loss Ratio)
3. Golden Fault M6.5, $237 Million Total Loss (1.3% Loss Ratio)
4. Williams Fork Fault M6.75, $178 Million Total Loss (0.9% Loss Ratio)
5. Valmont Fault M5.0, $11.4 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- 1882 RMNP Repeat M6.6

HAZUS County Summary

Las Animas County

Scenarios:

1. Random M6.5, $33.8 Million Total Loss (0.9% Loss Ratio)

2. N Sangre Fault M7.5 CEUS, $31.6 Million Total Loss (0.9% Loss Ratio)

3. Cheraw Fault M7.0, $3.97 Million Total Loss (0.1% Loss Ratio)

4. N Sangre Fault M7.5 WUS, $3.4 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- N Sangre Fault M7.5 CEUS

HAZUS County Summary

Lincoln County

Scenarios:

1. Random M6.5, $118 Million Total Loss (6.3% Loss Ratio)

2. Anton Scarp (suspect) M7.6, $59.2 Million Total Loss (3.2% Loss Ratio)

3. Cheraw Fault M7.0, $22.5 Million Total Loss (1.2% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

Logan County

Scenarios:

1. Random M6.5, $347 Million Total Loss (11.3% Loss Ratio)

2. Anton Scarp (suspect) M7.6, $300 Million Total Loss (9.8% Loss Ratio)

3. Rocky Mountain Arsenal M6.25, $2.12 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Rocky Mountain Arsenal M6.25

HAZUS County Summary

Mesa County

Scenarios:

1. Random M7.0, $2.96 Billion Total Loss (32.7% Loss Ratio)

2. Random M6.5, $2.12 Billion Total Loss (23.5% Loss Ratio)

3. Cimarron Fault M6.75, $55.4 Million Total Loss (0.6% Loss Ratio)

4. Roubideau Creek Fault M5.5, $4.7 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M7.0
- Random M6.5
- Cimarron Fault M6.75

HAZUS County Summary

Mineral County

Scenarios:

1. Random M6.5, $74.4 Million Total Loss (11.2% Loss Ratio)

2. Cannibal Fault M7.0, $43.1 Million Total Loss (6.5% Loss Ratio)

3. N Sangre Fault M7.5 CEUS, $9.52 Million Total Loss (1.4% Loss Ratio)

4. Cimarron Fault M6.75, $2.75 Million Total Loss (0.4% Loss Ratio)

Maps:

- Random M6.5
- Cannibal Fault M7.0

HAZUS County Summary

Moffat County

Scenarios:

1. Random M6.5, $36.1 Million Total Loss (1.3% Loss Ratio)

2. Frontal Fault M7.0, $5.11 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- Frontal Fault M7.0

HAZUS County Summary

Montezuma County

Scenarios:

1. Random M6.5, $260 Million Total Loss (8.5% Loss Ratio)

2. Cannibal Fault M7.0, $9.80 Million Total Loss (0.3% Loss Ratio)

Maps:

- Random M6.5
- Cannibal Fault M7.0

HAZUS County Summary

Montrose County

Scenarios:

1. Cimarron Fault M6.75, $497 Million Total Loss (13.2% Loss Ratio)
2. Busted Boiler Fault M6.5, $432 Million Total Loss (11.5% Loss Ratio)
3. Random M6.5, $257 Million Total Loss (6.8% Loss Ratio)
4. Cannibal Fault M7.0, $174 Million Total Loss (4.6% Loss Ratio)
5. Roubideau Creek Fault M5.5, $78.2 Million Total Loss (2.1% Loss Ratio)

Maps:

- Random M6.5
- Cimarron Fault M6.75

HAZUS County Summary

Morgan County

Scenarios:

1. Anton Scarp (suspect) M7.6, $2.44 Billion Total Loss (45.2% Loss Ratio)
2. Random M6.5, $1.38 Billion Total Loss (25.6% Loss Ratio)
3. Rocky Mountain Arsenal M6.25, $21.8 Million Total Loss (0.4% Loss Ratio)

Maps:

- Random M6.5
- Rocky Mountain Arsenal M6.25

HAZUS County Summary

Otero County

Scenarios:

1. Cheraw Fault M7.0, $416 Million Total Loss (14.2% Loss Ratio)

2. Random M6.5, $334 Million Total Loss (11.4% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

Ouray County

Scenarios:

1. Random M6.5, $147 Million Total Loss (18.8% Loss Ratio)
2. Busted Boiler Fault M6.5, $104 Million Total Loss (13.3% Loss Ratio)
3. Cannibal Fault M7.0, $36.5 Million Total Loss (4.7% Loss Ratio)
4. Cimarron Fault M6.75, $32.7 Million Total Loss (4.2% Loss Ratio)
5. Roubideau Creek Fault M5.5, $2.8 Million Total Loss (0.4% Loss Ratio)

Maps:

- Random M6.5
- Busted Boiler Fault M6.5

HAZUS County Summary

Park County

Scenarios:

1. Mosquito Fault M7.0, $169 Million Total Loss (6.0% Loss Ratio)
2. Chase Gulch Fault M6.75, $166 Million Total Loss (5.9% Loss Ratio)
3. Random M6.5, $153 Million Total Loss (5.4% Loss Ratio)
4. Frontal Fault M7.0, $75.9 Million Total Loss (2.7% Loss Ratio)
5. S Sawatch Fault M7.25, $72.2 Million Total Loss (2.6% Loss Ratio)
6. N Sawatch Fault M7.0, $66.9 Million Total Loss (2.4% Loss Ratio)
7. Ute Pass Fault M7.0, $34.5 Million Total Loss (1.2% Loss Ratio)
8. Rampart Fault M7.0, $25.9 Million Total Loss (0.9% Loss Ratio)
9. Williams Fork Fault M6.75, $18.5 Million Total Loss (0.7% Loss Ratio)
10. Golden Fault M6.5, $13.0 Million Total Loss (0.5% Loss Ratio)
11. N Sangre Fault M7.5 WUS, $4.17 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- Chase Gulch Fault M6.75
- Mosquito Fault M7.0

HAZUS County Summary

Phillips County

Scenarios:

1. Random M6.5, $74.1 Mllion Total Loss (6.4% Loss Ratio)

2. Anton Scarp (suspect) M7.6, $17.6 Million Total Loss (1.5% Loss Ratio)

3. Rocky Mountain Arsenal M6.25, $0.0 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Rocky Mountain Arsenal M6.25

HAZUS County Summary

Pitkin County

Scenarios:

1. Random M6.5, $375 Million Total Loss (16.9% Loss Ratio)
2. N Sawatch Fault M7.0, $169 Million Total Loss (7.6% Loss Ratio)
3. S Sawatch Fault M7.25, $115 Million Total Loss (5.2% Loss Ratio)
4. Mosquito Fault M7.0, $61.4 Million Total Loss (2.8% Loss Ratio)
5. Frontal Fault M7.0, $32.5 Million Total Loss (1.5% Loss Ratio)
6. Williams Fork Fault M6.75, $13.2 Million Total Loss (0.6% Loss Ratio)
7. Cimarron Fault M6.75, $12.6 Million Total Loss (0.6% Loss Ratio)
8. Chase Gulch Fault M6.75, $10.9 Million Total Loss (0.5% Loss Ratio)

Maps:

- Random M6.5
- N Sawatch Fault M7.0

HAZUS County Summary

Prowers County

Scenarios:

1. Random M6.5, $210 Million Total Loss (9.1% Loss Ratio)

2. Cheraw Fault M7.0, $60.9 Million Total Loss (2.6% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS County Summary

Pueblo County

Scenarios:

1. Random M6.5, $2.32 Billion Total Loss (22.0% Loss Ratio)
2. N Sangre Fault M7.5 CEUS, $484 Million Total Loss (4.6% Loss Ratio)
3. Ute Pass Fault M7.0, $288 Million Total Loss (2.7% Loss Ratio)
4. Goodpasture Fault M6.0, $243 Million Total Loss (2.3% Loss Ratio)
5. Rampart Fault M7.0, $203 Million Total Loss (1.9% Loss Ratio)
6. Cheraw Fault M7.0, $171 Million Total Loss (1.6% Loss Ratio)
7. N Sangre Fault M7.5 WUS, $25.6 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- N Sangre Fault M7.5 CEUS
- Ute Pass Fault M7.0
- Goodpasture Fault M6.0

HAZUS County Summary

Rio Blanco County

Scenarios:

1. Random M6.5, $51.4 Million Total Loss (3.3% Loss Ratio)

2. Frontal Fault M7.0, $6.7 Million Total Loss (0.4% Loss Ratio)

Maps:

- Random M6.5
- Frontal Fault M7.0

HAZUS County Summary

Rio Grande County

Scenarios:

1. Random M6.5 CEUS, $199 Million Total Loss (11.2% Loss Ratio)
2. N Sangre Fault M7.5 CEUS, $124 Million Total Loss (7.0% Loss Ratio)
3. Random M6.5 WUS, $88.8 Million Total Loss (5.0% Loss Ratio)
4. Cannibal Fault M7.0, $36.6 Million Total Loss (2.1% Loss Ratio)
5. N Sangre Fault M7.5 WUS, $16.3 Million Total Loss (0.9% Loss Ratio)

Maps:

- Random M6.5 WUS
- Cannibal Fault M7.0 CEUS

HAZUS County Summary

Routt County

Scenarios:

1. Random M6.5, $462 Million Total Loss (14.8% Loss Ratio)
2. Frontal Fault M7.0, $56.0 Million Total Loss (1.8% Loss Ratio)
3. Williams Fork Fault M6.75, $40.4 Million Total Loss (1.3% Loss Ratio)
4. Mosquito Fault M7.0, $23.2 Million Total Loss (0.7% Loss Ratio)
5. 1882 RMNP M6.6, $16.5 Million Total Loss (0.5% Loss Ratio)

Maps:

- Random M6.5
- Frontal Fault M7.0

HAZUS County Summary

Saguache County

Scenarios:

1. N Sangre Fault M7.5 CEUS, $104 Million Total Loss (6.9% Loss Ratio)
2. Random M6.5 CEUS, $94.0 Million Total Loss (6.2% Loss Ratio)
3. Random M6.5 WUS, $53.1 Million Total Loss (3.5% Loss Ratio)
4. S Sawatch Fault M7.25, $28.6 Million Total Loss (1.9% Loss Ratio)
5. N Sangre Fault M7.5 WUS, $25.2 Million Total Loss (1.7% Loss Ratio)
6. Cannibal Fault M7.0, $16.3 Million Total Loss (1.1% Loss Ratio)

Maps:

- Random M6.5 WUS and CEUS
- N Sangre Fault M7.5 WUS and CEUS

HAZUS County Summary

San Juan County

Scenarios:

1. Random M6.5, $20.1 Million Total Loss (5.4% Loss Ratio)

2. Cannibal Fault M7.0, $2.4 Million Total Loss (0.6% Loss Ratio)

3. Busted Boiler Fault M6.5, $0.9 Million Total Loss (0.2% Loss Ratio)

Maps:

- Random M6.5
- Cannibal Fault M7.0

HAZUS County Summary

San Miguel County

Scenarios:

1. Busted Boiler Fault M6.5, $36.2 Million Total Loss (2.7% Loss Ratio)

2. Random M6.5, $32.6 Million Total Loss (2.4% Loss Ratio)

3. Cimarron Fault M6.75, $7.5 Million Total Loss (0.6% Loss Ratio)

4. Roubideau Creek Fault M5.5, $0.8 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Busted Boiler Fault M6.5

HAZUS County Summary

Sedgwick County

Scenarios:

1. Random M6.5, $62.8 Million Total Loss (5.9% Loss Ratio)
2. Anton Scarp (suspect) M7.6, $4.0 Million Total Loss (0.4% Loss Ratio)
3. Rocky Mountain Arsenal M6.25, $0.0 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Rocky Mountain Arsenal M6.25

HAZUS County Summary

Summit County

Scenarios:

1. Frontal Fault M7.0, $1.35 Billion Total Loss (32.2% Loss Ratio)
2. Mosquito Fault M7.0, $1.06 Billion Total Loss (25.3% Loss Ratio)
3. Random M6.5, $830 Million Total Loss (19.8% Loss Ratio)
4. Williams Fork Fault M6.75, $436 Million Total Loss (10.4% Loss Ratio)
5. N Sawatch Fault M7.0, $217 Million Total Loss (5.2% Loss Ratio)
6. S Sawatch Fault M7.25, $141 Million Total Loss (3.4% Loss Ratio)
7. Chase Gulch Fault M6.75, $73.3 Million Total Loss (1.8% Loss Ratio)
8. Ute Pass Fault M7.0, $42.7 Million Total Loss (1.0% Loss Ratio)
9. Golden Fault M6.5, $27.1 Million Total Loss (0.7% Loss Ratio)

Maps:

- Random M6.5
- Frontal Fault M7.0
- Mosquito Fault M7.0

HAZUS County Summary

Teller County

Scenarios:

1. Ute Pass Fault M7.0, $524 Million Total Loss (26.8% Loss Ratio)
2. Rampart Fault M7.0, $260 Million Total Loss (13.3% Loss Ratio)
3. Random M6.5, $255 Million Total Loss (13.1% Loss Ratio)
4. Chase Gulch Fault M6.75, $50.0 Million Total Loss (2.6% Loss Ratio)
5. S Sawatch Fault M7.25, $18.0 Million Total Loss (0.9% Loss Ratio)
6. N Sangre Fault M7.5 WUS, $2.4 Million Total Loss (0.1% Loss Ratio)

Maps:

- Random M6.5
- Ute Pass Fault M7.0

HAZUS County Summary

Washington County

Scenarios:

1. Anton Scarp (suspect) M7.6, $228 Million Total Loss (10.6% Loss Ratio)

2. Random M6.5, $71.8 Million Total Loss (3.3% Loss Ratio)

3. Rocky Mountain Arsenal M6.25, $1.09 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Rocky Mountain Arsenal M6.25
- Anton Scarp M7.6

HAZUS County Summary

Weld County

Scenarios:

1. Random M6.5, $945 Million Total Loss (6.6% Loss Ratio)
2. Rocky Mountain Arsenal M6.25, $502 Million Total Loss (3.5% Loss Ratio)
3. Golden Fault M6.5, $299 Million Total Loss (2.1% Loss Ratio)
4. Walnut Creek Fault M6.0, $212 Million Total Loss (1.5% Loss Ratio)
5. Valmont Fault M5.0, $40.2 Million Total Loss (0.3% Loss Ratio)

Maps:

- Random M6.5
- Rocky Mountain Arsenal M6.25

HAZUS County Summary

Yuma County

Scenarios:

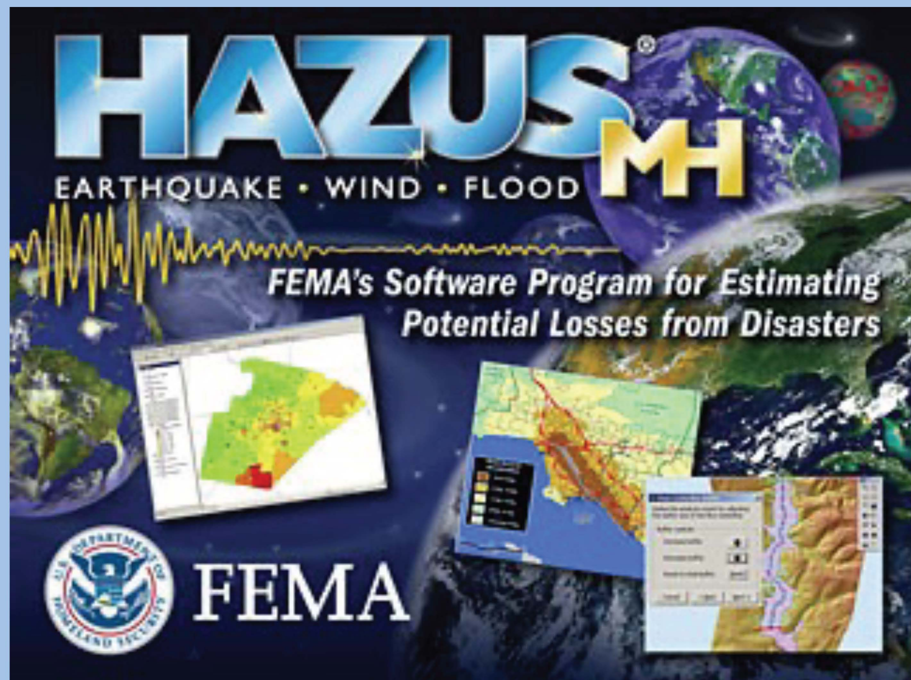
1. Anton Scarp (suspect) M7.6, $214 Million Total Loss (8.1% Loss Ratio)
2. Random M6.5, $201 Million Total Loss (7.6% Loss Ratio)
3. Cheraw Fault M7.0, $3.29 Million Total Loss (0.1% Loss Ratio)
4. Rocky Mountain Arsenal M6.25, $0.4 Million Total Loss (0.0% Loss Ratio)

Maps:

- Random M6.5
- Cheraw Fault M7.0

HAZUS:
Presentations

Loss Estimates for Earthquake Scenarios in Colorado using HAZUS-MH



May 2006

Colorado Geological Survey Participants:
Lauren Heerschap, Vince Matthews,
Matthew Morgan, Jennifer McHarge

Additional Assistance:
Douglas Bausch – FEMA Region VIII
Trevor Burr – Metro State College of Denver

How Hazus Works

Inventory and Census Data
Building type, value, occupancy
Population

+

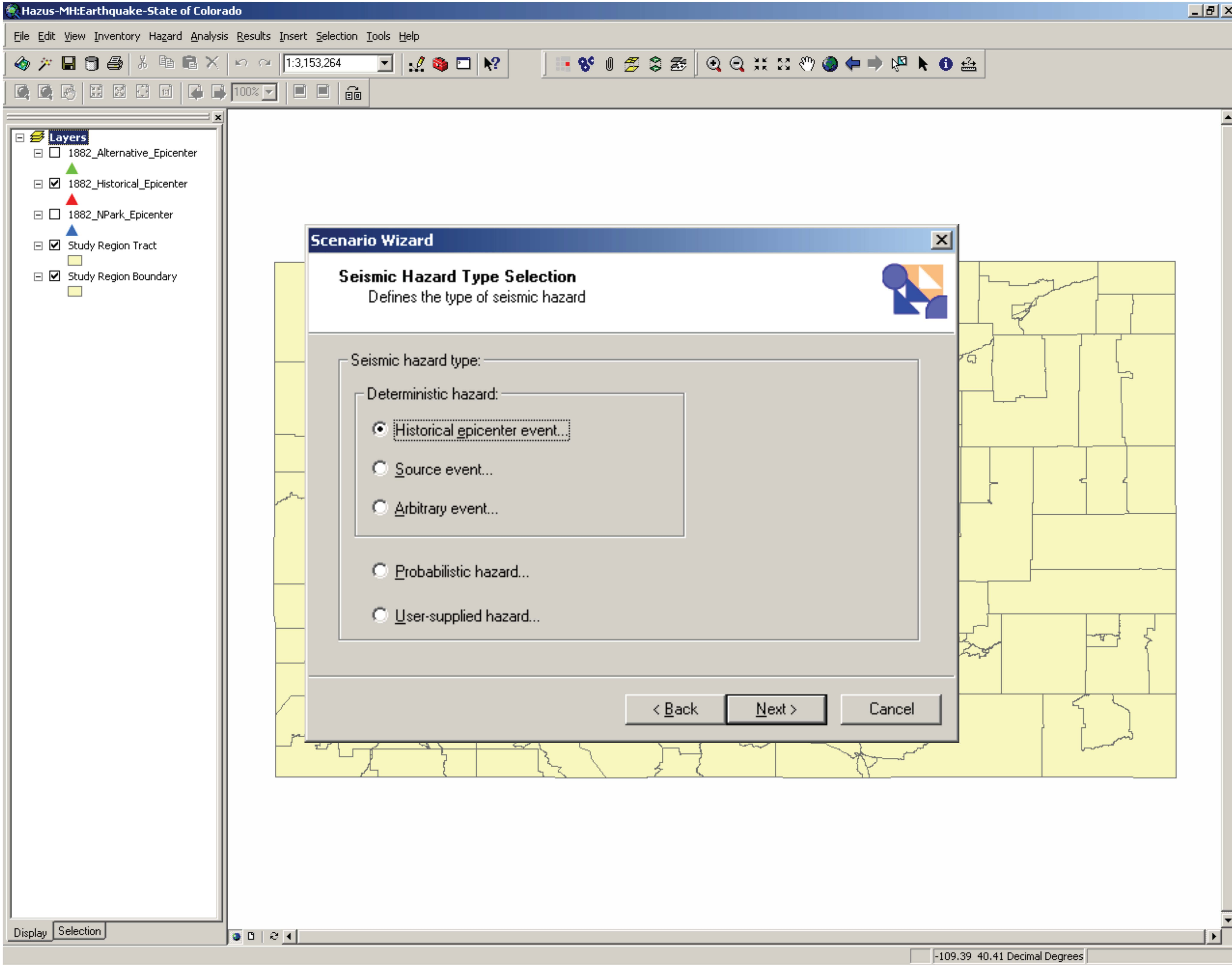
Data from USGS Seismic Hazard Maps

↓

Geographic Information System (GIS)

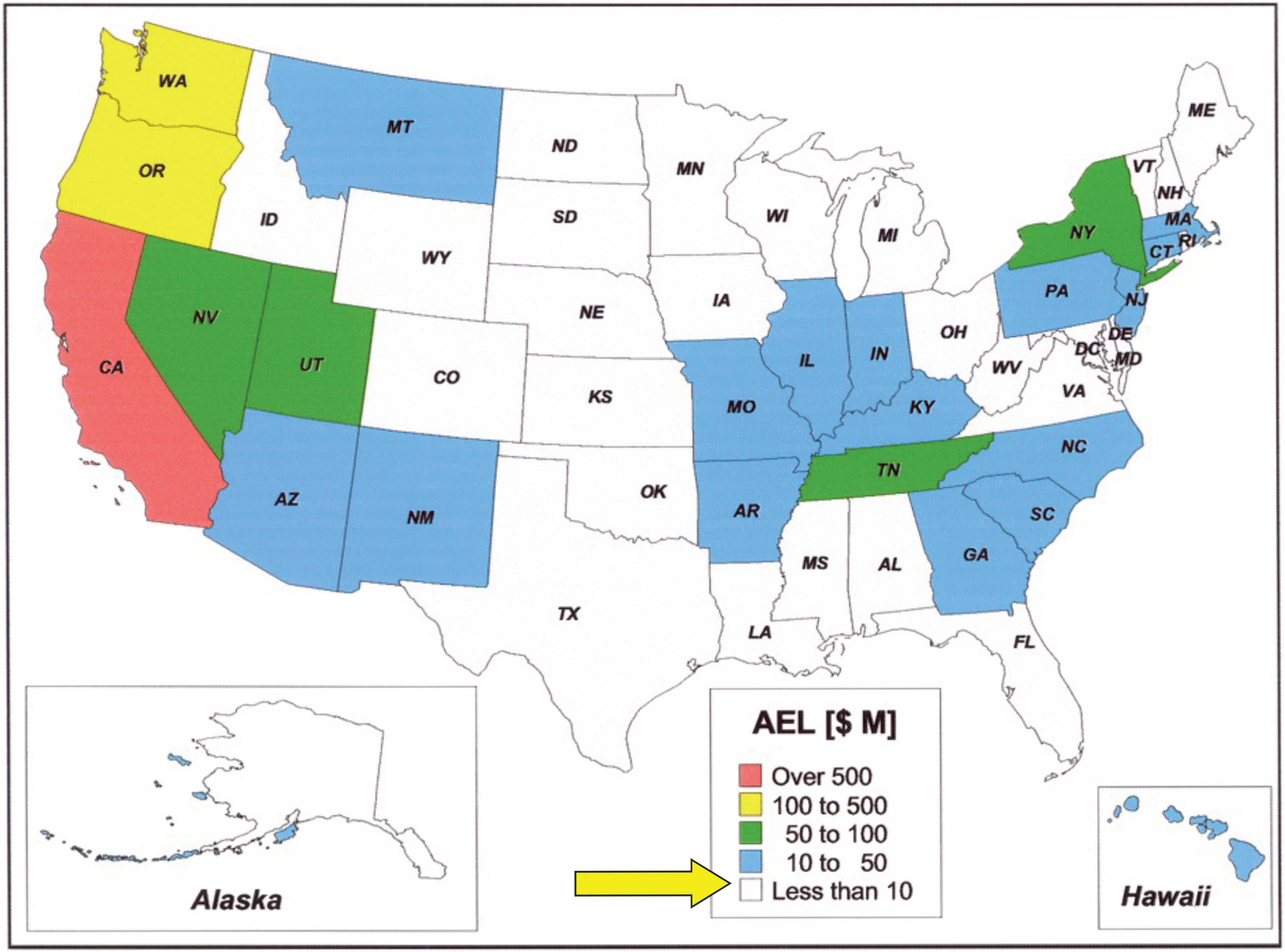
Results Shapefiles

Results Reports


Hazus-MH:Earthquake-State of Colorado
File Edit View Inventory Hazard Analysis Results Insert Selection Tools Help
1:3,153,264
Layers
1882_Alternative_Epicenter
1882_Historical_Epicenter
1882_NPark_Epicenter
Study Region Tract
Study Region Boundary
Display
Selection
Scenario Wizard
Seismic Hazard Type Selection
Defines the type of seismic hazard
Seismic hazard type:
Deterministic hazard:
Historical epicenter event...
Source event...
Arbitrary event...
Probabilistic hazard...
User-supplied hazard...
< Back
Next >
Cancel
-109.39 40.41 Decimal Degrees

Types of Analyses

- **Probabilistic**
  - Probability of exceeding a level of ground motion in a specified time period
  - Loss estimate from specific return period
  - Annualized losses
- **Deterministic**

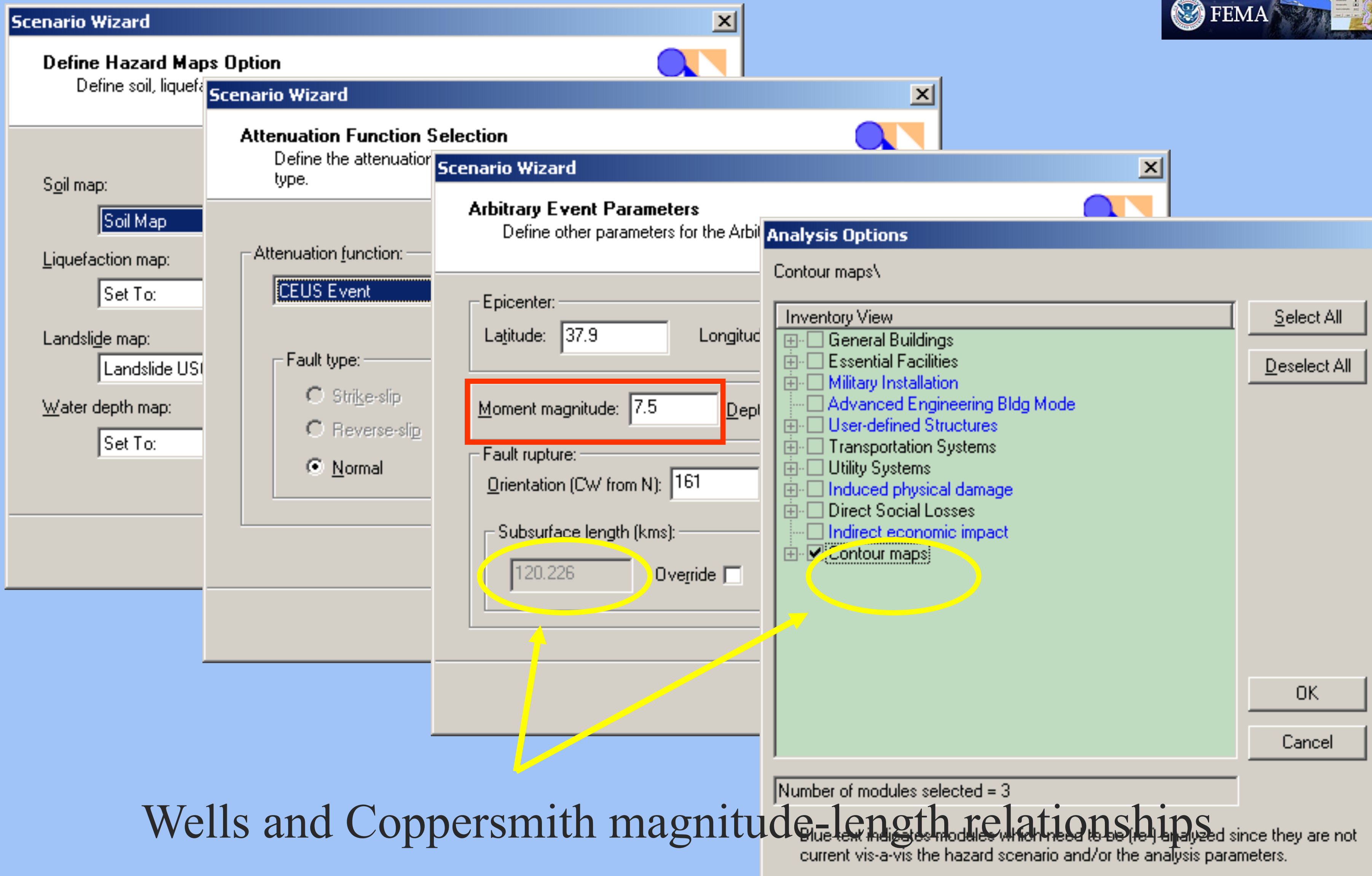


From "Hazus 99 Estimated Annualized Earthquake Losses for the United States", FEMA 2001

Types of Analyses

- **Probabilistic**
  - –Probability of exceeding a level of ground motion in a specified time period
  - –Loss estimate from specific return period
  - –Annualized losses
- **Deterministic**
  - –Allow specific questions to be answered
  - –"What would casualty and economic losses be in a worst-case scenario along a given fault?"
  - – M 6.25 at Rocky Mountain Arsenal could cause $5.7 billion in Denver County alone

Deterministic Scenarios



Wells and Coppersmith magnitude-length relationships

Analysis Results

- Ground shaking maps
- Direct physical damage
  - Buildings, Critical Facilities, T
    Utility Systems
- Induced physical damage
  - Debris, Fire, Inundation, HazM
- Direct and indirect econo
- Social Losses
  - Casualties at 3 times of day
  - Shelter Needs

Table 11: Casualty Estimates

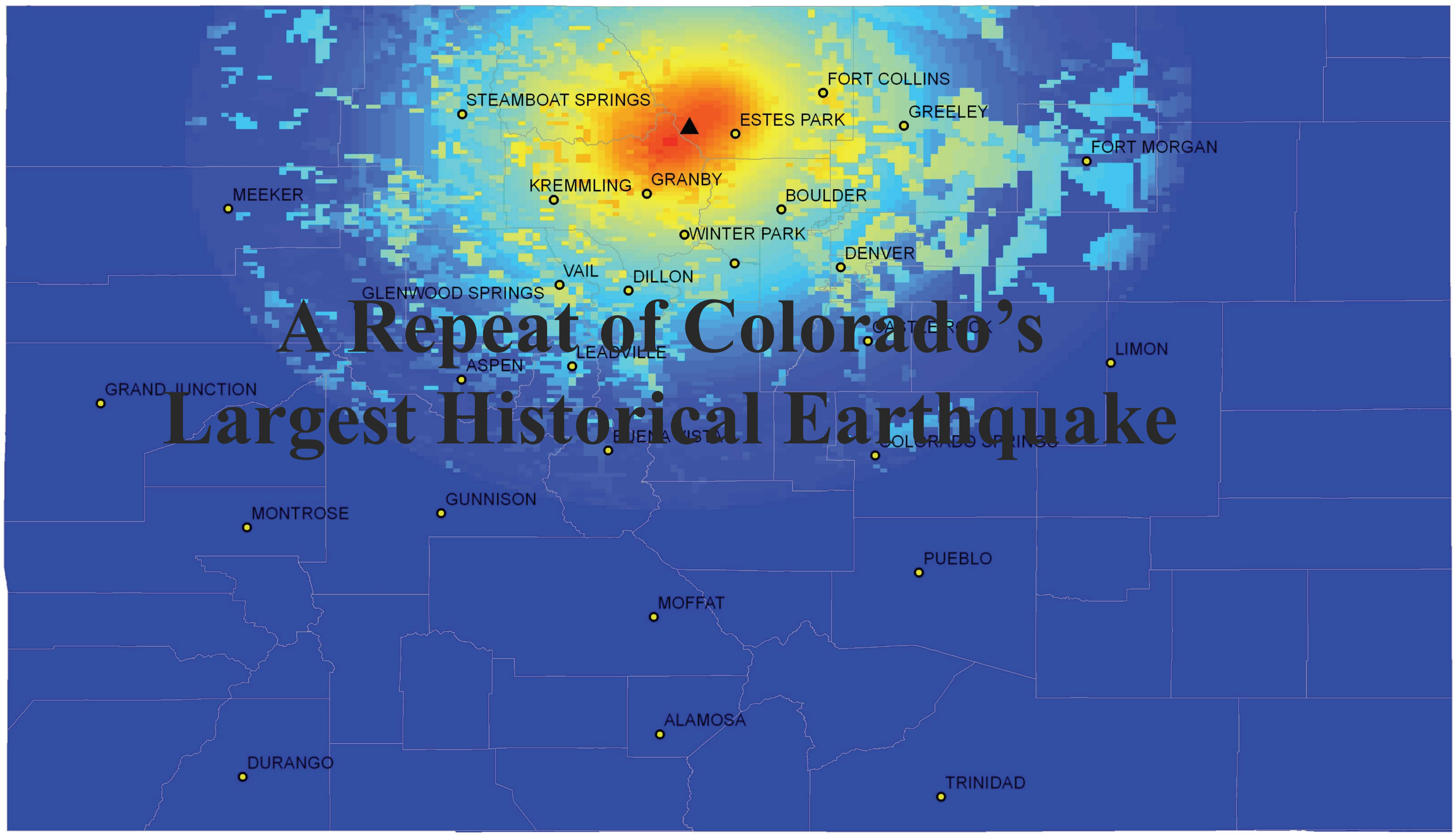
		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	53	13	2	4
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	47	12	2	4
	Industrial	51	12	2	3
	Other-Residential	1,271	282	32	60
	Single Family	1,787	405	58	115
	Total	**3,210**	**724**	**96**	**186**
2 PM	Commercial	3,125	784	119	234
	Commuting	1	1	1	0
	Educational	533	142	22	44
	Hotels	9	2	0	1
	Industrial	378	91	13	25
	Other-Residential	234	51	6	10
	Single Family	335	76	11	21
	Total	**4,615**	**1,147**	**173**	**335**
5 PM	Commercial	2,350	594	91	176
	Commuting	21	28	48	9
	Educational	80	21	3	6
	Hotels	14	4	1	1
	Industrial	237	57	8	16
	Other-Residential	473	105	12	22
	Single Family	695	157	23	44
	Total	**3,870**	**966**	**186**	**274**

Why Run Hazus Scenarios in Colorado?

- Provide information to better prepare emergency managers and responders
- Increase awareness for policy makers of the consequences of a strong earthquake

A Repeat of Colorado's Largest Historical Earthquake

1882 Earthquake, Rocky Mountain National Park Epicenter
M 6.6, CEUS Attenuation

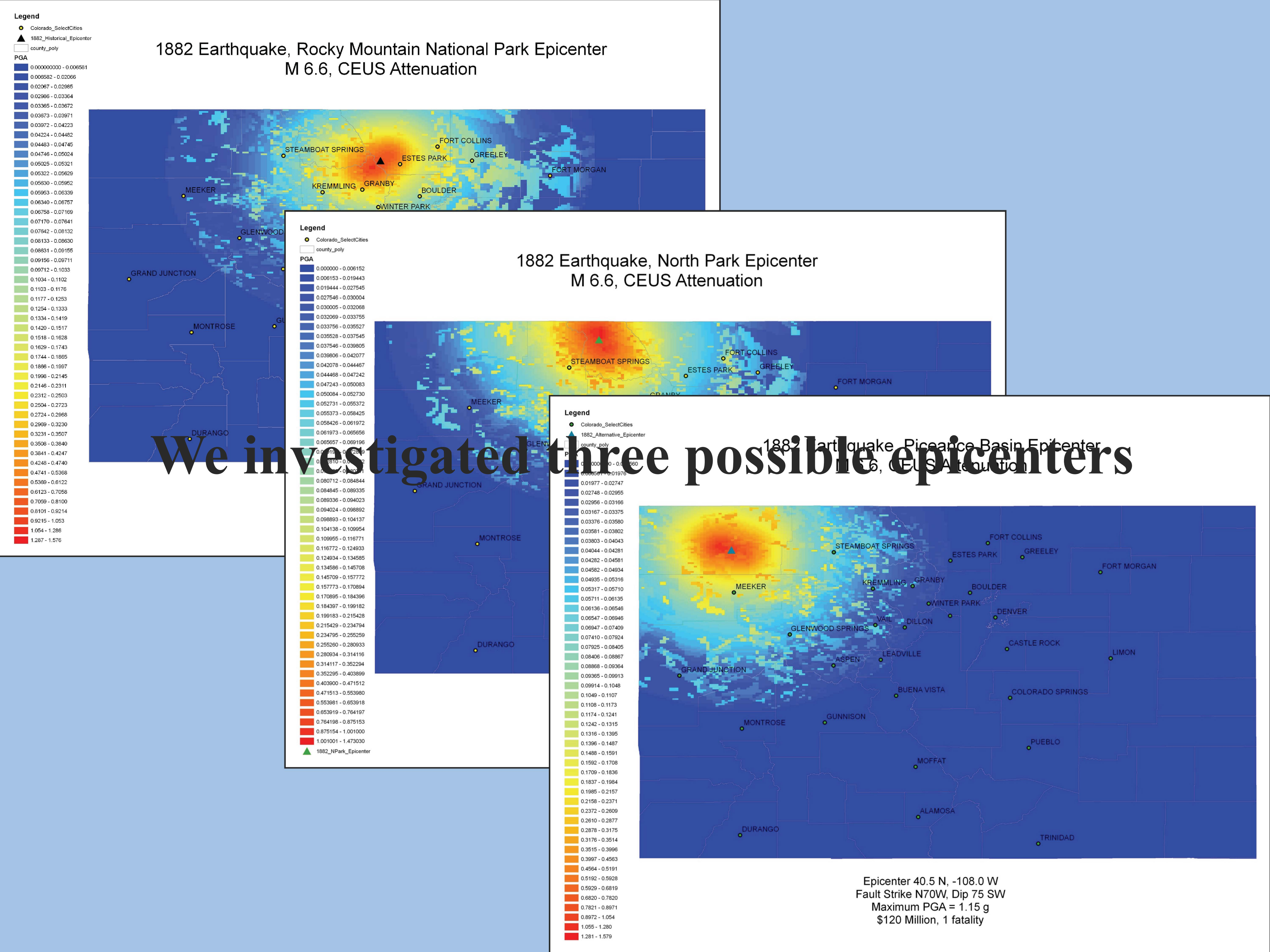


Perceived Shaking	Not Felt	Very Weak	Weak	Light	Moderate	Strong	Very Strong	Violent	Extreme
Potential Damage	None	None	None	Very Slight	Slight	Moderate	Extensive	Complete	Complete/Collapse
Peak Ground Acceleration (%g)	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
Modified Mercalli Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+

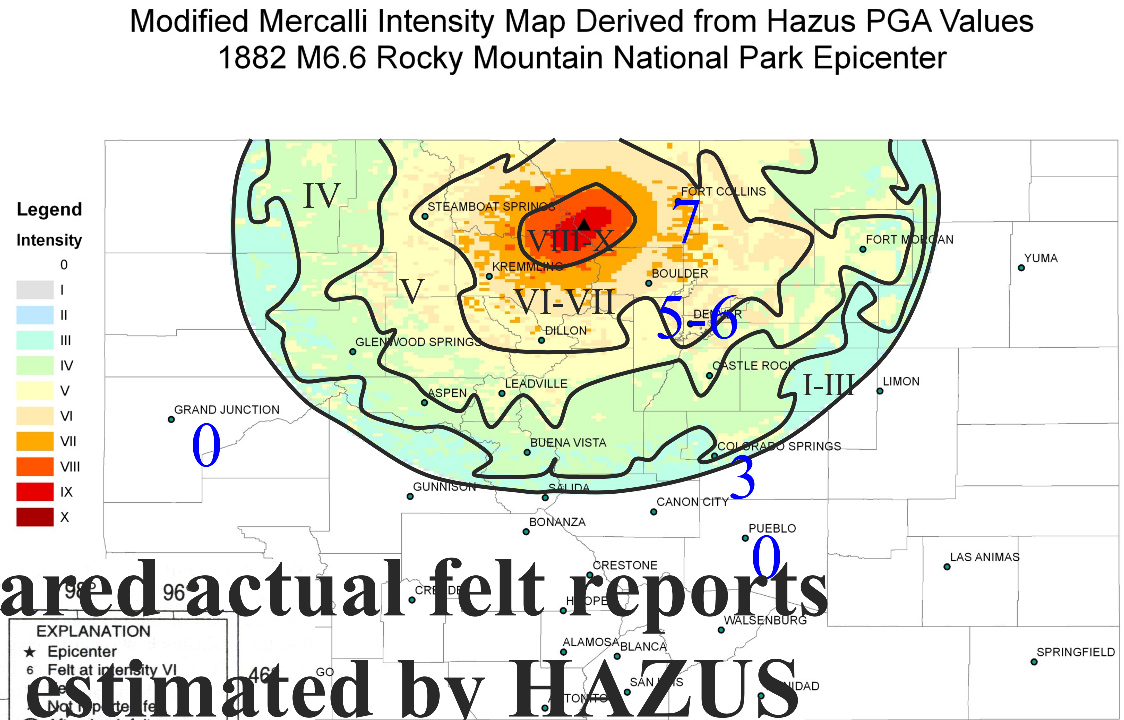
If a repeat of the 1882 M6.6 were to occur near Estes Park, we would have…

- **$2.8 billion** in economic losses statewide
- **35,000 buildings** with moderate or higher damage
- **190 casualties** requiring hospitalization
- **2,650** displaced households

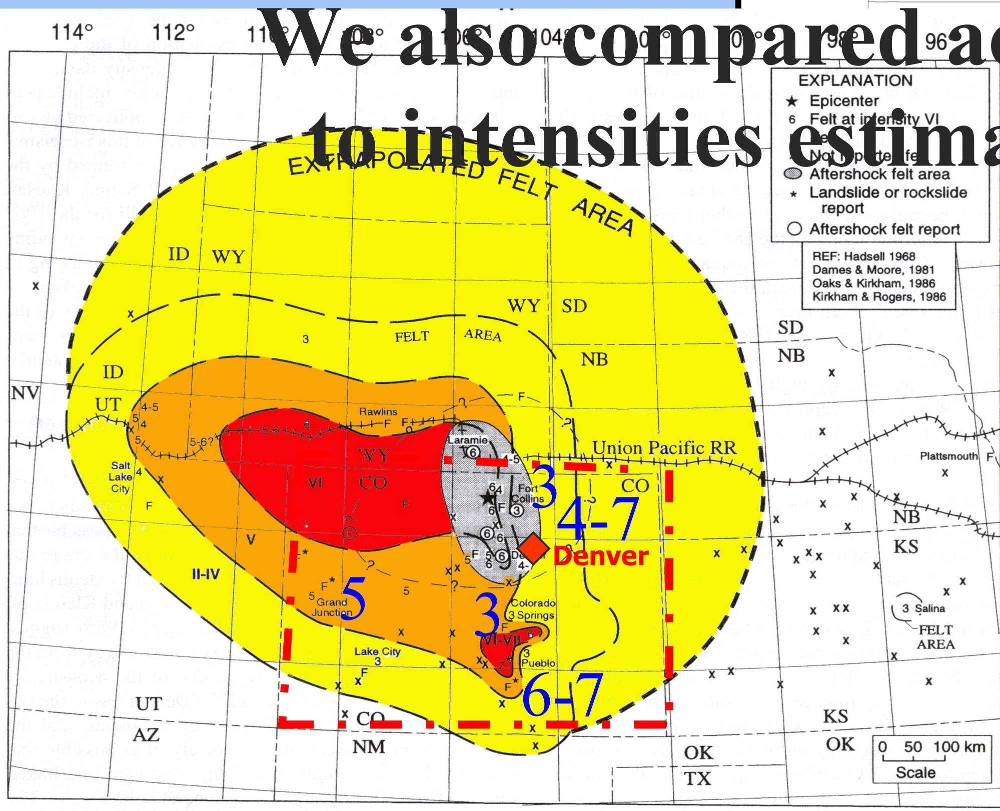
We investigated three possible epicenters



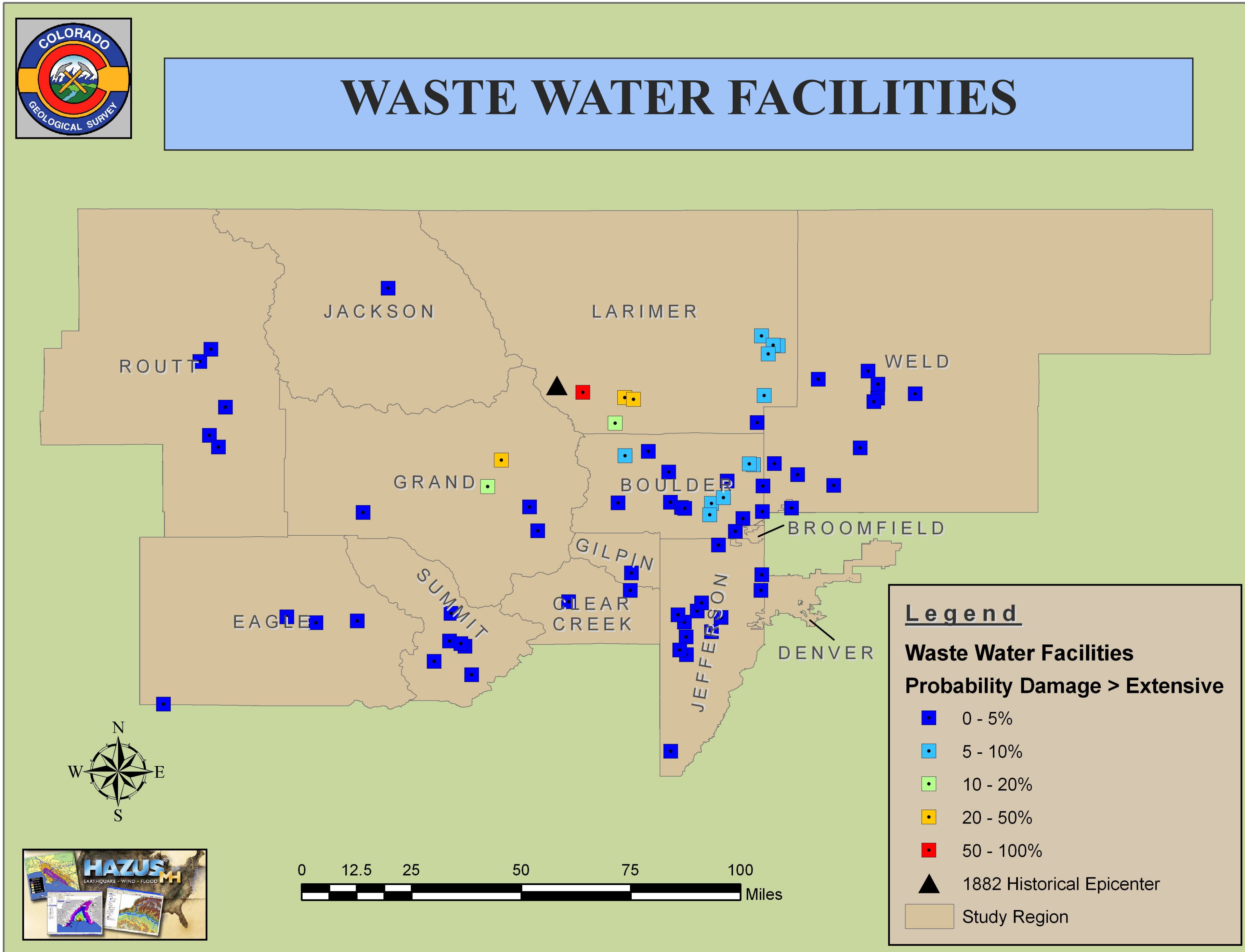
MMI derived from PGA



We also compared actual felt reports to intensities estimated by HAZUS

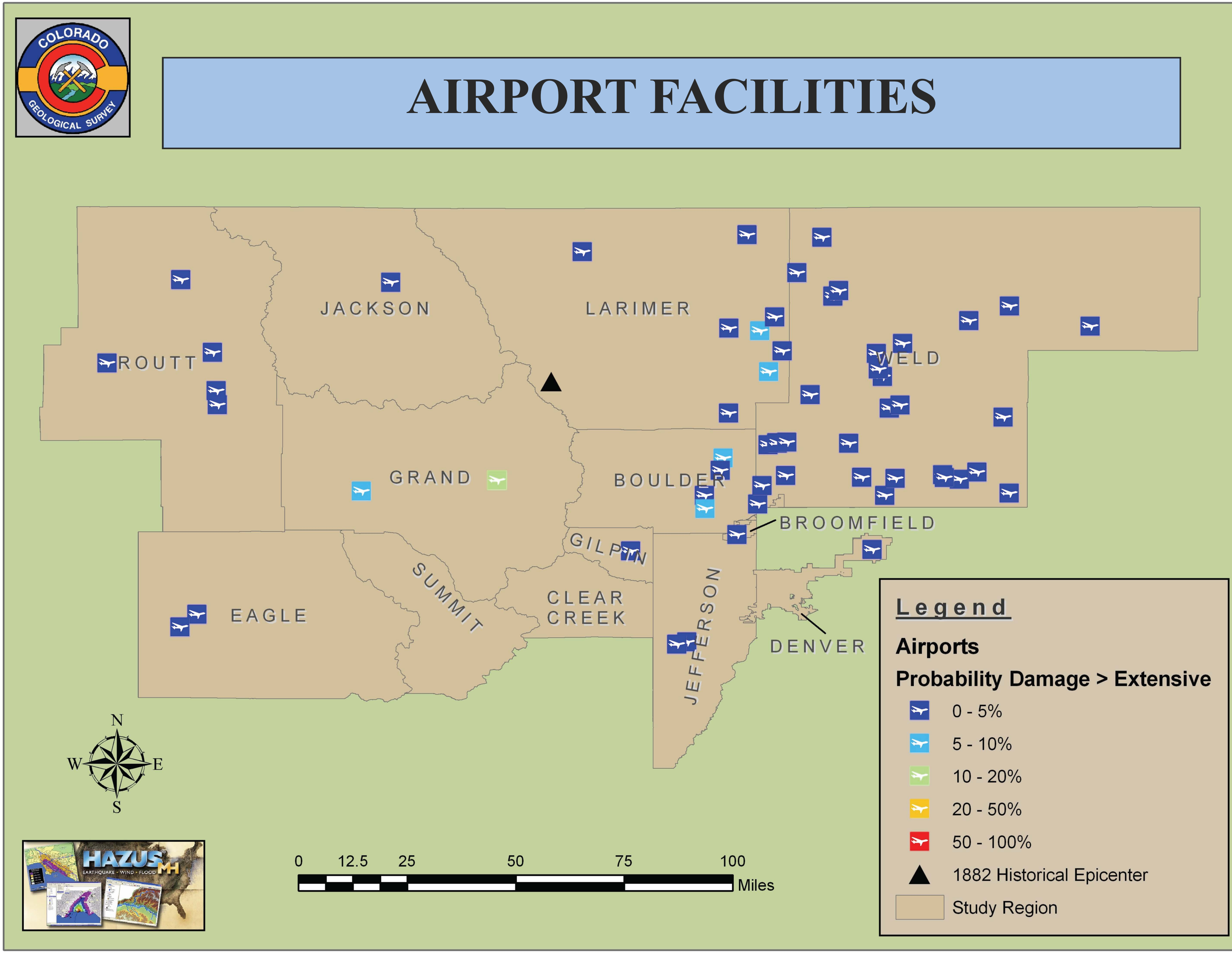


Intensity map from 1882 felt reports

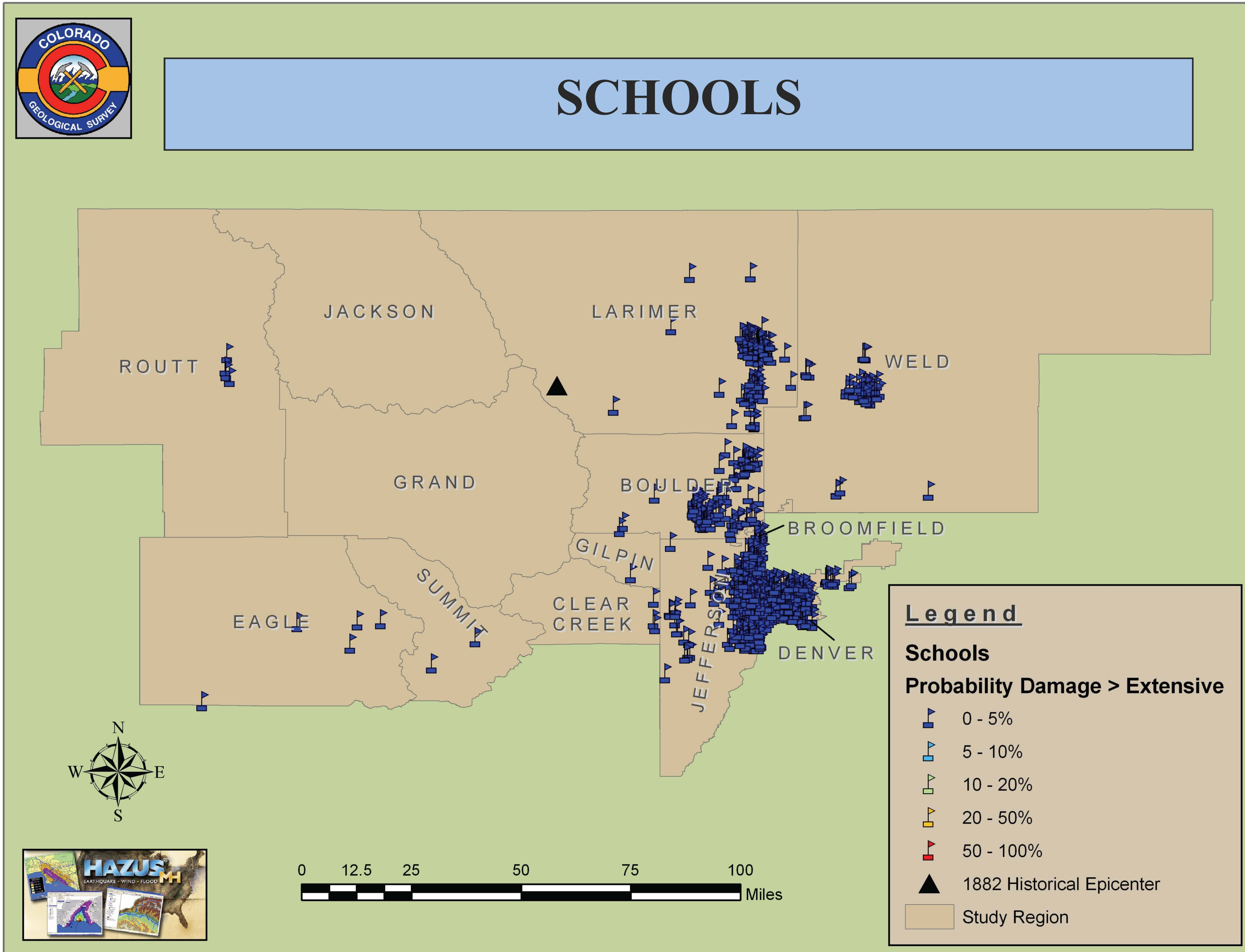


COLORADO GEOLOGICAL SURVEY
WASTE WATER FACILITIES
JACKSON
LARIMER
ROUTT
WELD
GRAND
BOULDER
BROOMFIELD
GILPIN
SUMMIT
CLEAR CREEK
EAGLE
JEFFERSON
DENVER
Legend
Waste Water Facilities
Probability Damage > Extensive
0 - 5%
5 - 10%
10 - 20%
20 - 50%
50 - 100%
1882 Historical Epicenter
Study Region
N
W
E
S
0
12.5
25
50
75
100
Miles
HAZUS MH
EARTHQUAKE · WIND · FLOOD

AIRPORT FACILITIES

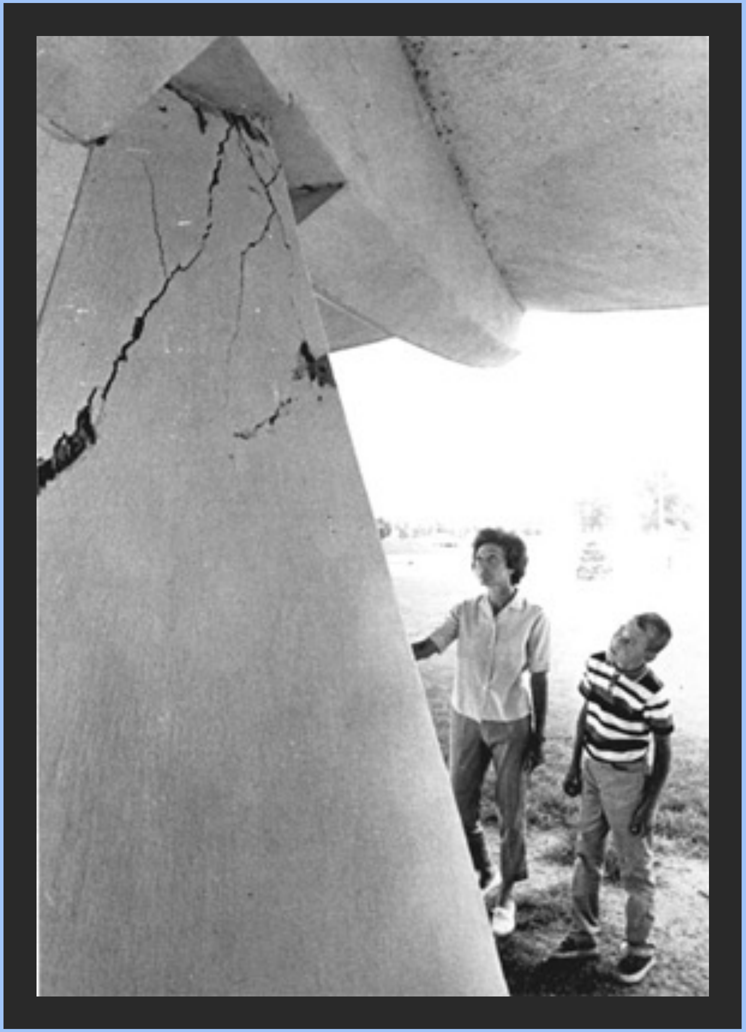


SCHOOLS

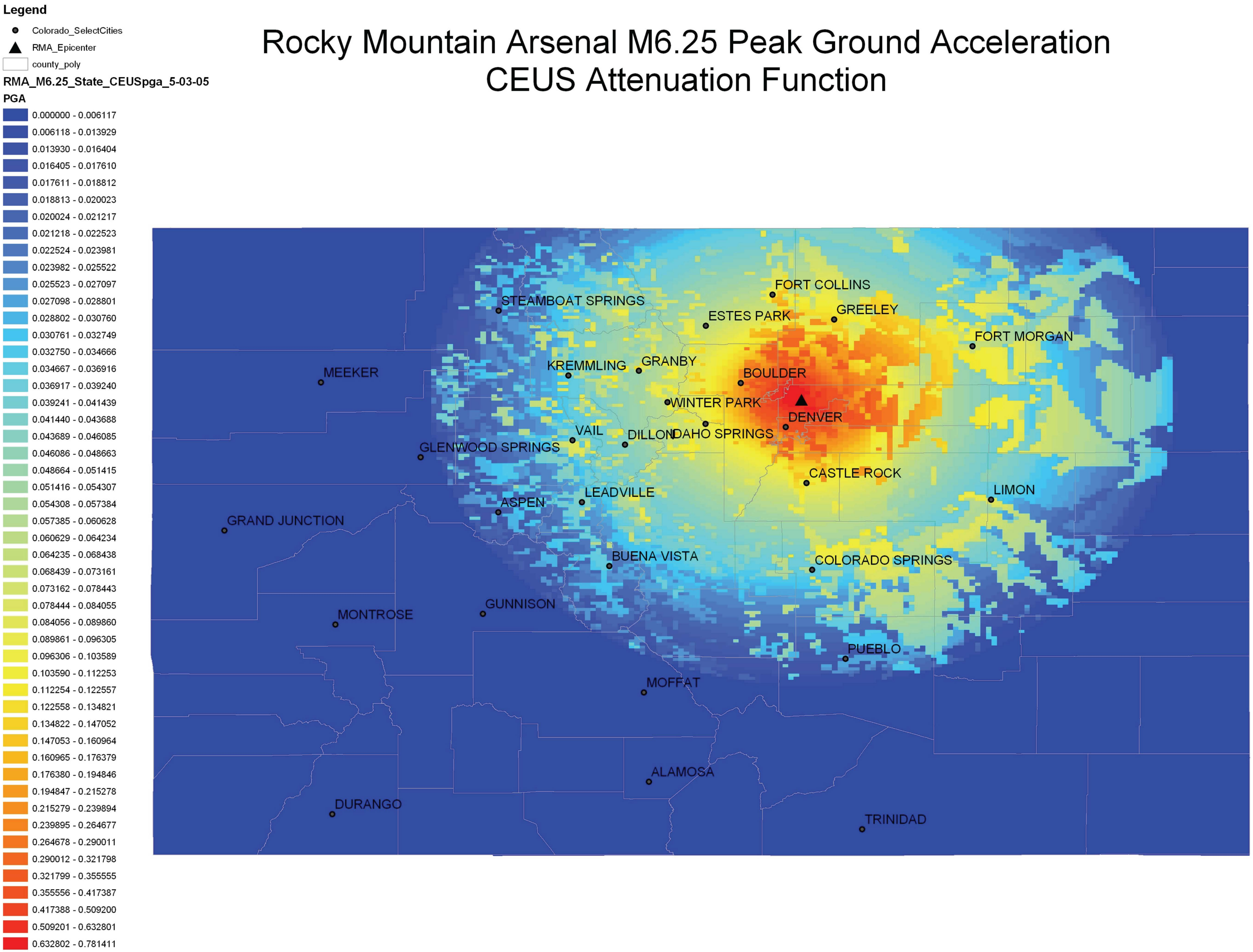

COLORADO GEOLOGICAL SURVEY
JACKSON
LARIMER
ROUTT
WELD
GRAND
BOULDER
BROOMFIELD
GILPIN
SUMMIT
CLEAR CREEK
EAGLE
JEFFERSON
DENVER
N
W
E
S
Legend
Schools
Probability Damage > Extensive
0 - 5%
5 - 10%
10 - 20%
20 - 50%
50 - 100%
1882 Historical Epicenter
Study Region
0
12.5
25
50
75
100
Miles
HAZUS MH
EARTHQUAKE · WIND · FLOOD

Rocky Mountain Arsenal Earthquakes

- 1962-1972 earthquake swarm NE of Denver
- 12 events caused damage
- Swarm occurred over a length of 15 km
- Wells and Coppersmith (1994) curve suggests maximum credible earthquake of M_w 6.25
- Bott and Wong (1996) give a maximum of M_w 6.0



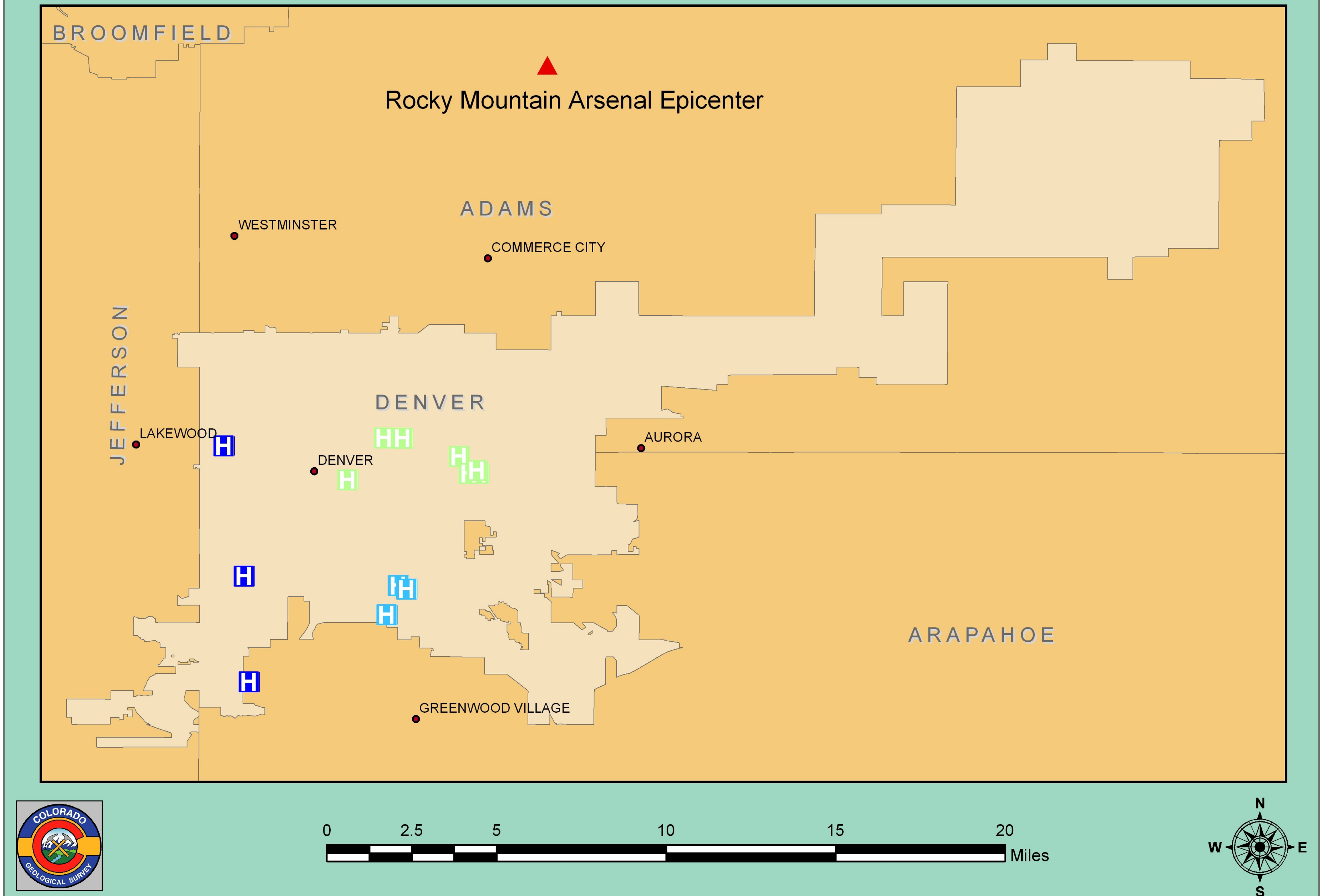
Rocky Mountain Arsenal M6.25 Peak Ground Acceleration
CEUS Attenuation Function



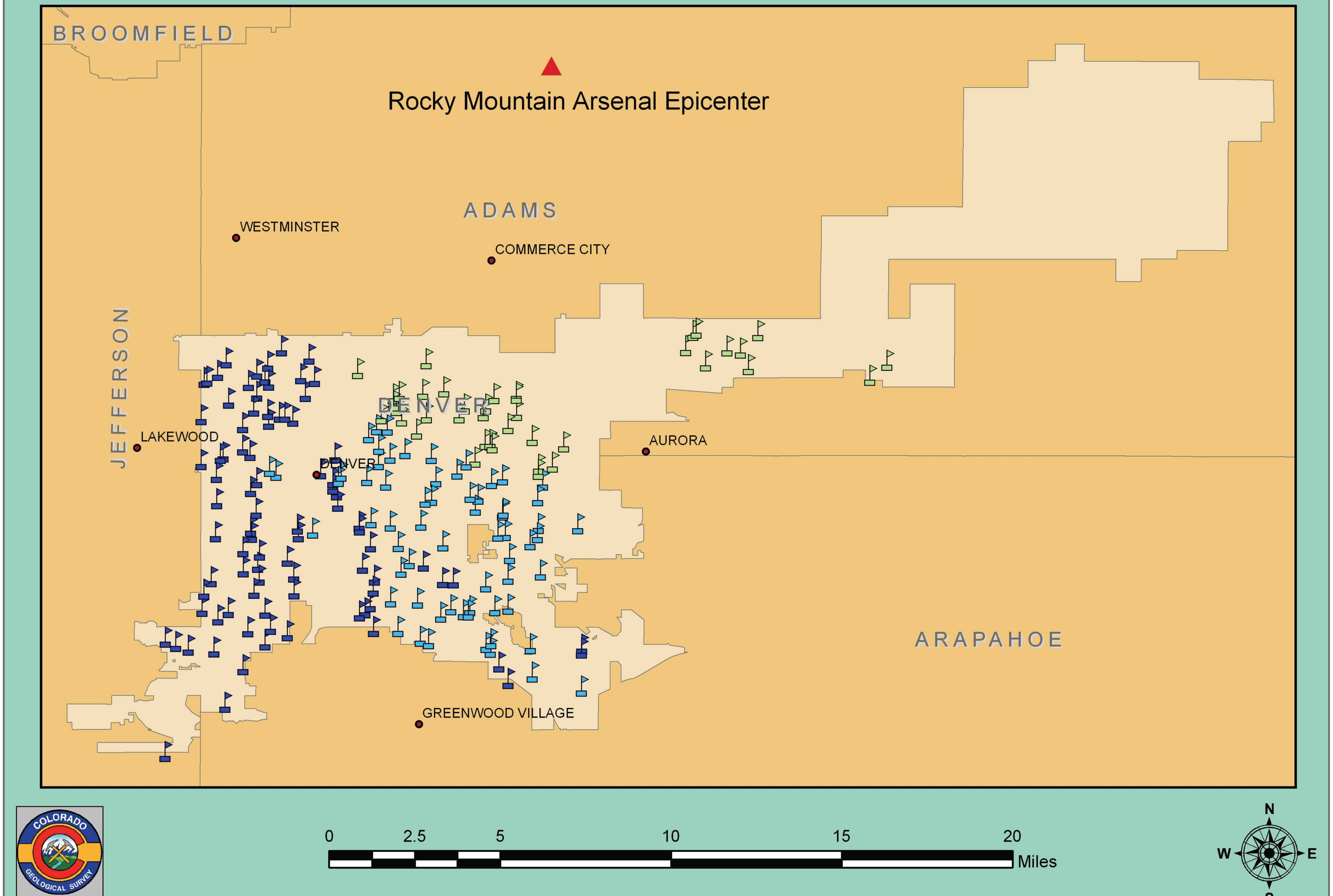
If a M6.25 were to occur near the Rocky Mountain Arsenal today…

- **$14.9 billion** in economic losses statewide
- **$5.6 billion** loss in Denver County alone
- **152,000 buildings** with moderate or higher damage
- **2,500 casualties** requiring hospitalization
- **28,500** displaced households

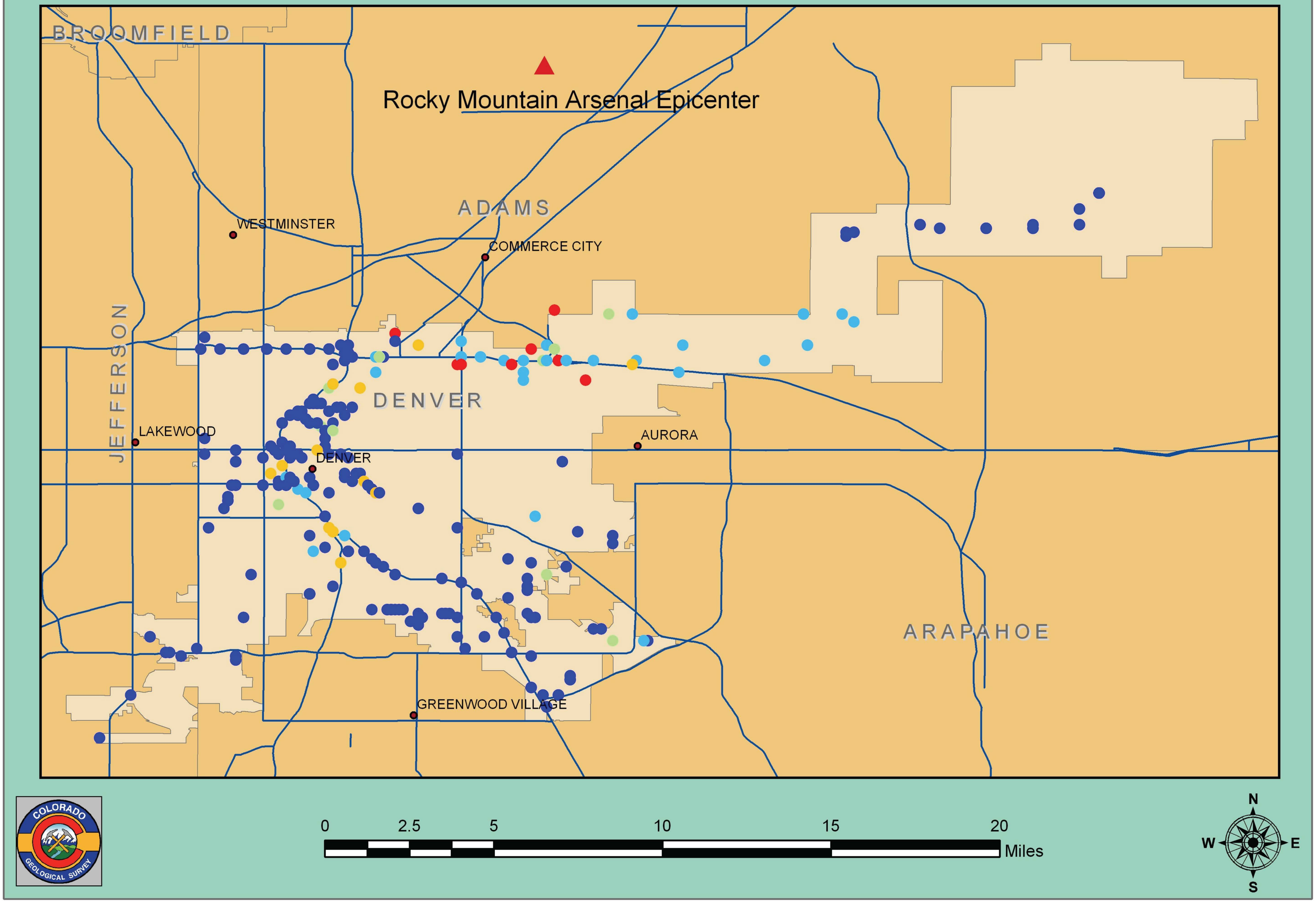
MEDICAL CARE FACILITIES



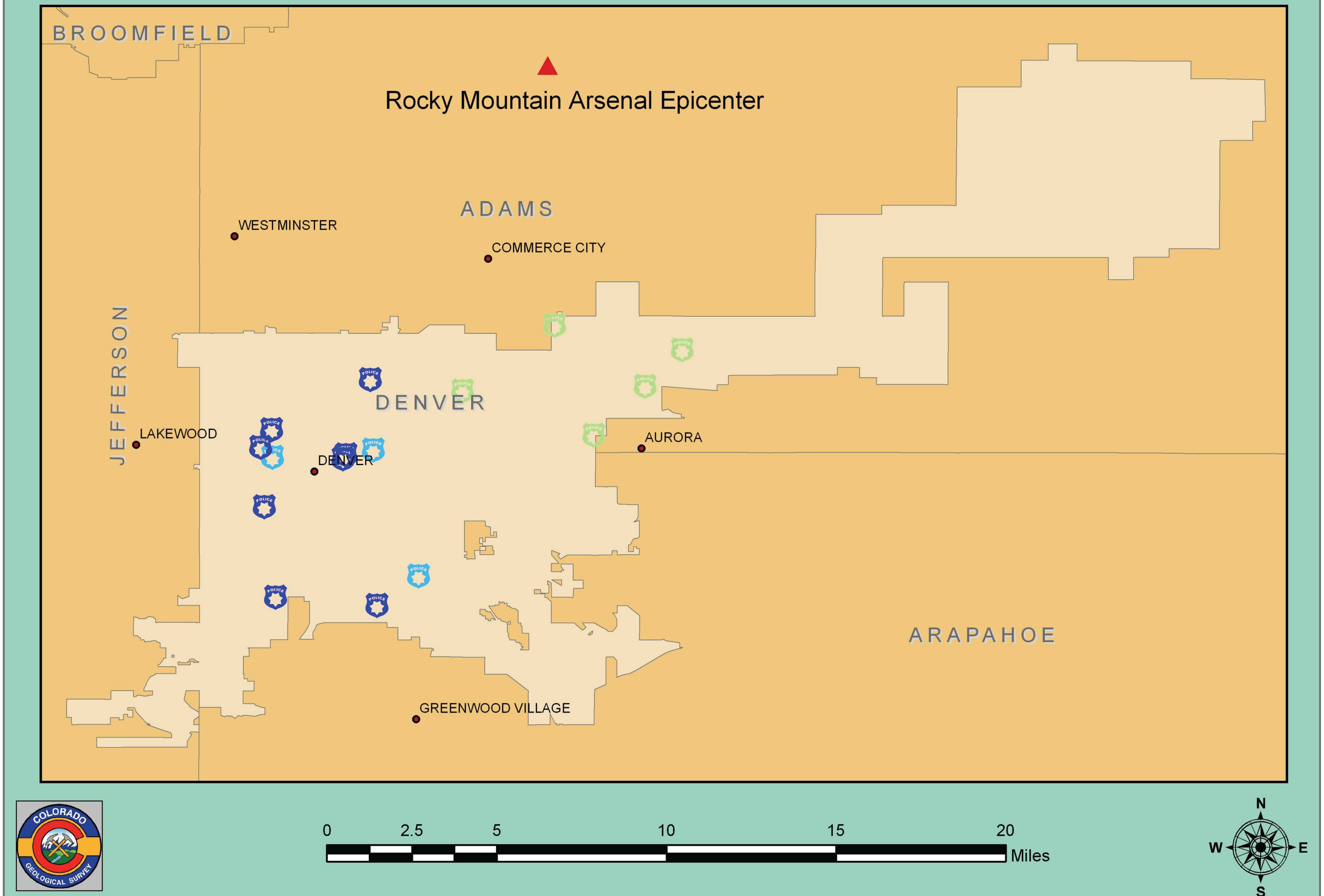
SCHOOLS


BROOMFIELD
Rocky Mountain Arsenal Epicenter
ADAMS
WESTMINSTER
COMMERCE CITY
JEFFERSON
LAKEWOOD
DENVER
DENVER
AURORA
ARAPAHOE
GREENWOOD VILLAGE
0
2.5
5
10
15
20
Miles
N
S
E
W
COLORADO
GEOLOGICAL SURVEY

HIGHWAY BRIDGES

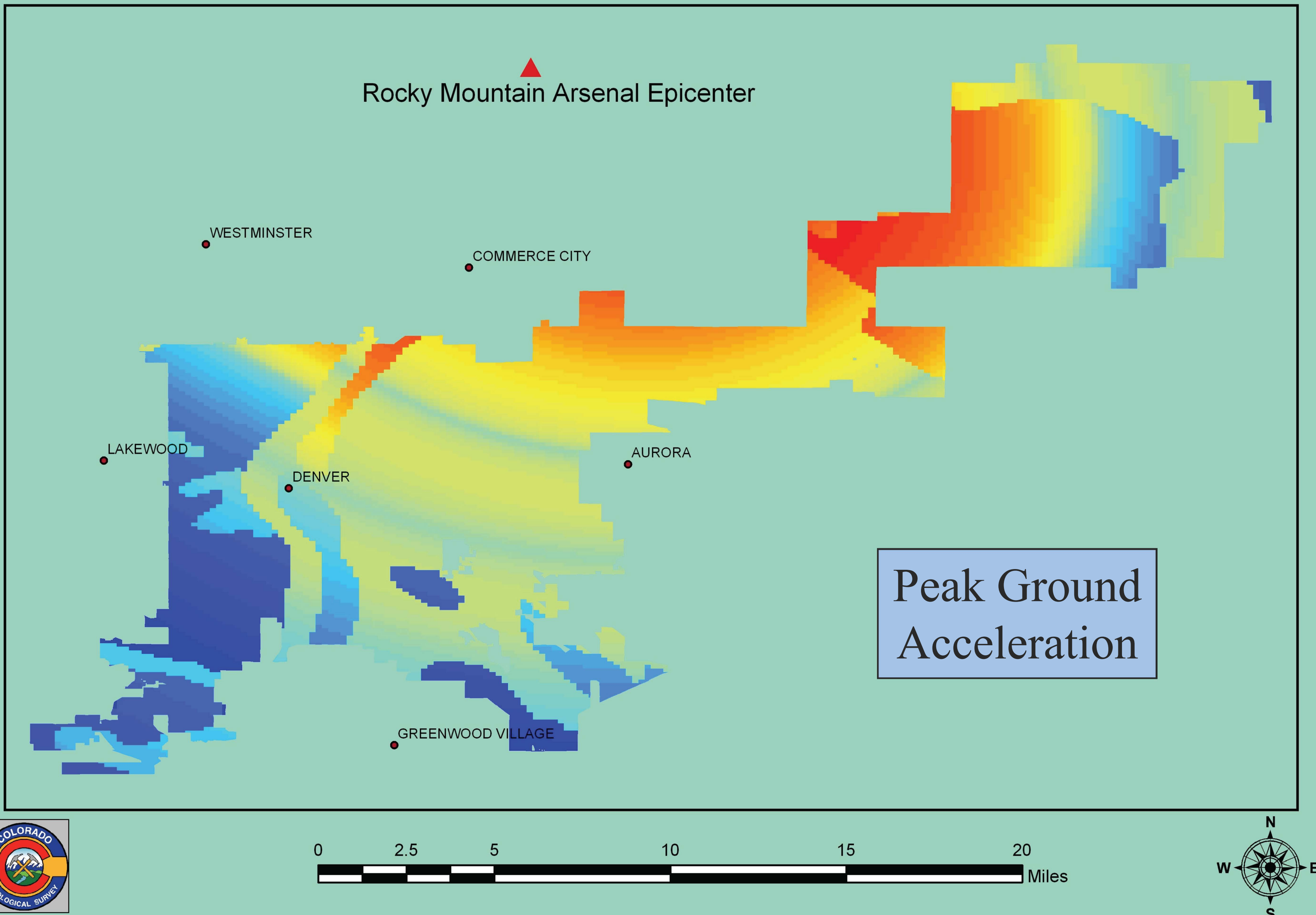


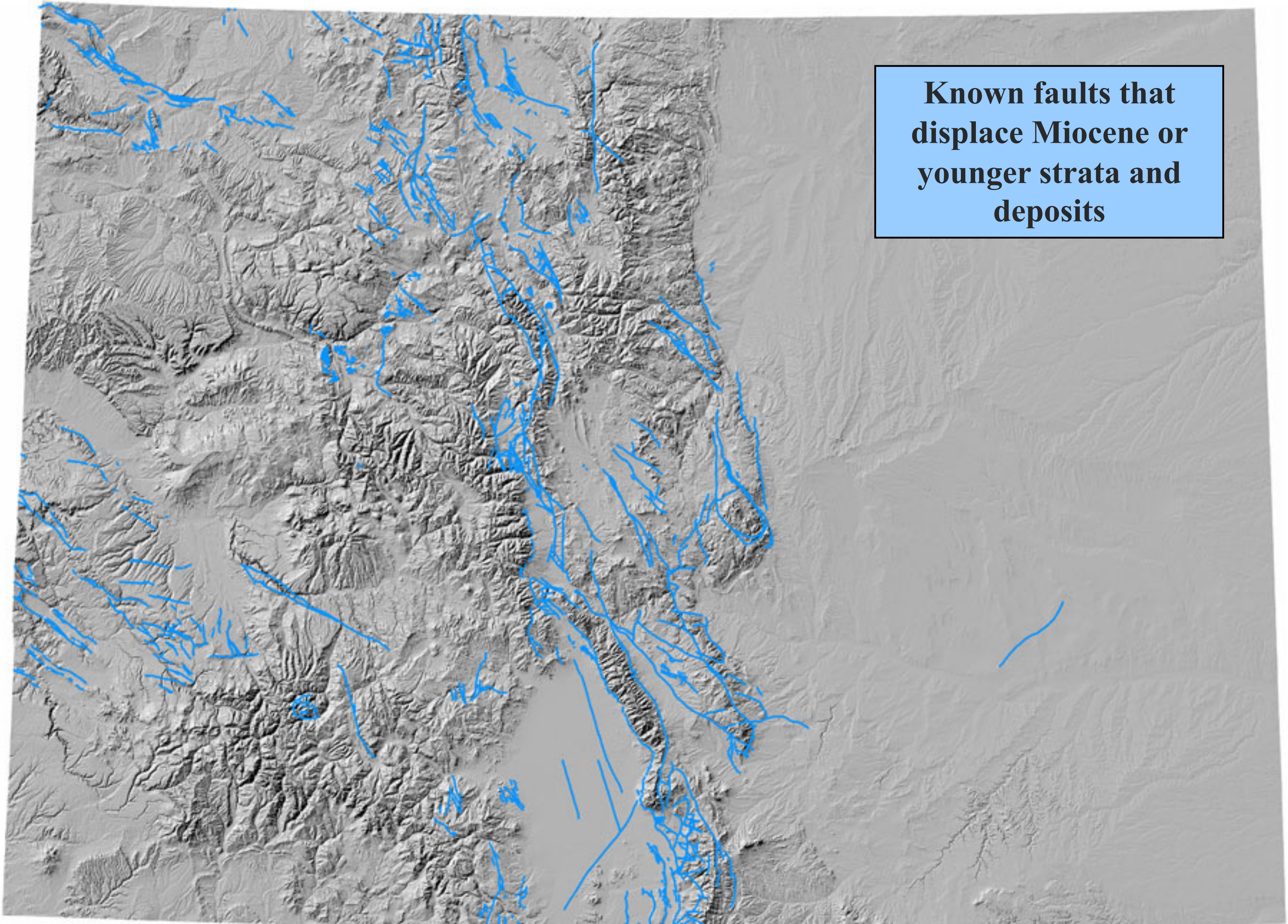
POLICE STATIONS

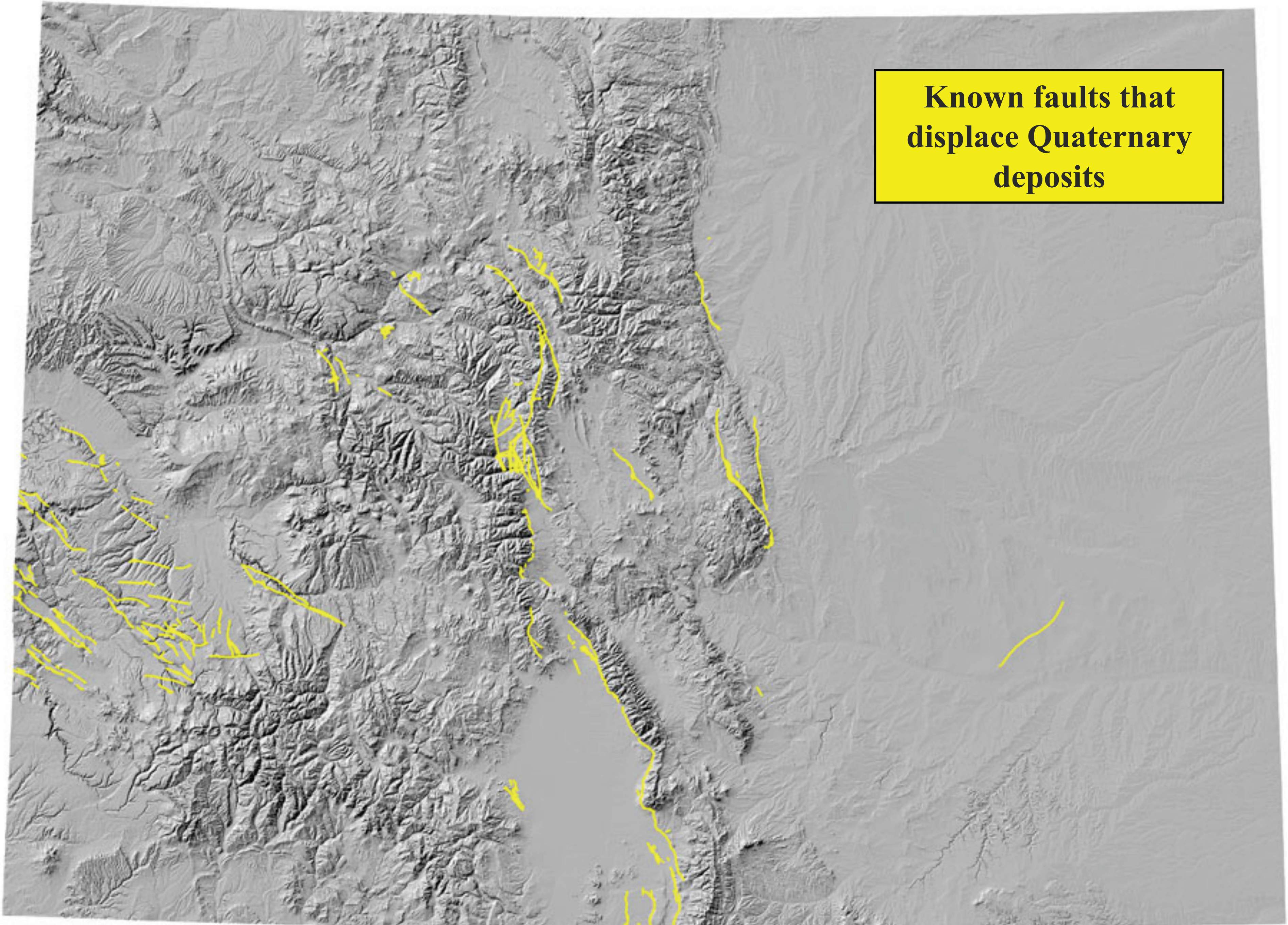


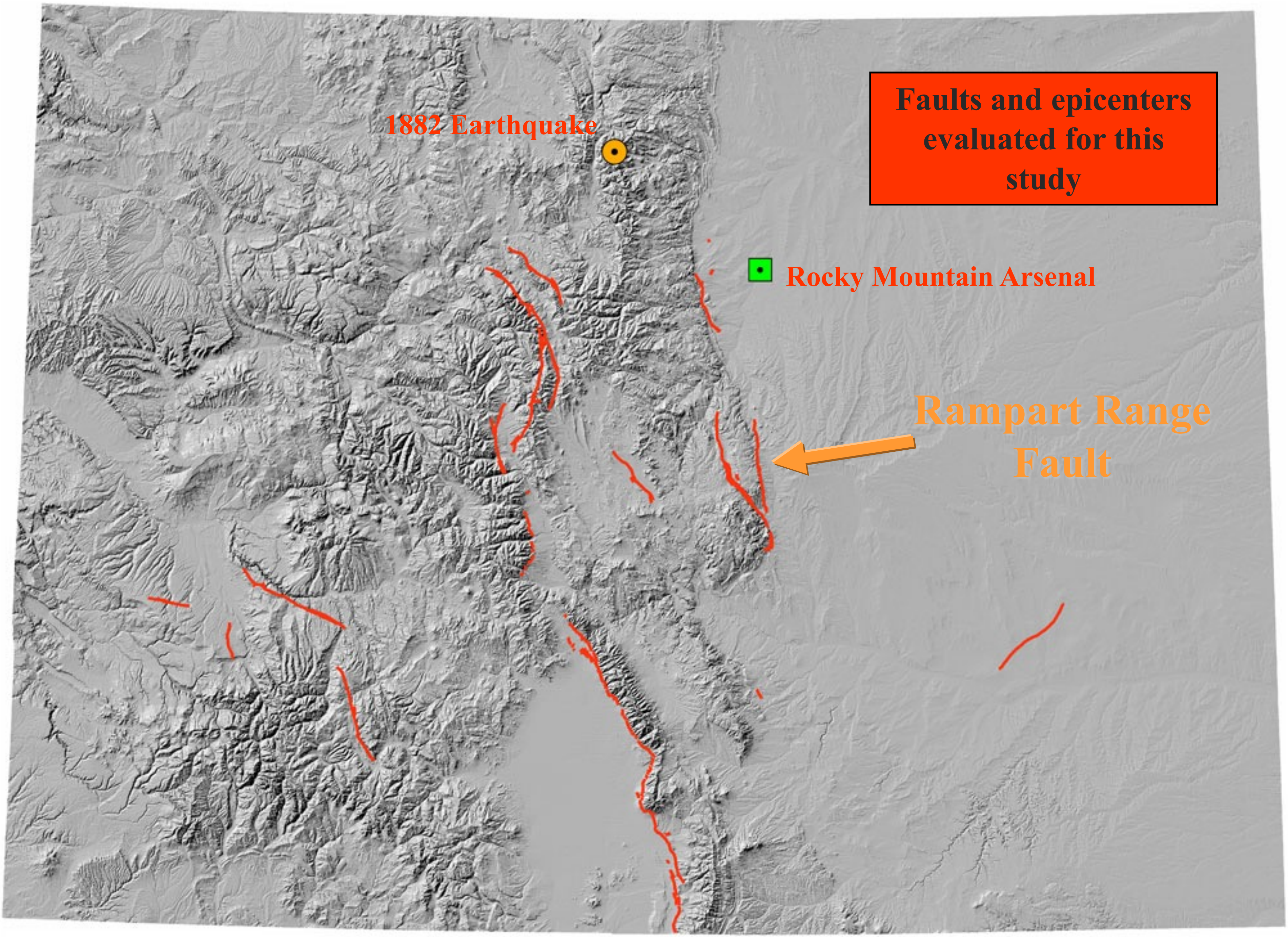
Study Region : Denver County

Hazard Scenario : Rocky Mountain Arsenal M6.25



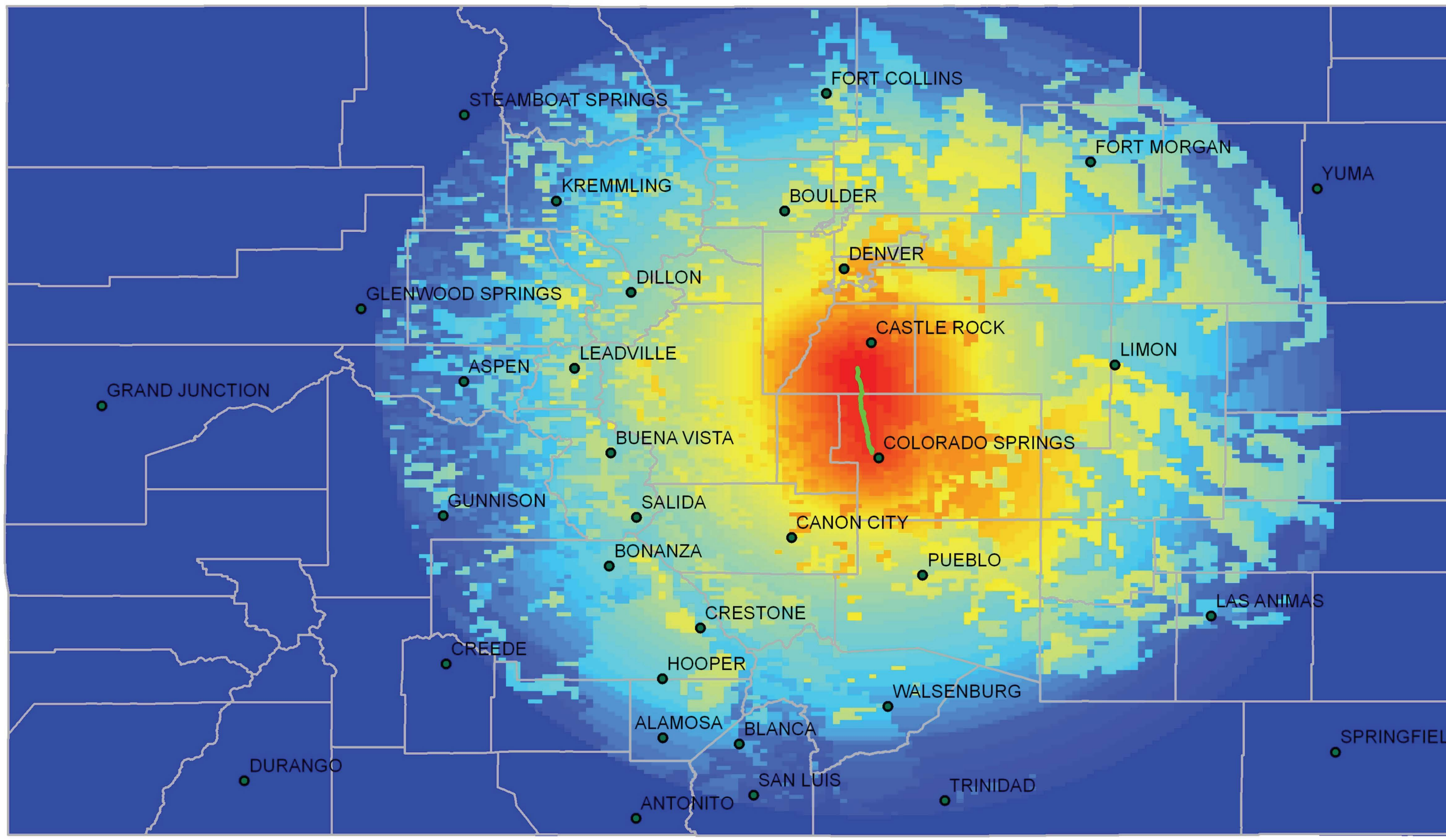

Known faults that displace Miocene or younger strata and deposits


Known faults that displace Quaternary deposits



Faults and epicenters evaluated for this study
1882 Earthquake
Rocky Mountain Arsenal
Rampart Range Fault

Rampart Fault M7.0 Peak Ground Acceleration
CEUS Attenuation Function

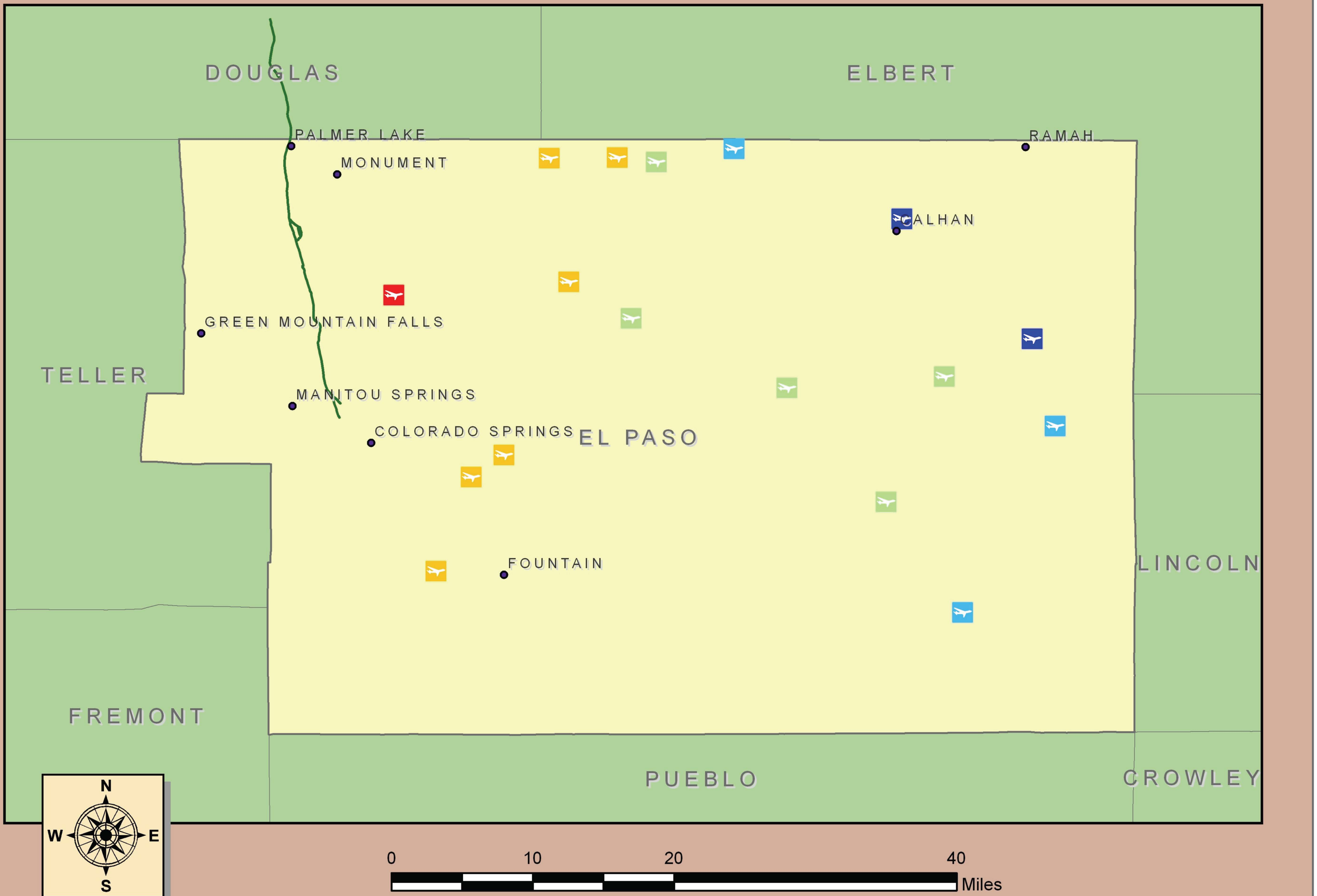


If a M7.0 were to occur on the Rampart Range Fault near Colorado Springs…

- **$23 billion** in statewide economic losses
- **$9.0 billion** in El Paso County alone
- **238,000 buildings** with moderate or higher damage
- **5,060 casualties** requiring hospitalization
- **46,700** displaced households

Facilities Damaged in El Paso County from a M7.0 Earthquake on the Rampart Fault

AIRPORTS



DOUGLAS
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PALMER LAKE
MONUMENT
RAMAH
CALHAN
GREEN MOUNTAIN FALLS
TELLER
MANITOU SPRINGS
COLORADO SPRINGS
EL PASO
FOUNTAIN
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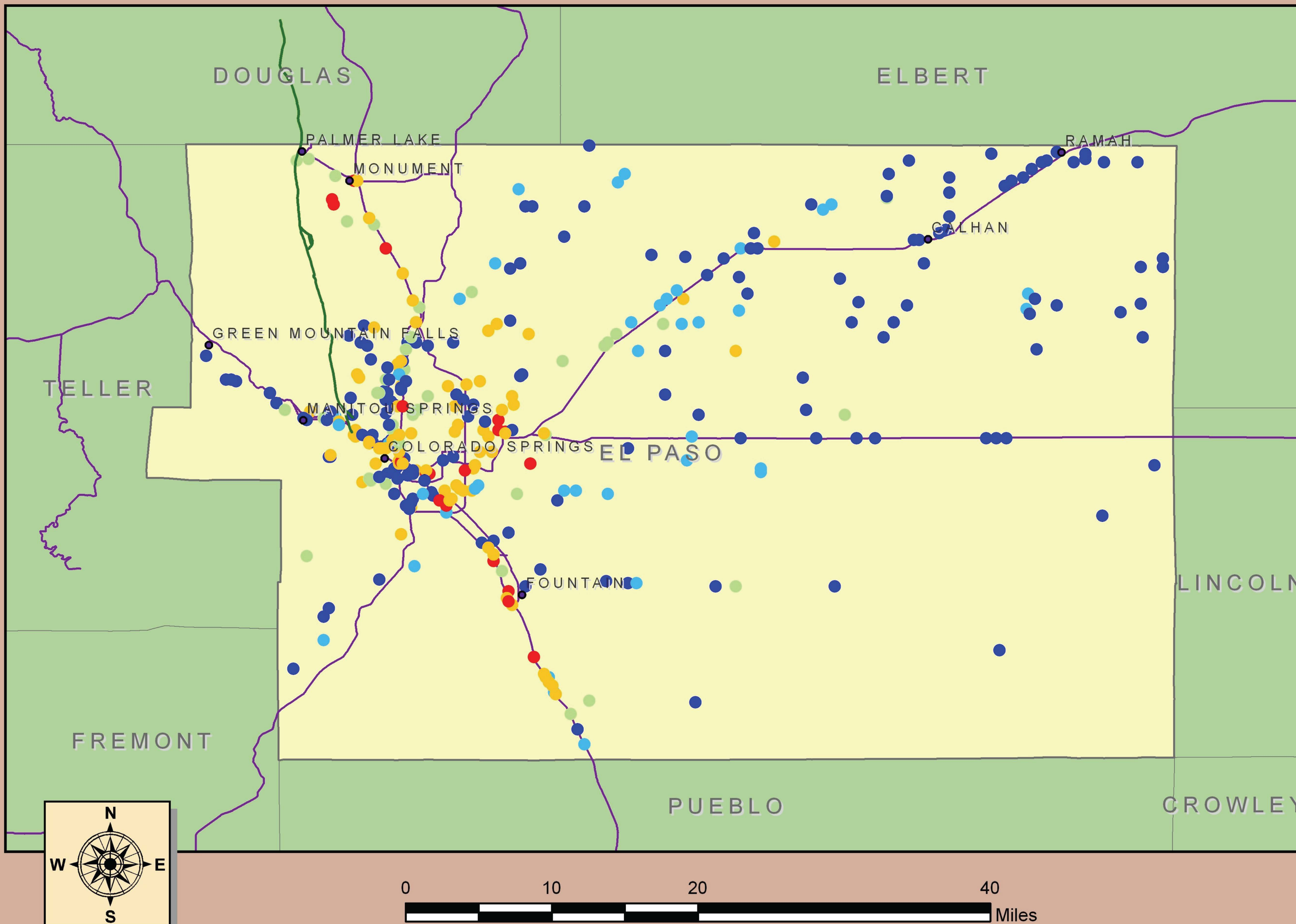
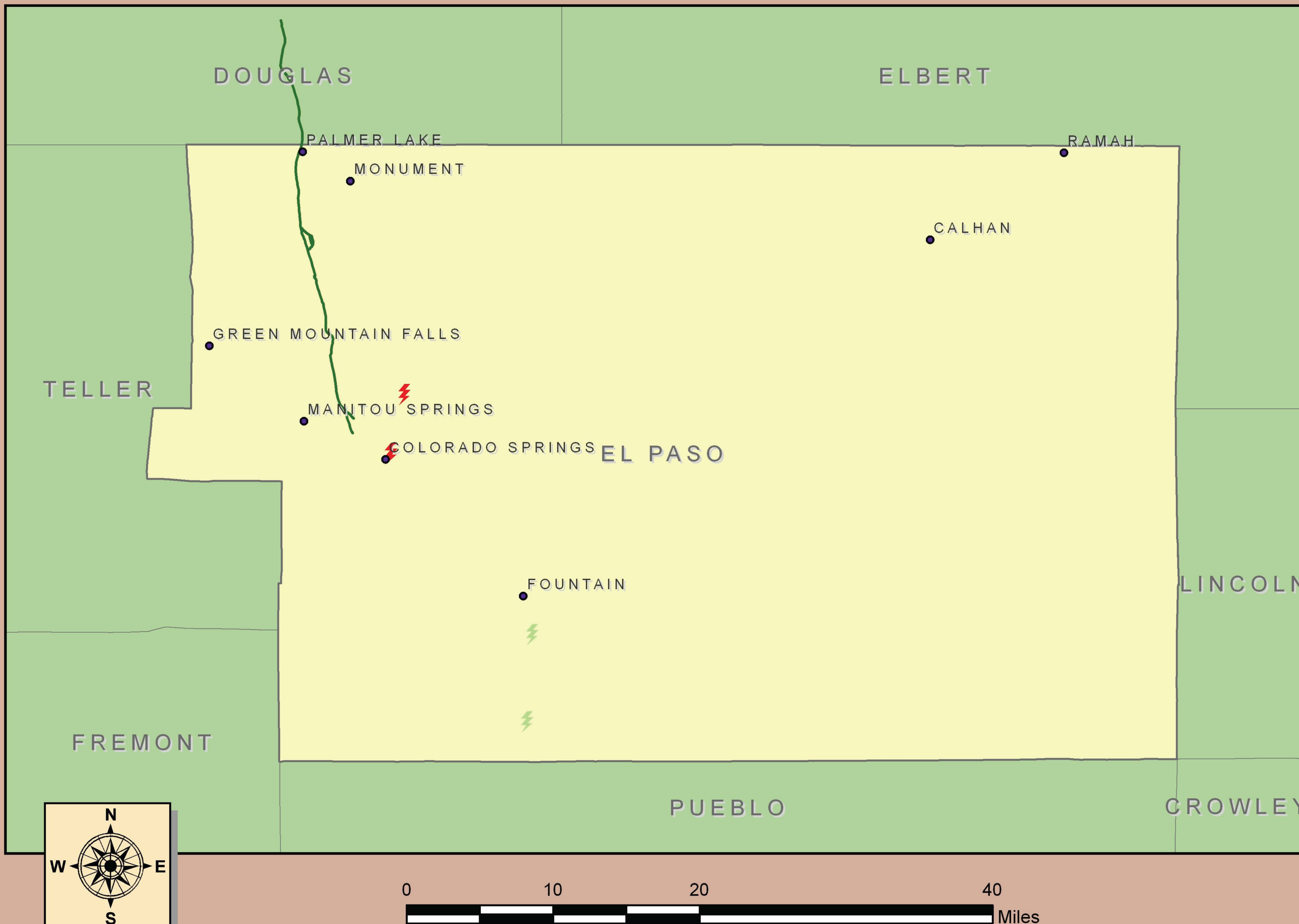
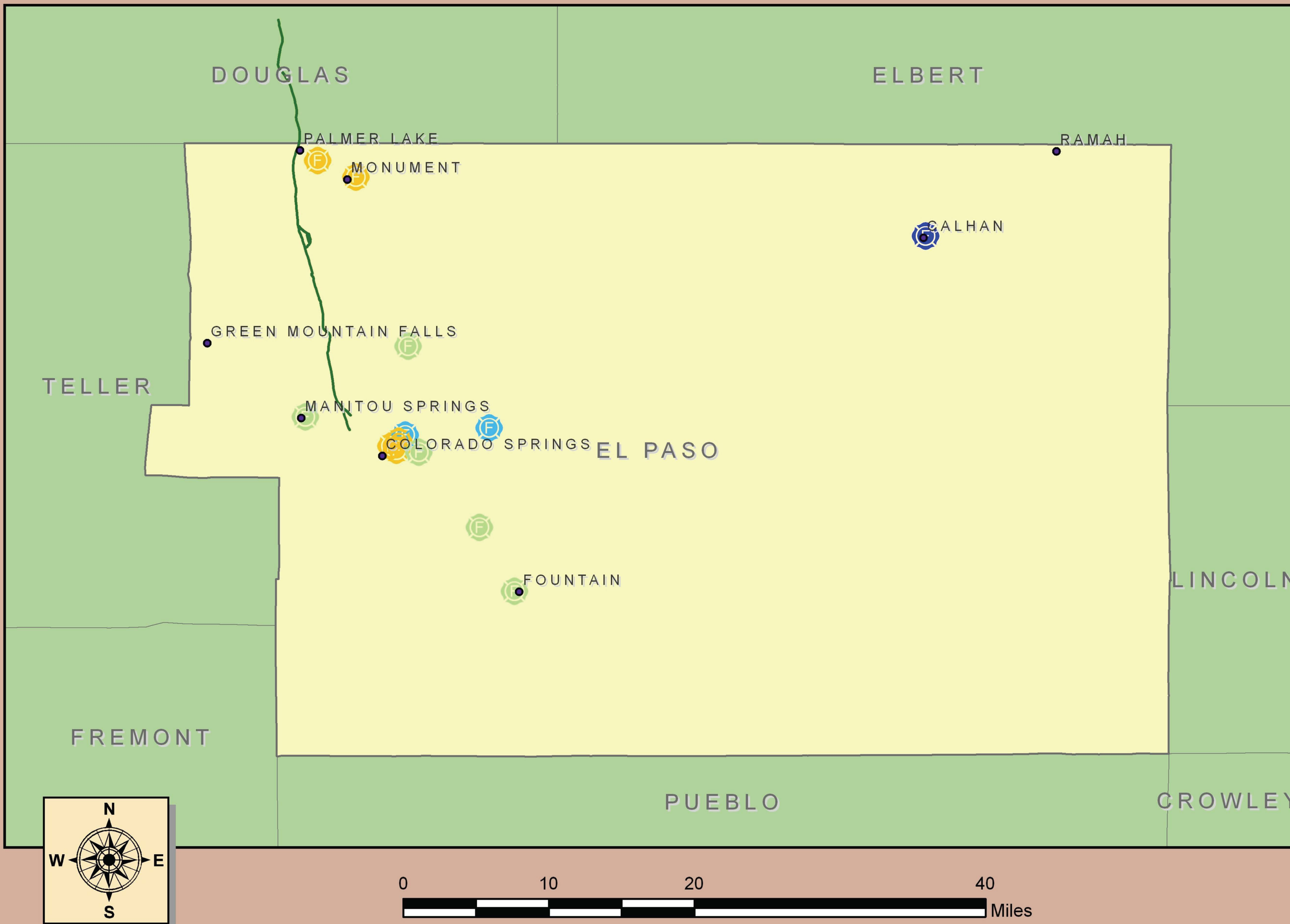
HIGHWAY BRIDGES



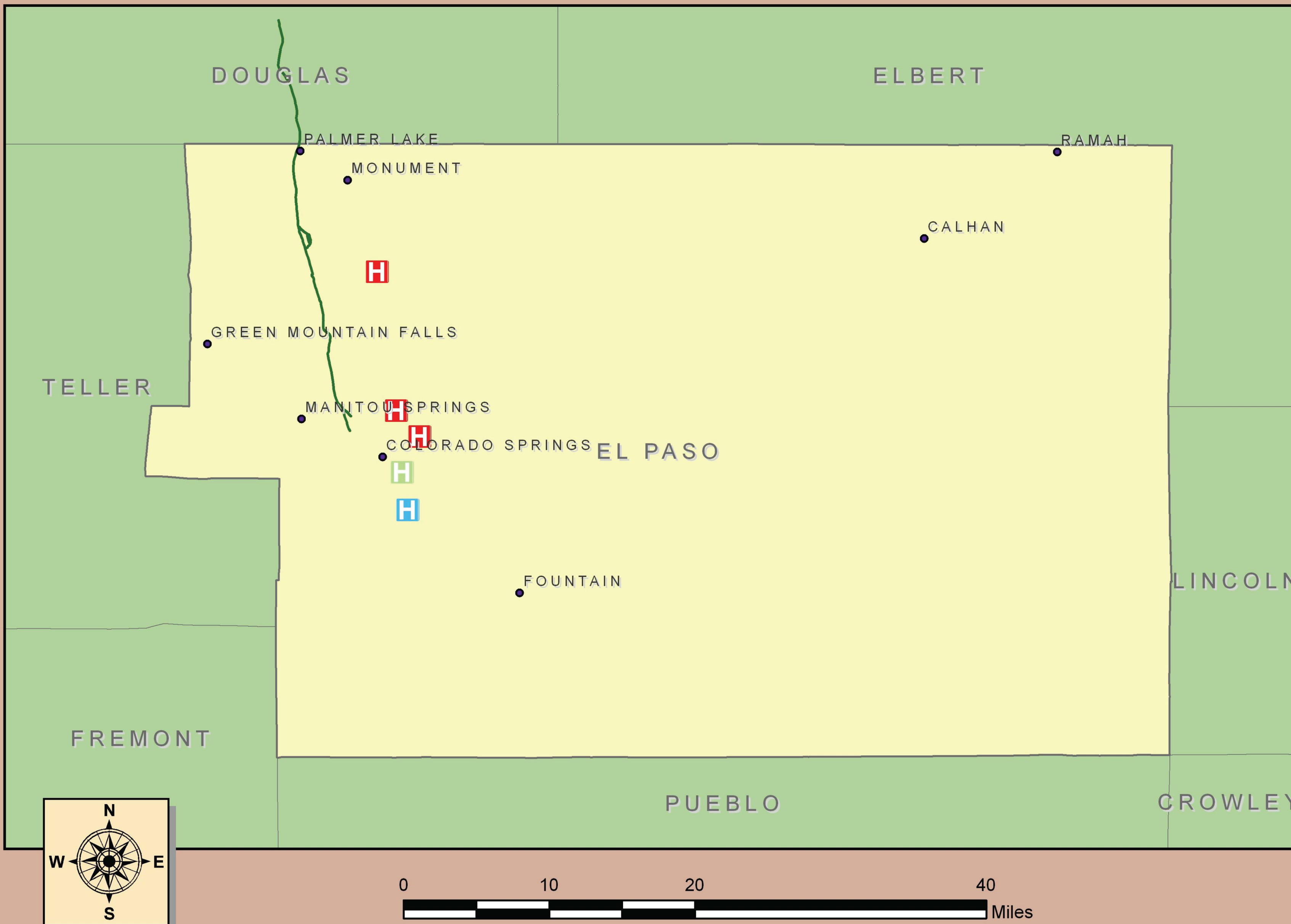
ELECTRICAL FACILITIES



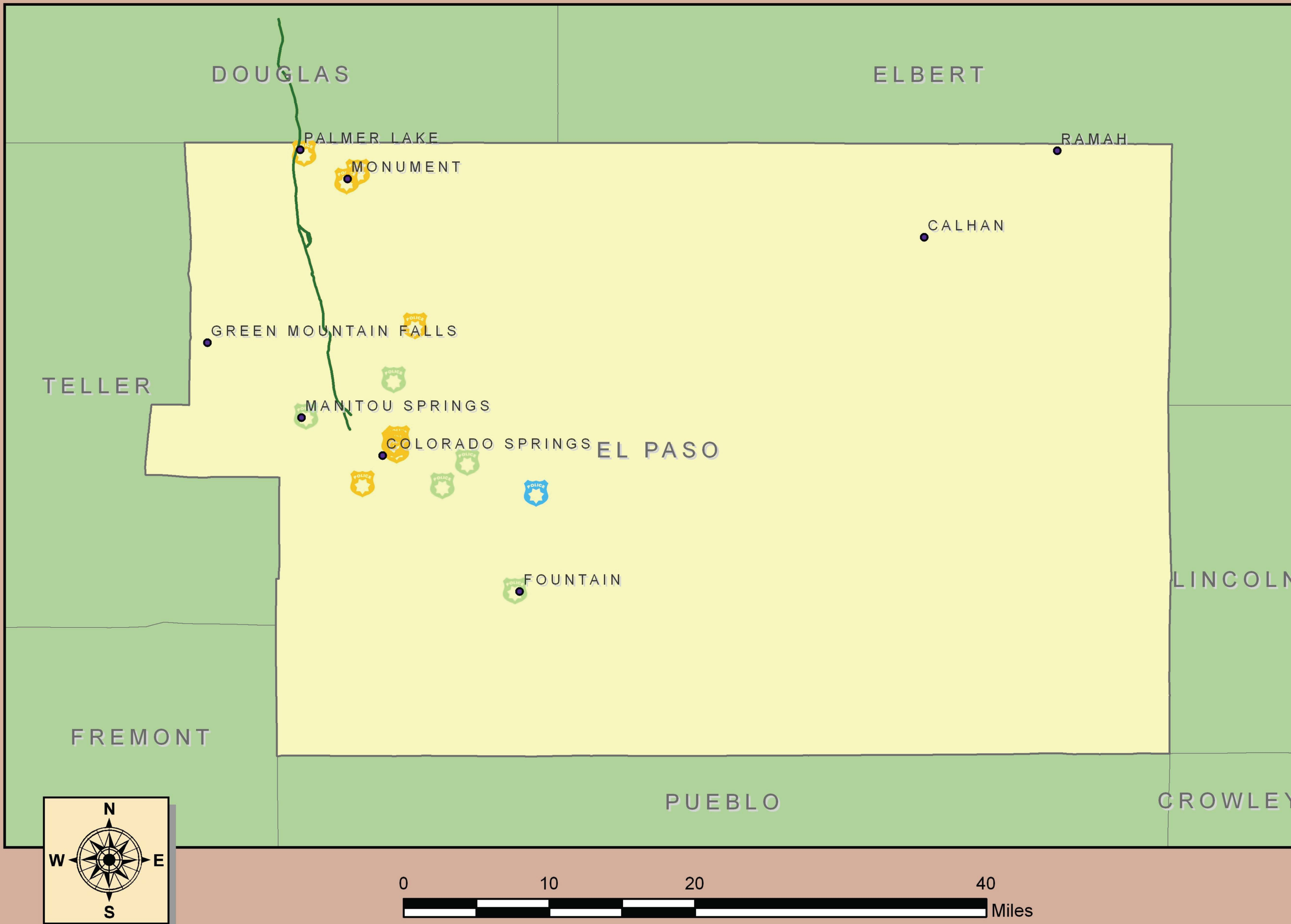
FIRE STATIONS



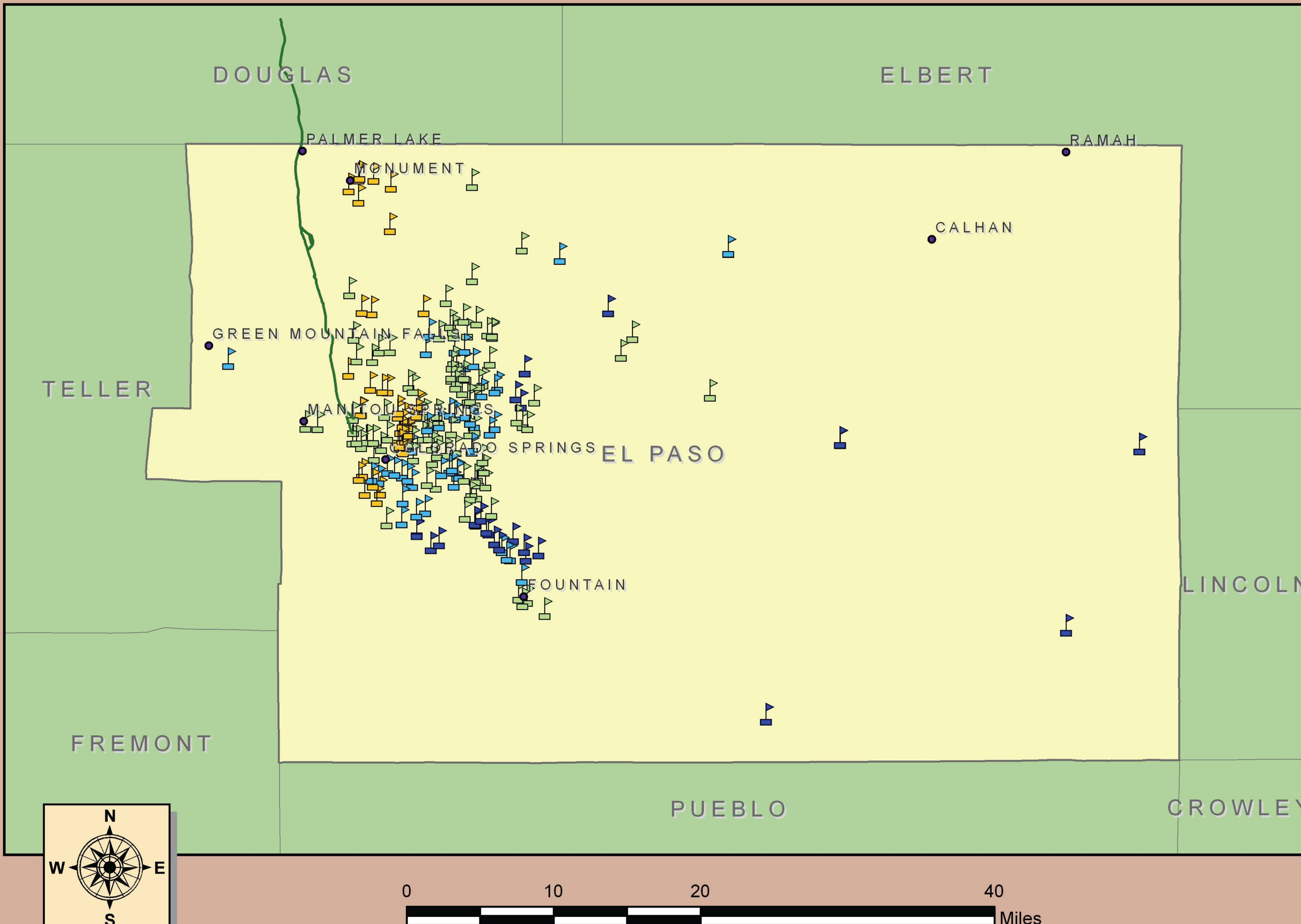
MEDICAL CARE FACILITIES



POLICE STATIONS



SCHOOLS


DOUGLAS
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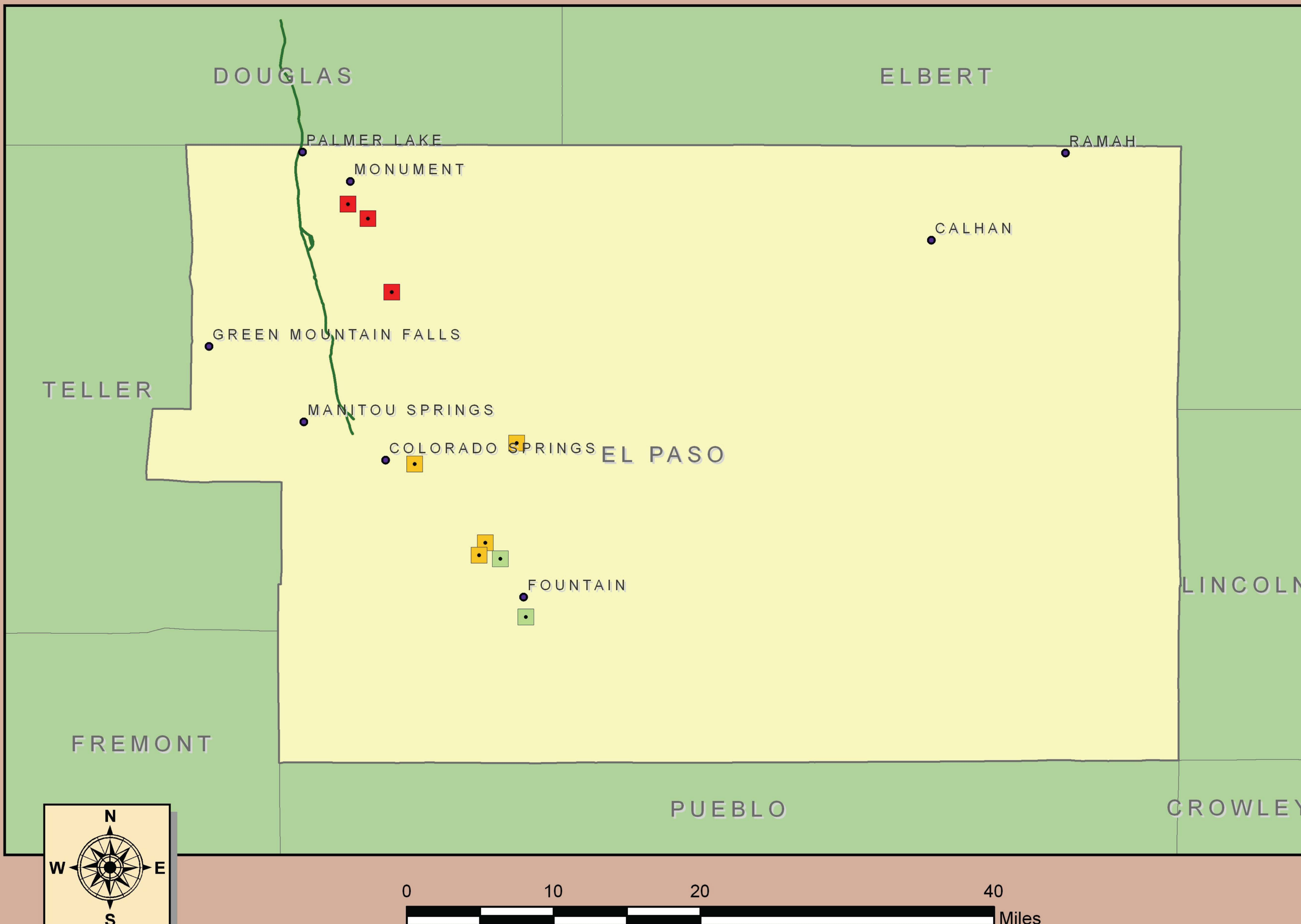
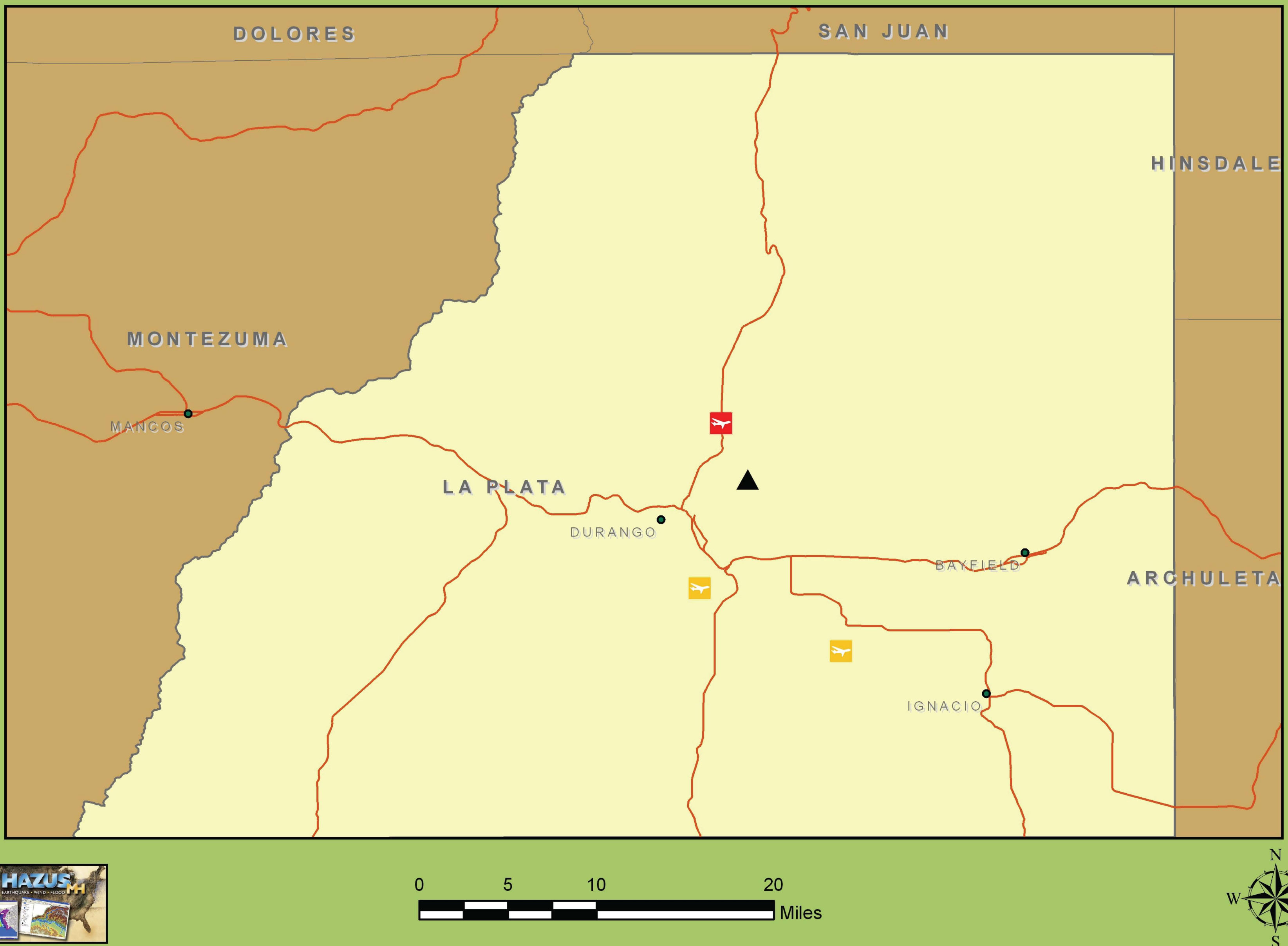
WASTE WATER FACILITIES



We also analyzed “Random” Earthquakes for each County

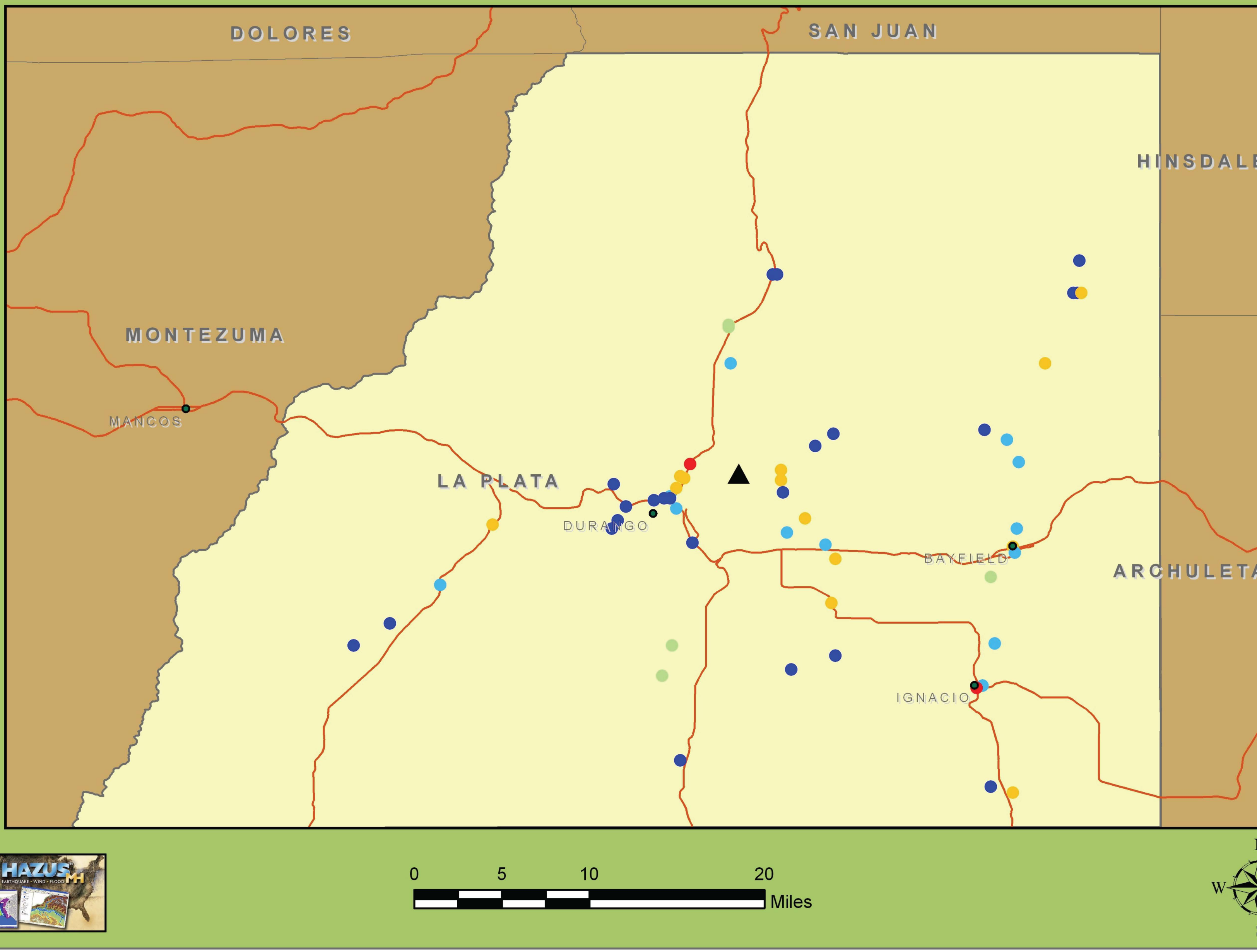
AIRPORTS

La Plata County M6.5 Random Earthquake



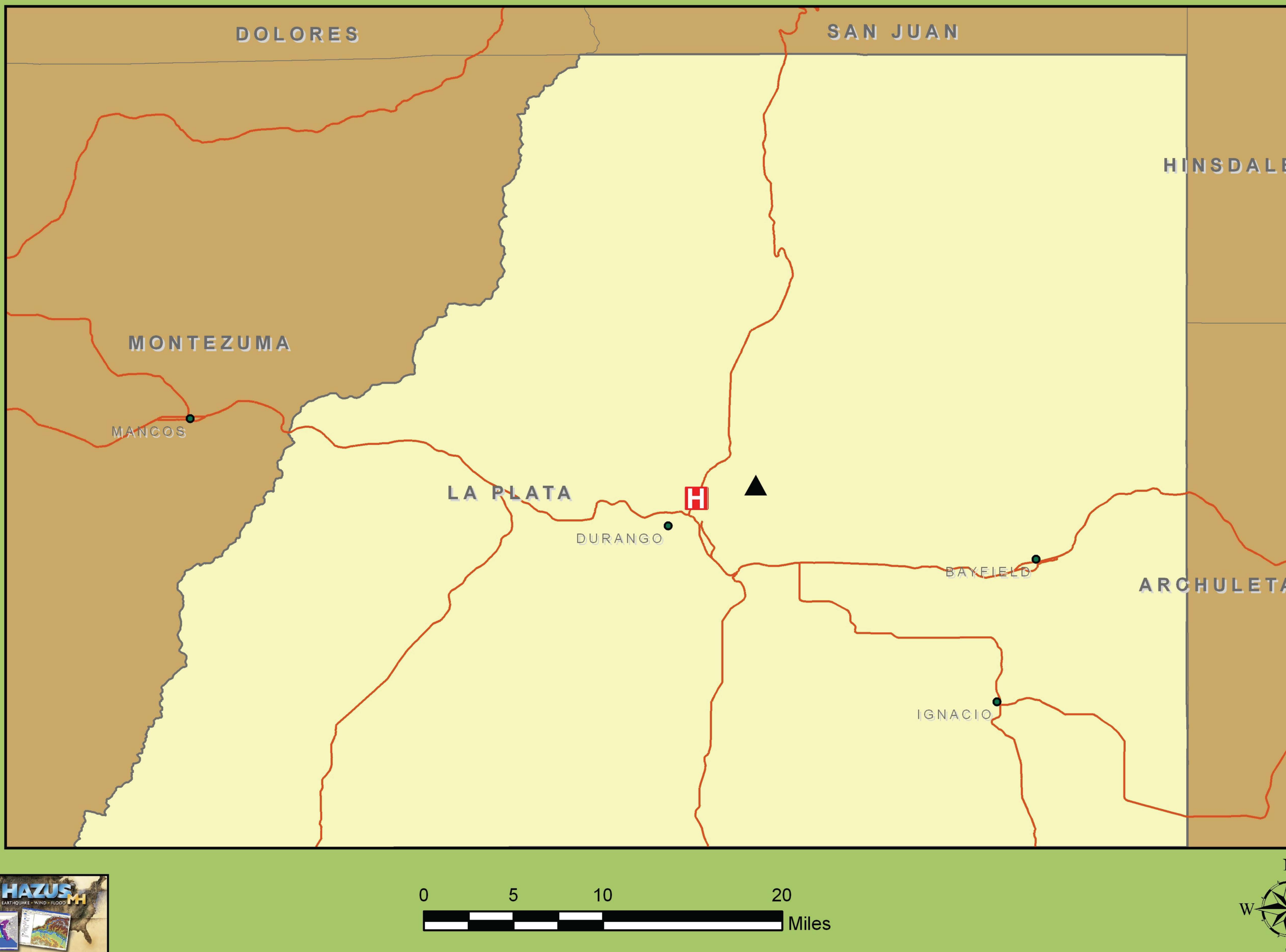
HIGHWAY BRIDGES

La Plata County M6.5 Random Earthquake



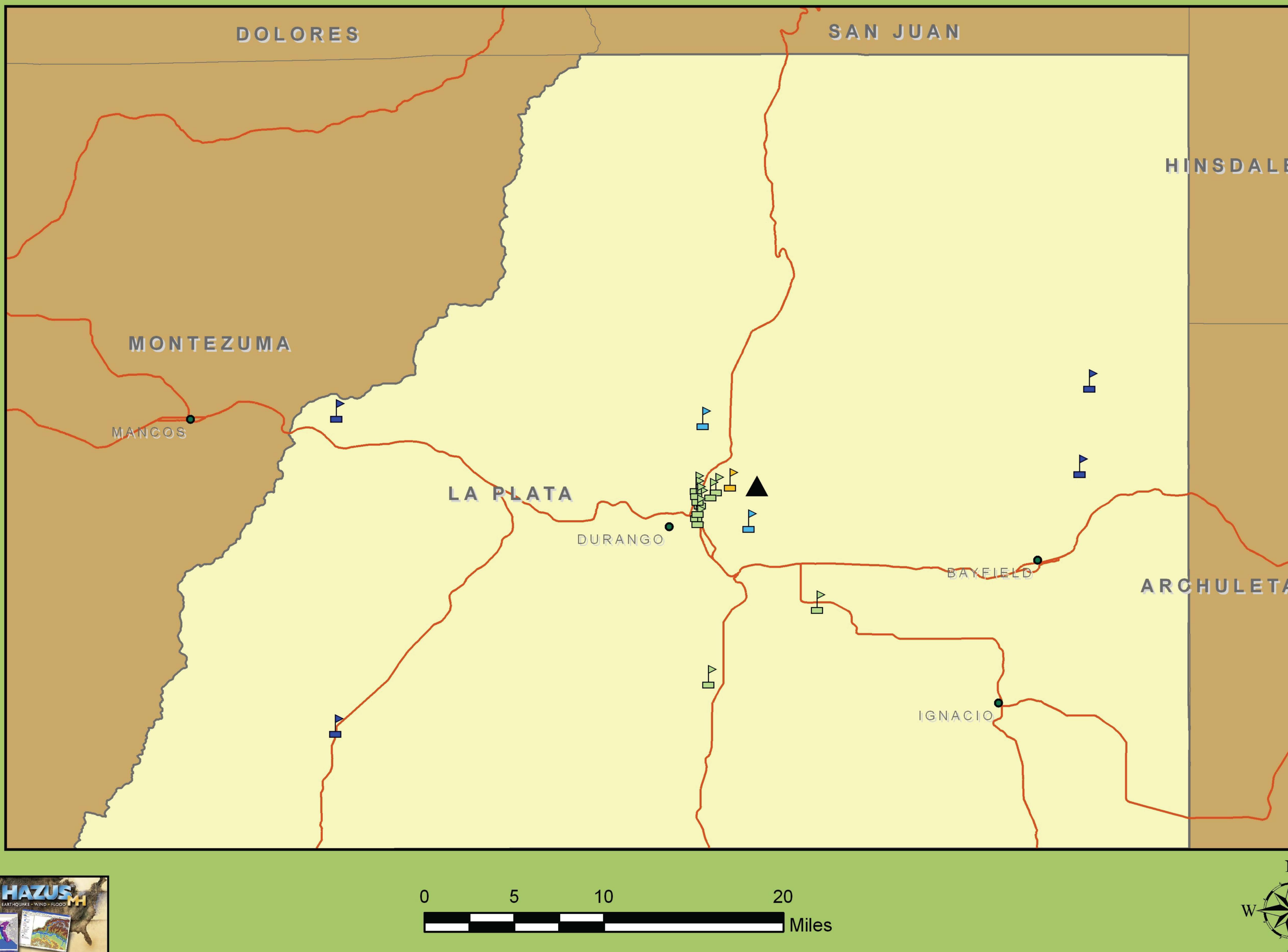
HOSPITALS

La Plata County M6.5 Random Earthquake



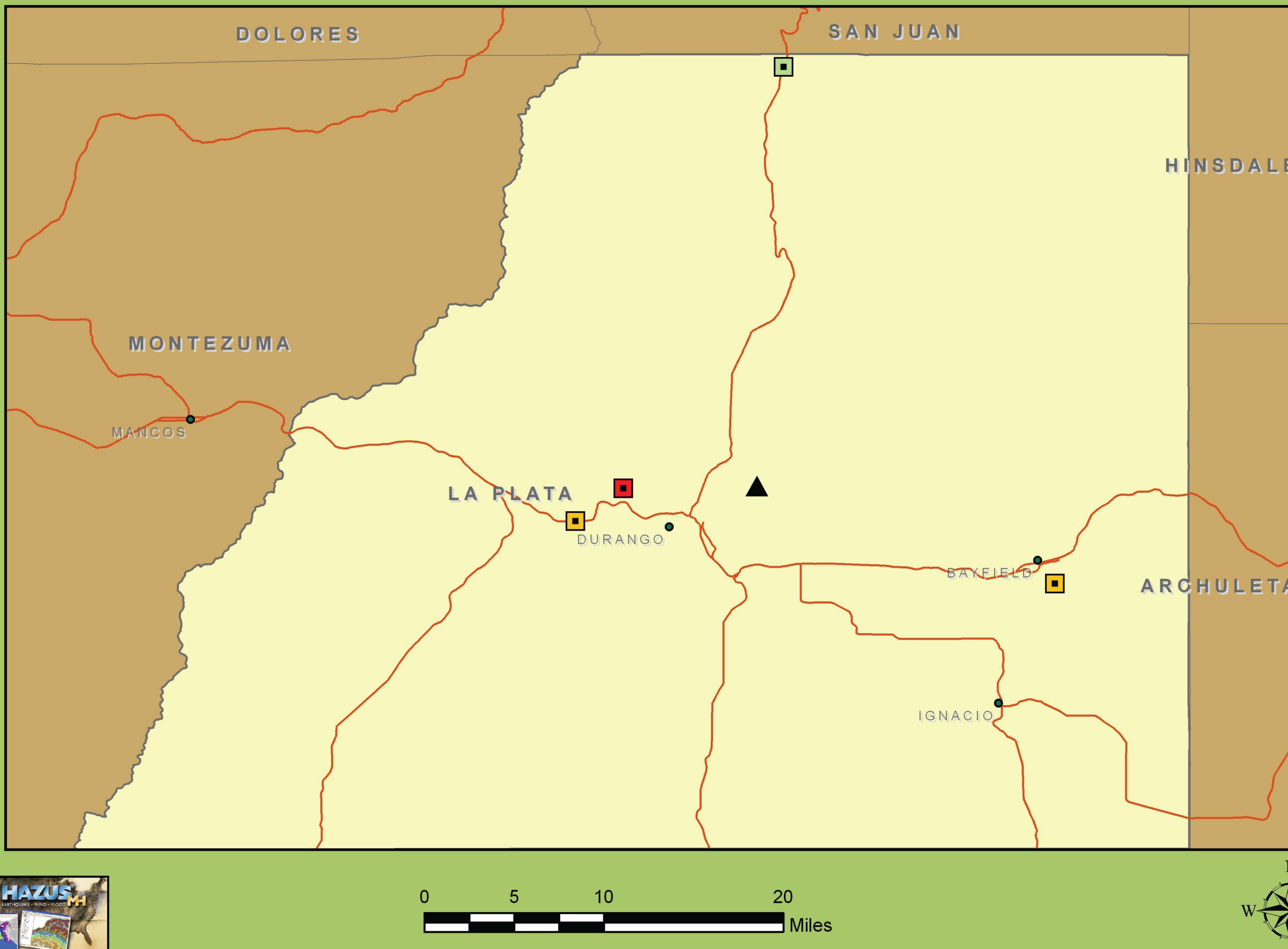
SCHOOLS

La Plata County M6.5 Random Earthquake

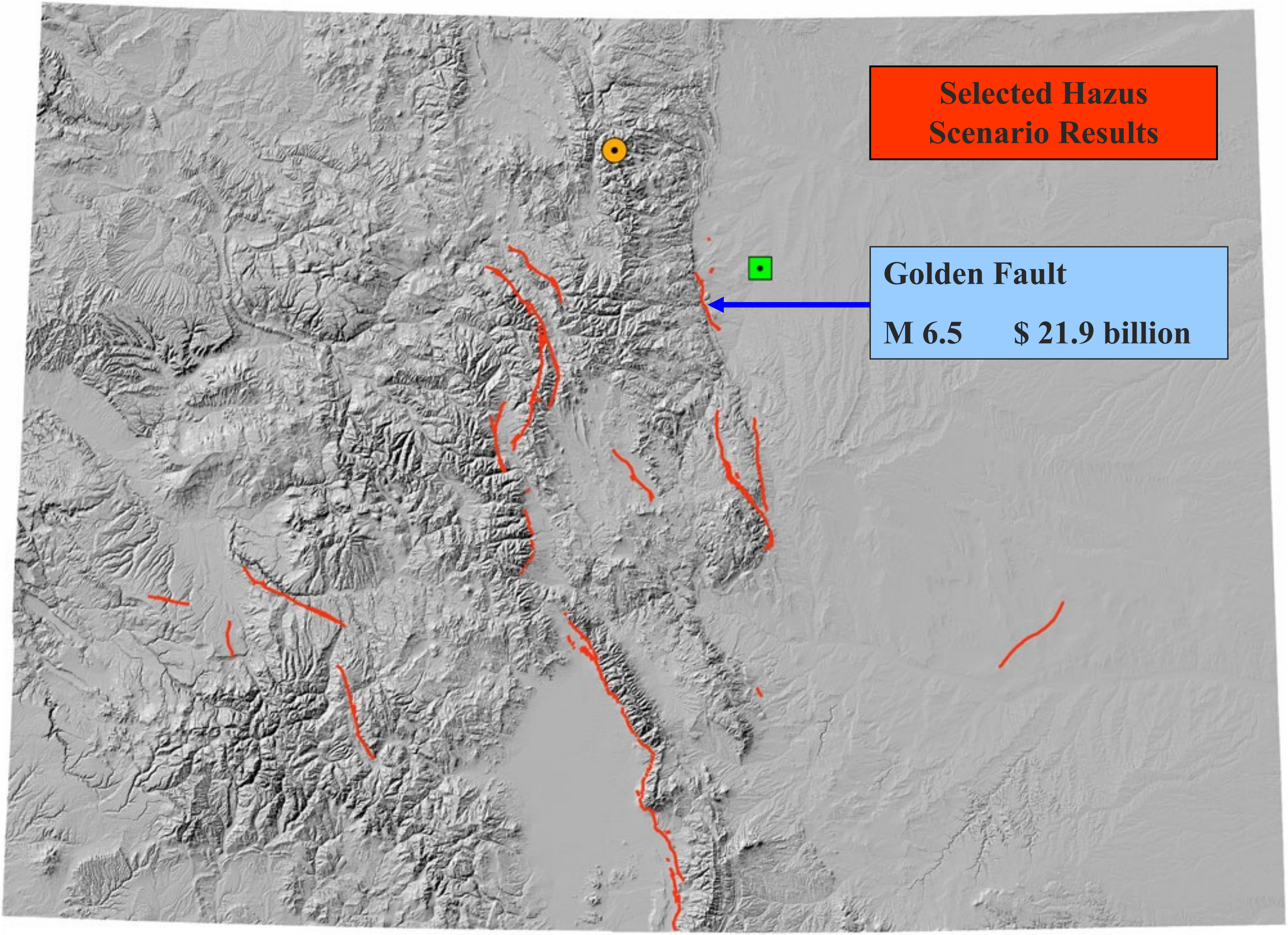


WASTE WATER FACILITIES

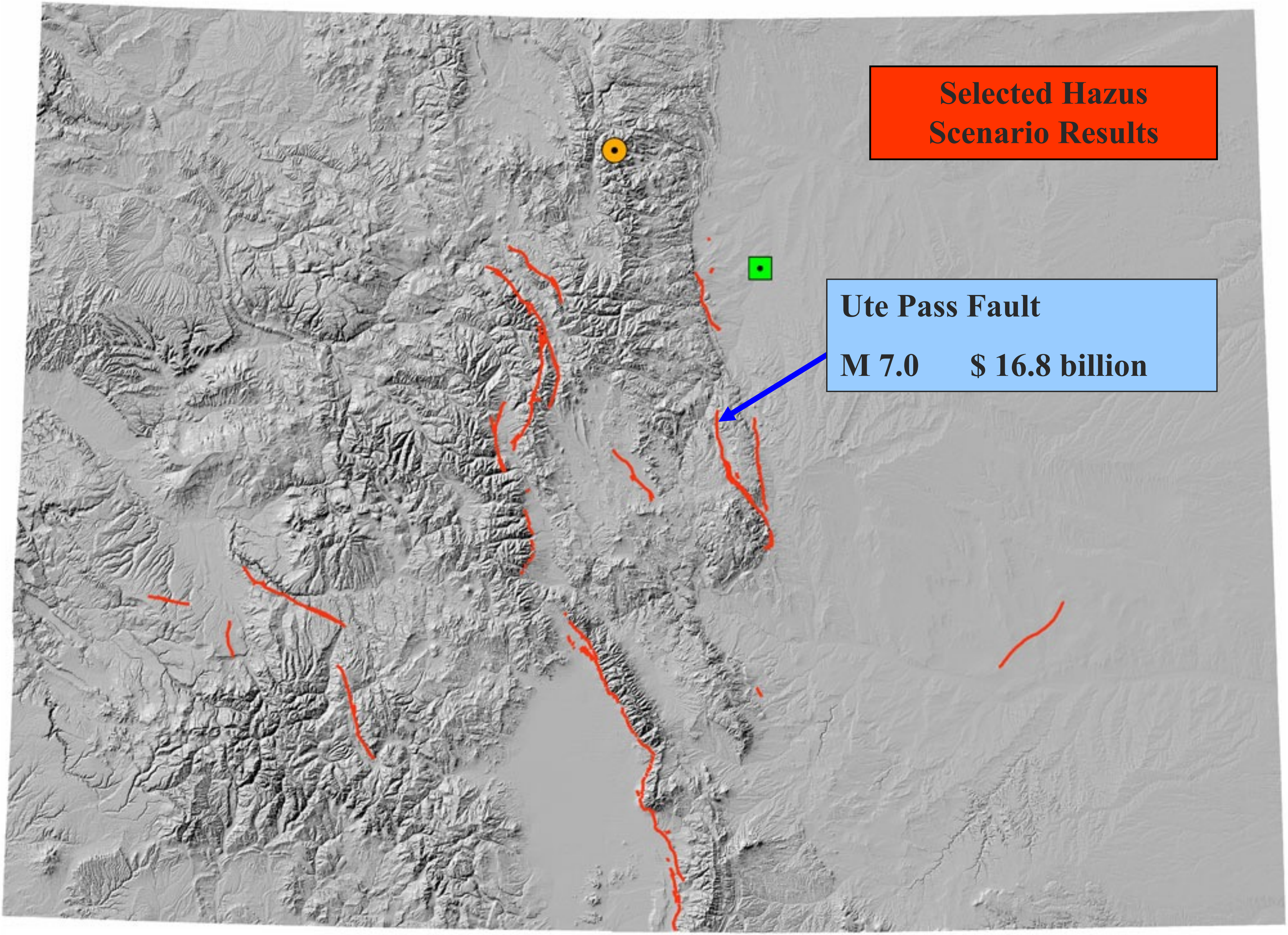
La Plata County M6.5 Random Earthquake



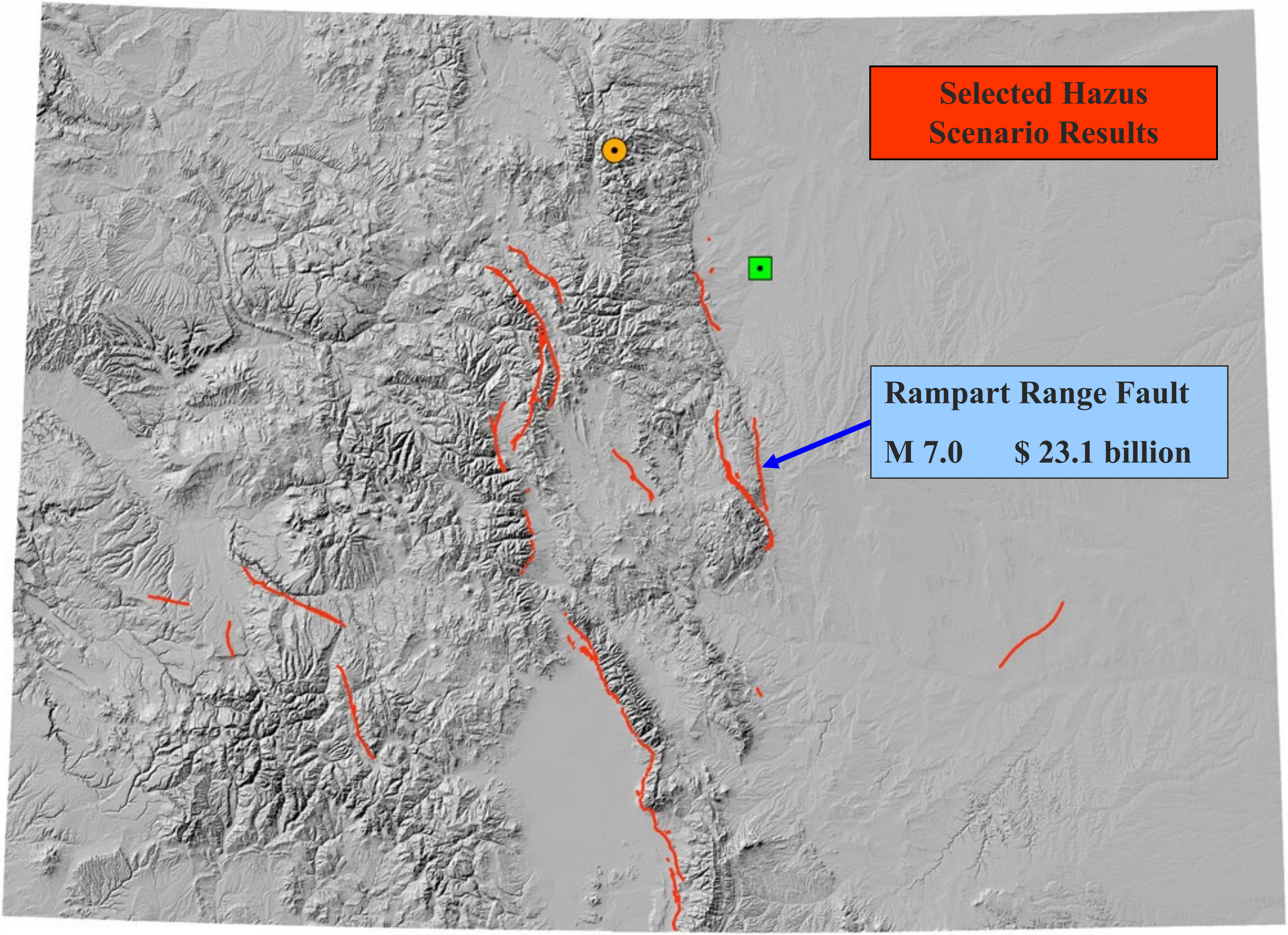
A Summary of
Statewide Worst-Case Scenarios

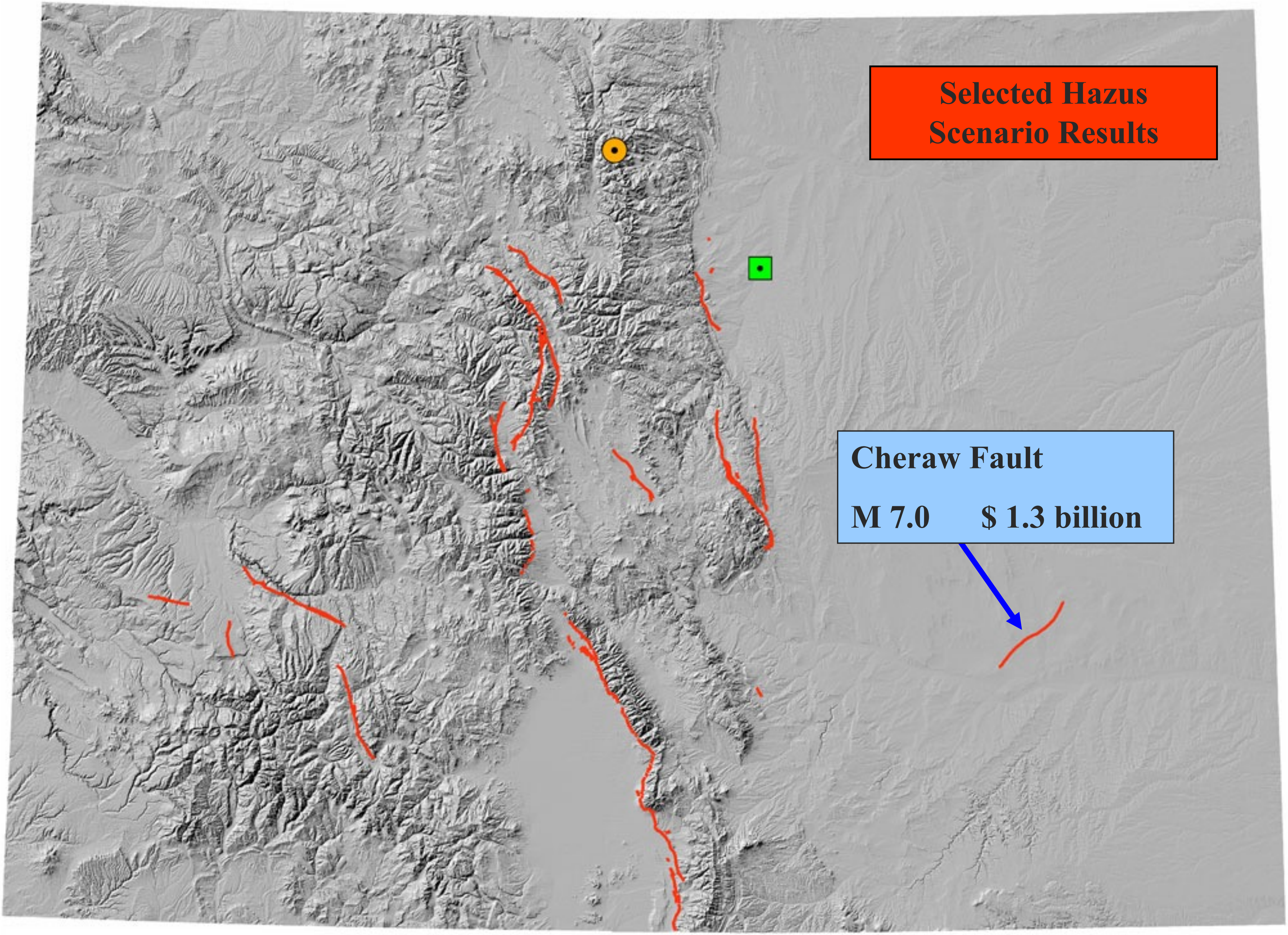


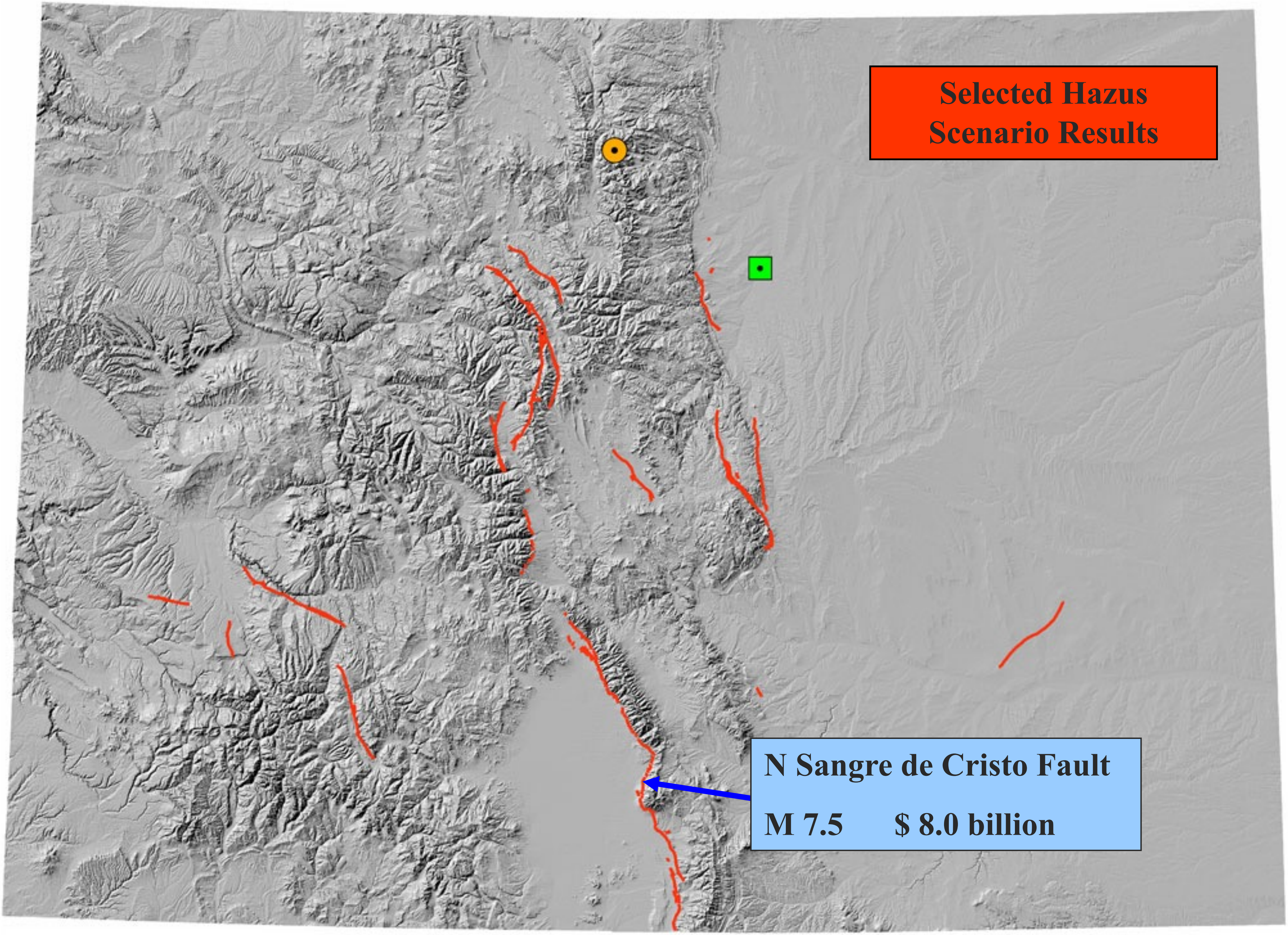
Selected Hazus Scenario Results
Golden Fault
M 6.5 $ 21.9 billion

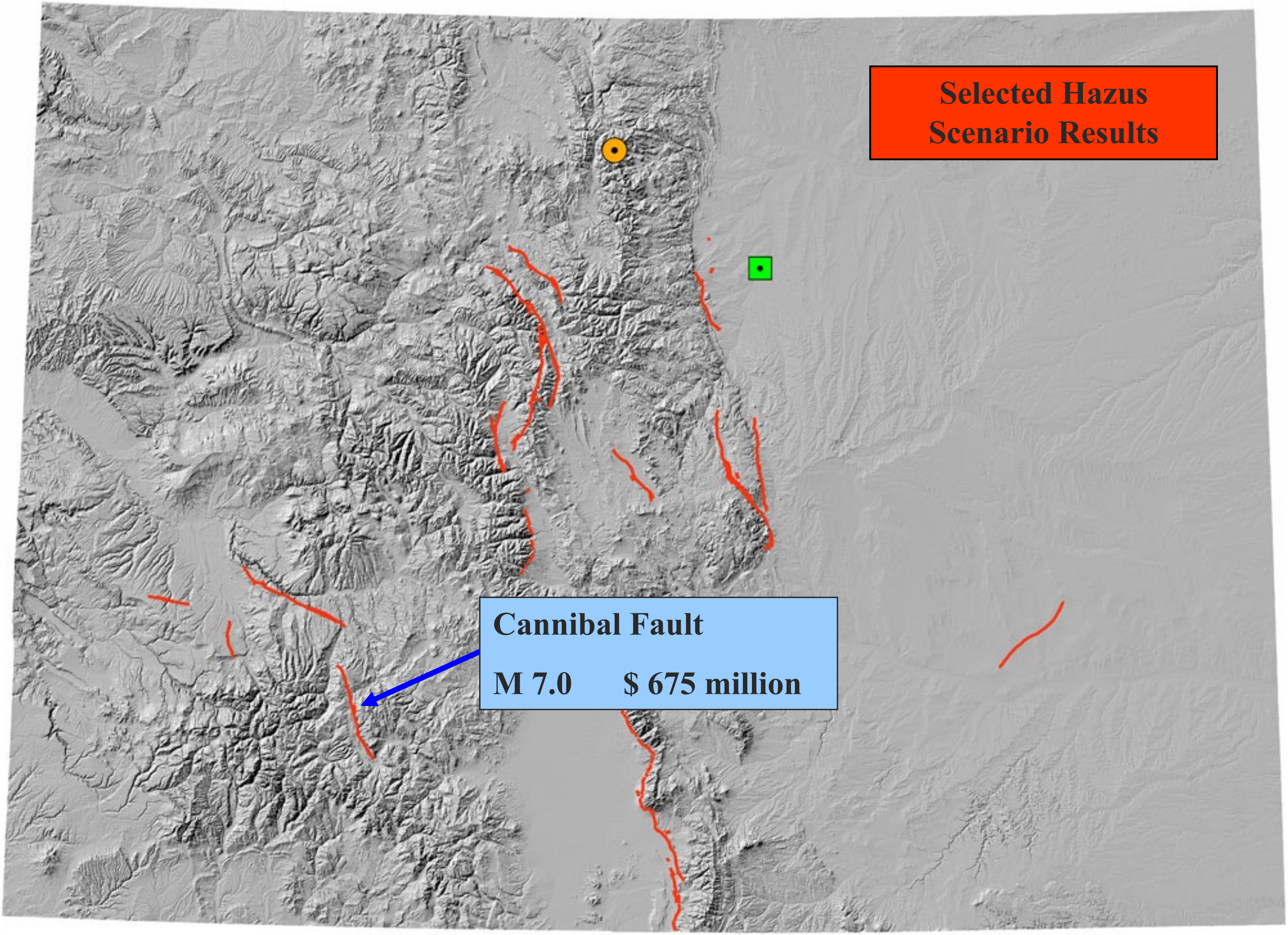


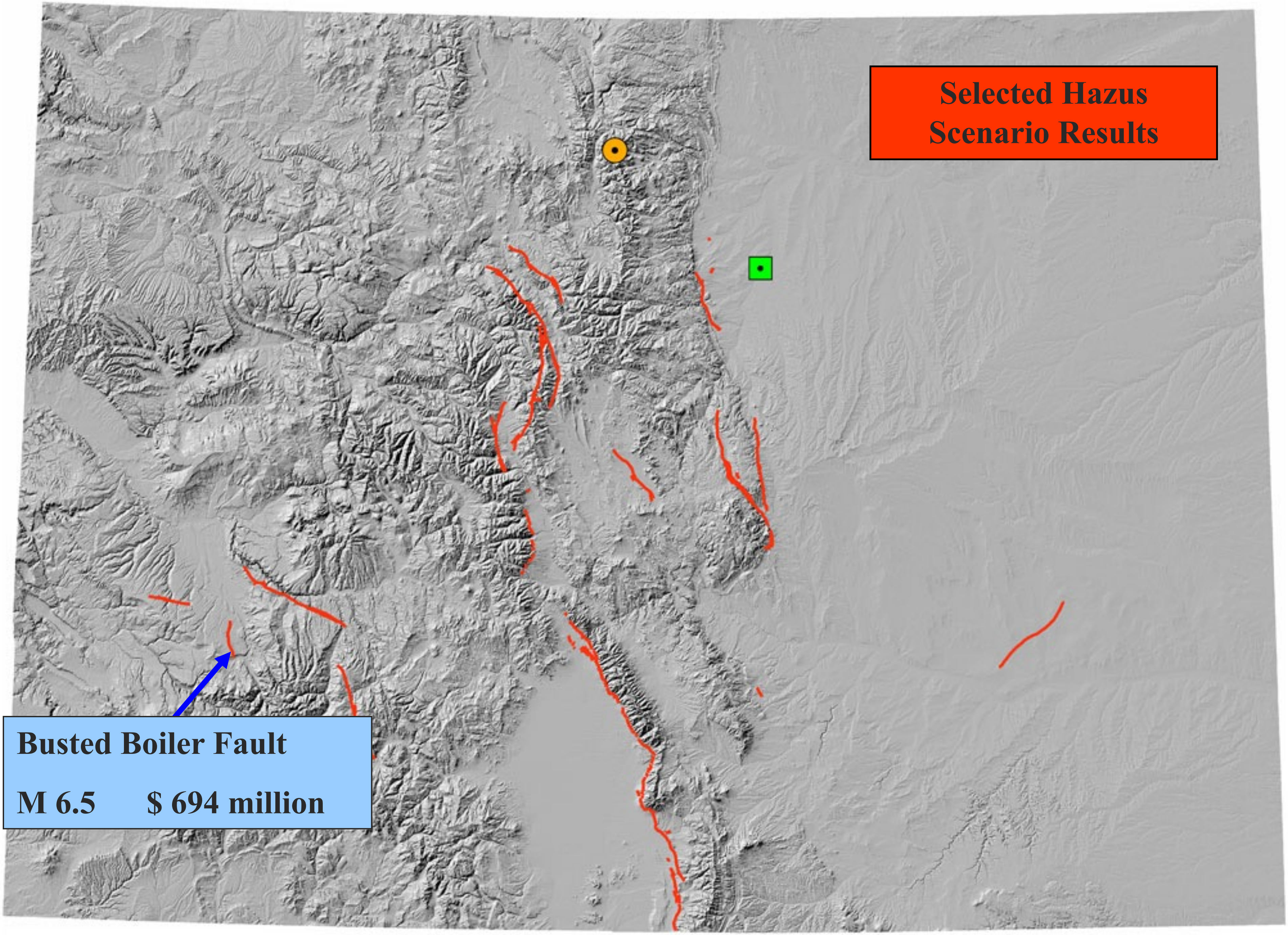
Selected Hazus Scenario Results
Ute Pass Fault
M 7.0 $ 16.8 billion

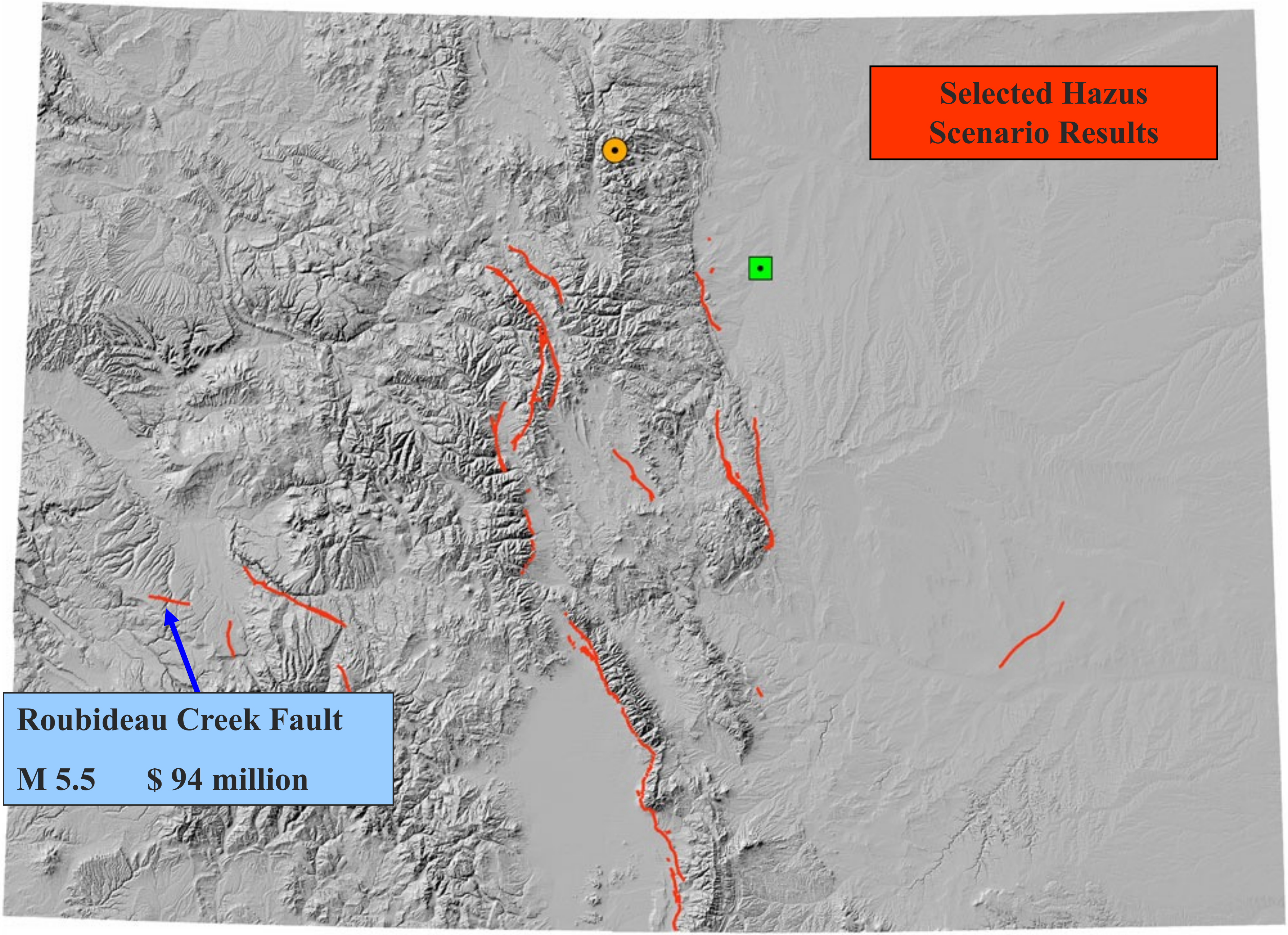

Selected Hazus Scenario Results
Rampart Range Fault
M 7.0 $ 23.1 billion


Selected Hazus Scenario Results
Cheraw Fault
M 7.0 $ 1.3 billion

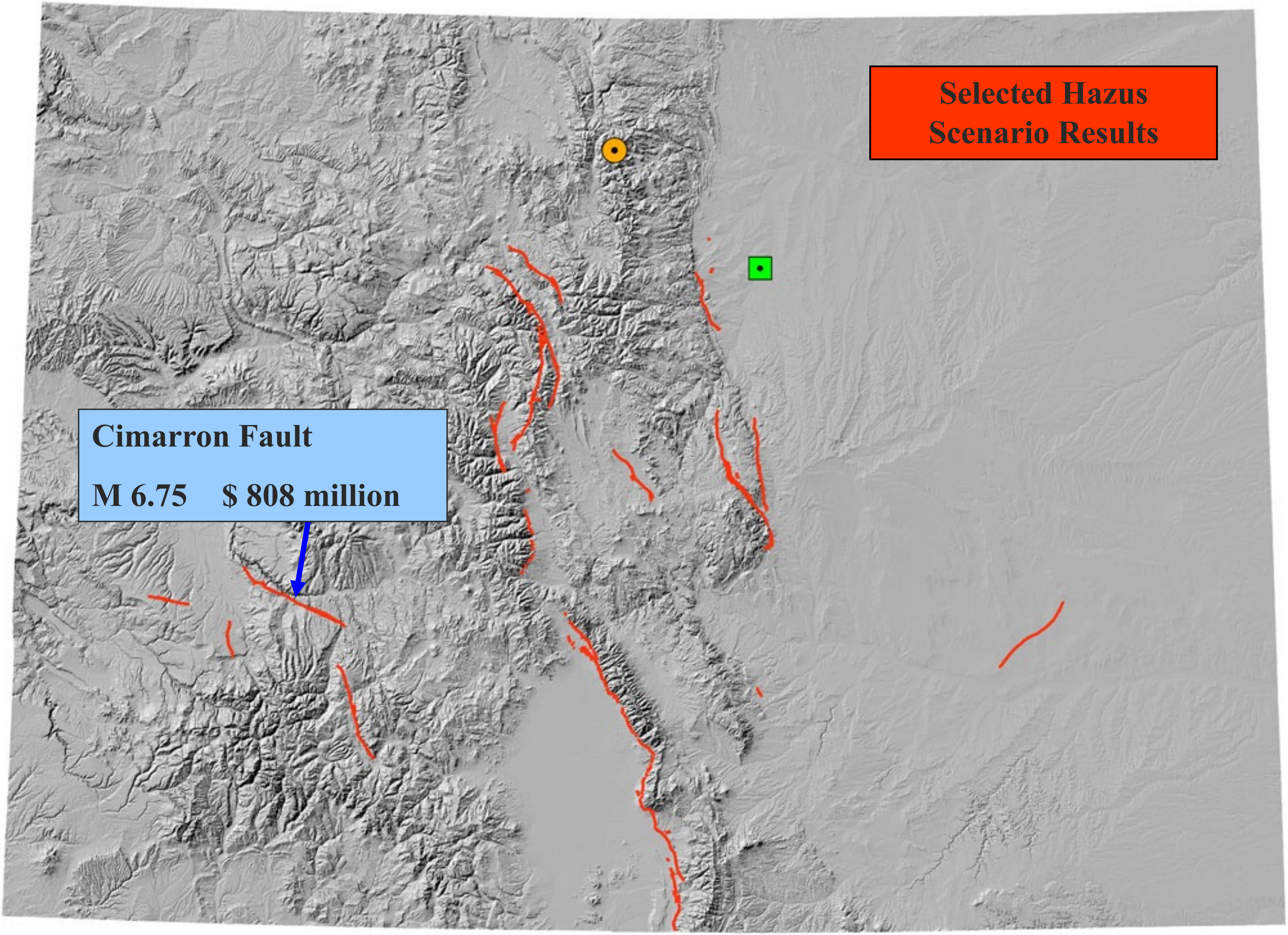

Selected Hazus
Scenario Results
N Sangre de Cristo Fault
M 7.5 $ 8.0 billion

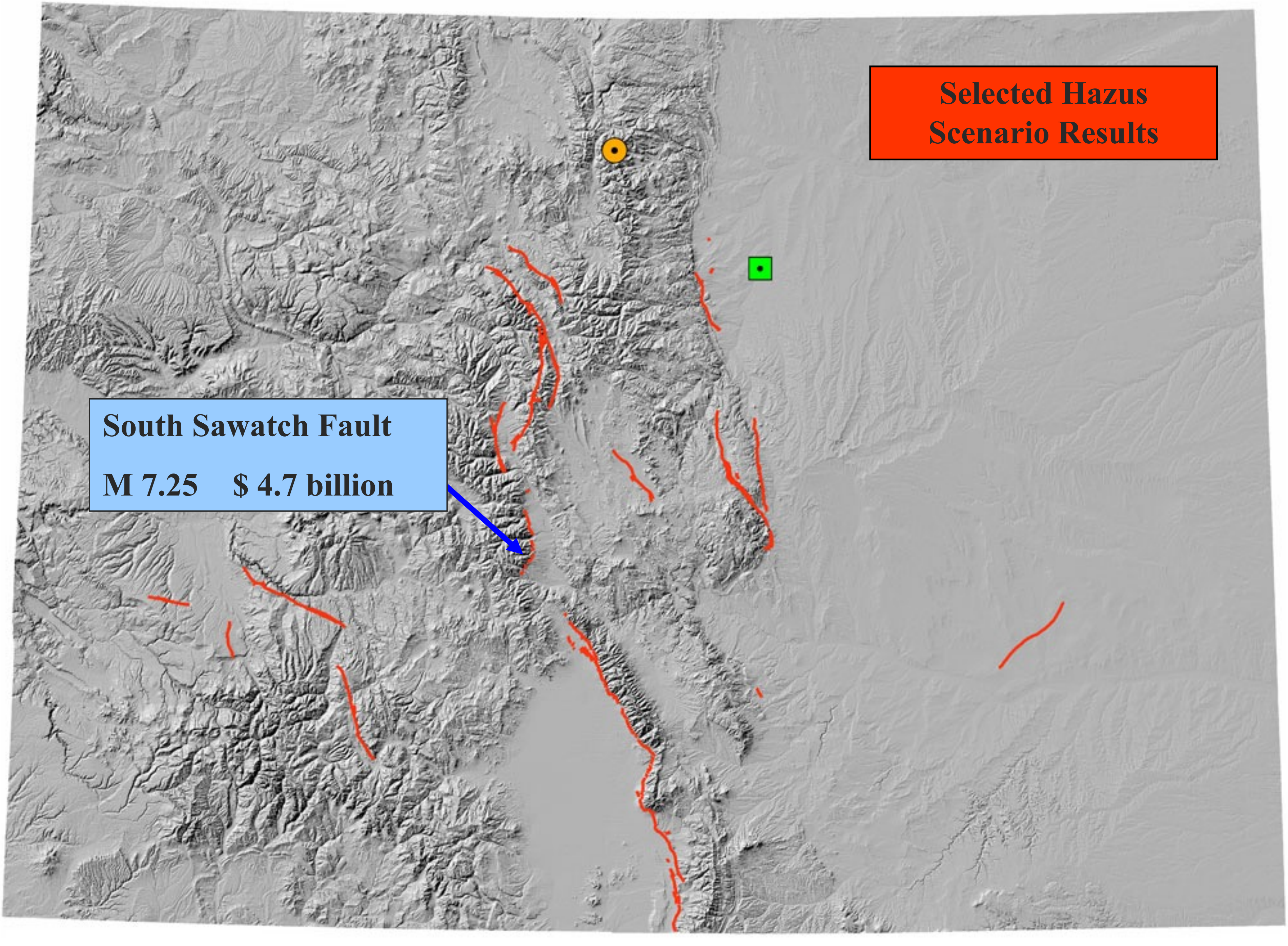

Selected Hazus
Scenario Results
Cannibal Fault
M 7.0 $ 675 million

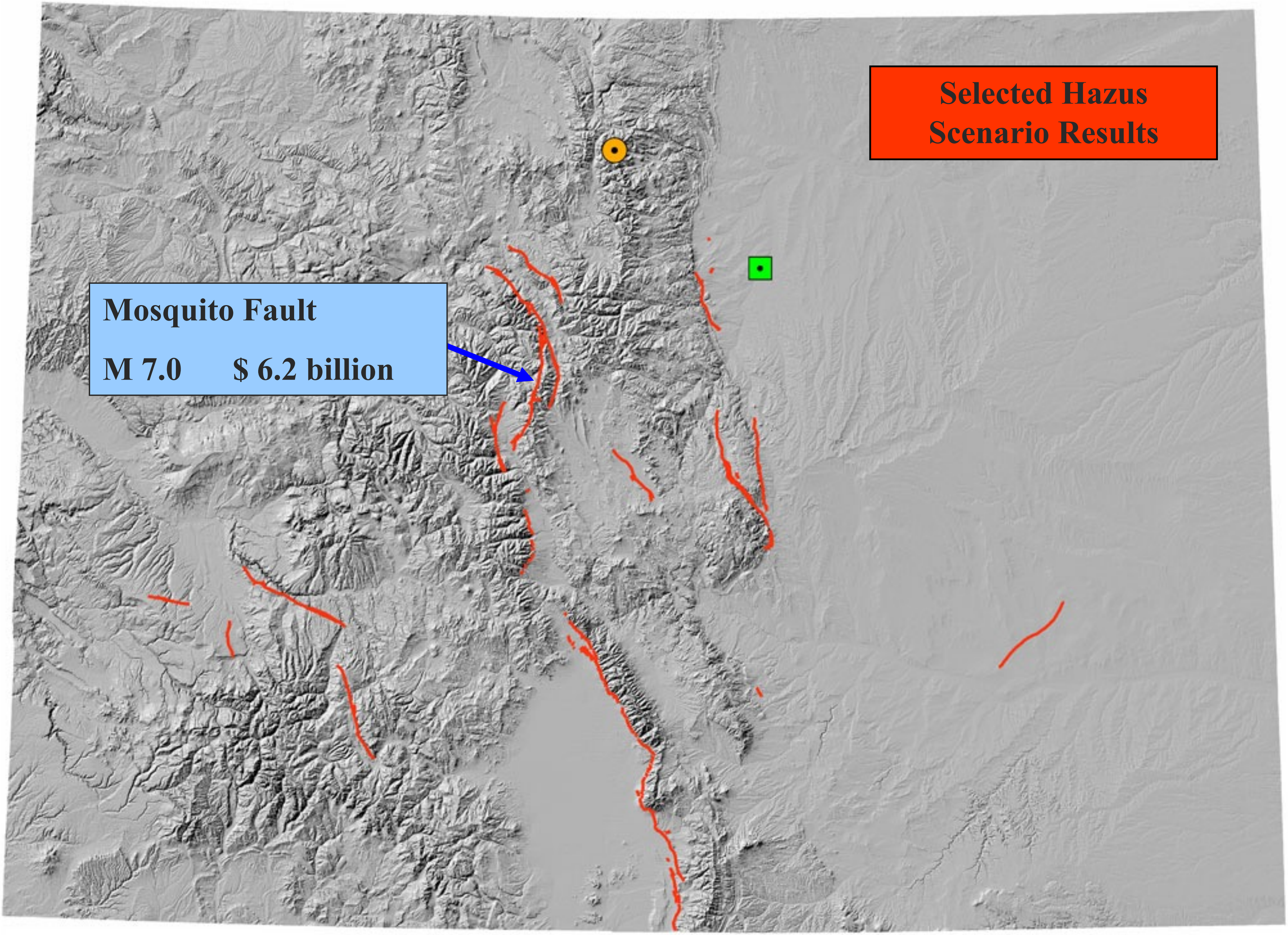

Selected Hazus Scenario Results
Busted Boiler Fault
M 6.5 $ 694 million

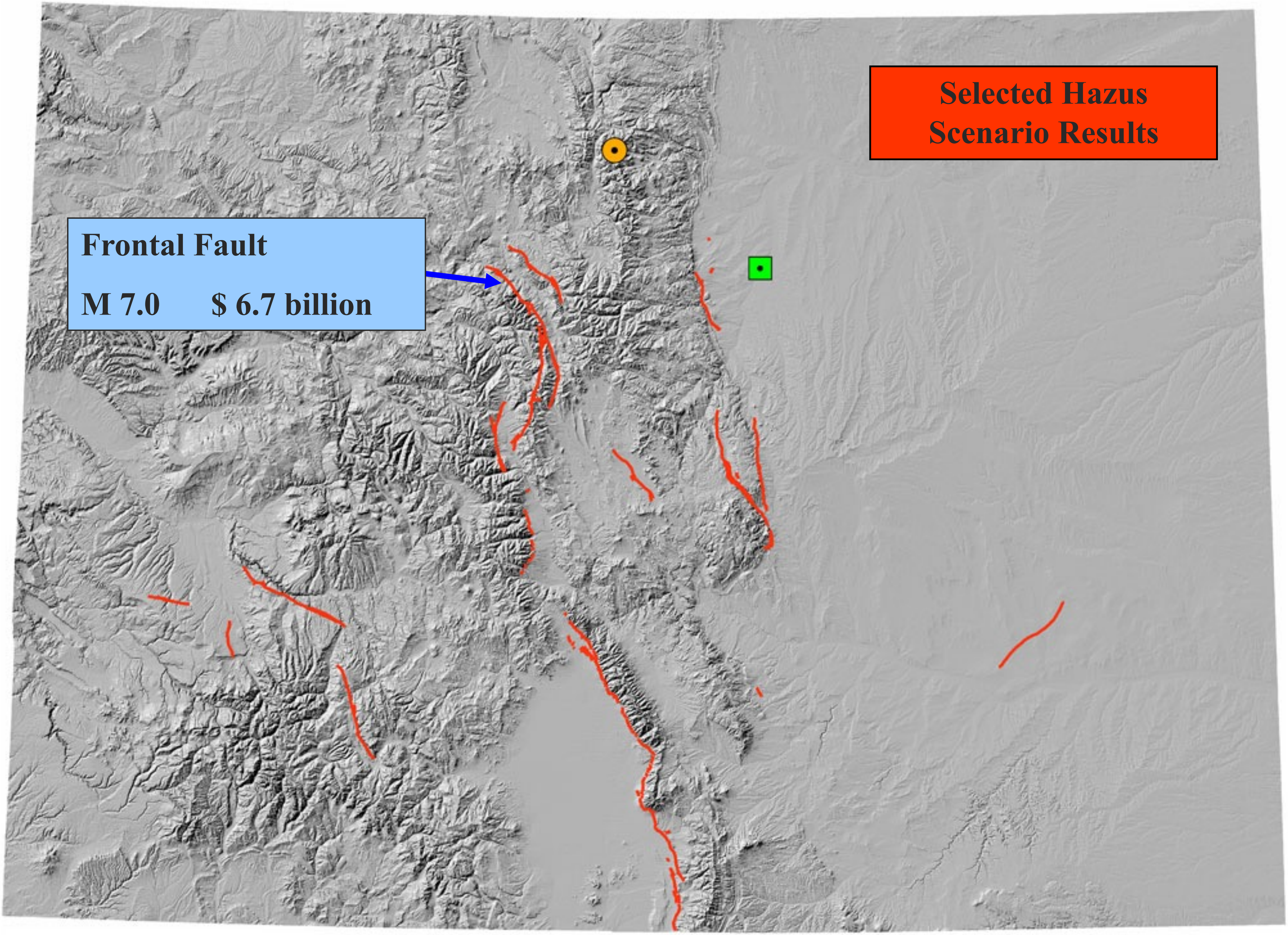


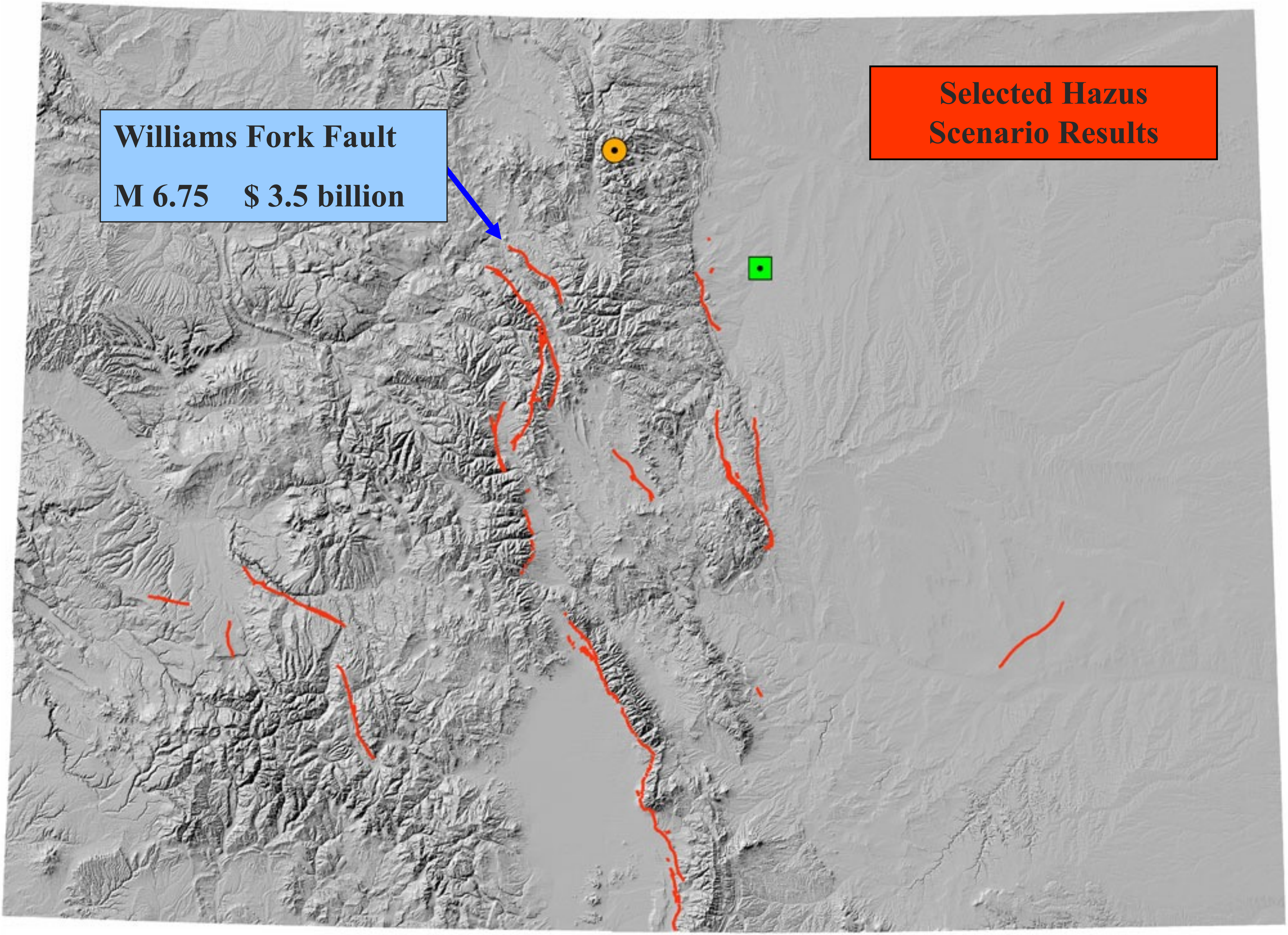
Selected Hazus
Scenario Results
Roubideau Creek Fault
M 5.5 $ 94 million


Selected Hazus
Scenario Results
Cimarron Fault
M 6.75 $ 808 million


Selected Hazus
Scenario Results
South Sawatch Fault
M 7.25 $ 4.7 billion


Selected Hazus
Scenario Results
Mosquito Fault
M 7.0 $ 6.2 billion

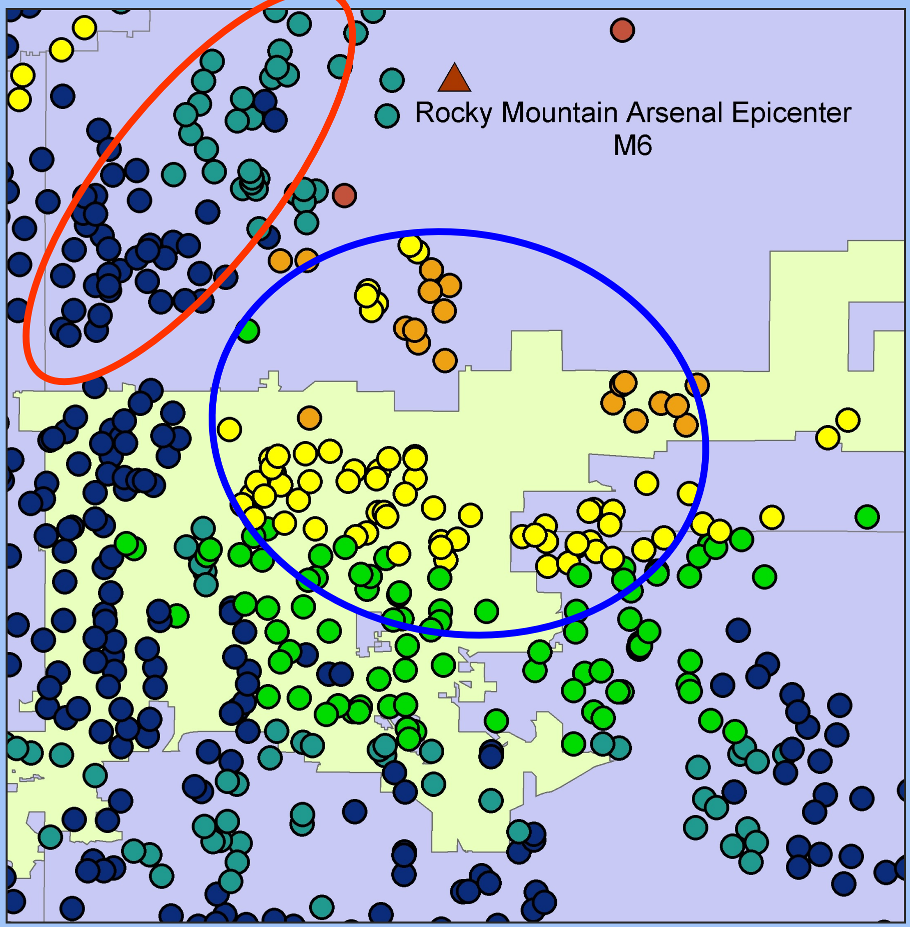

Selected Hazus
Scenario Results
Frontal Fault
M 7.0 $ 6.7 billion

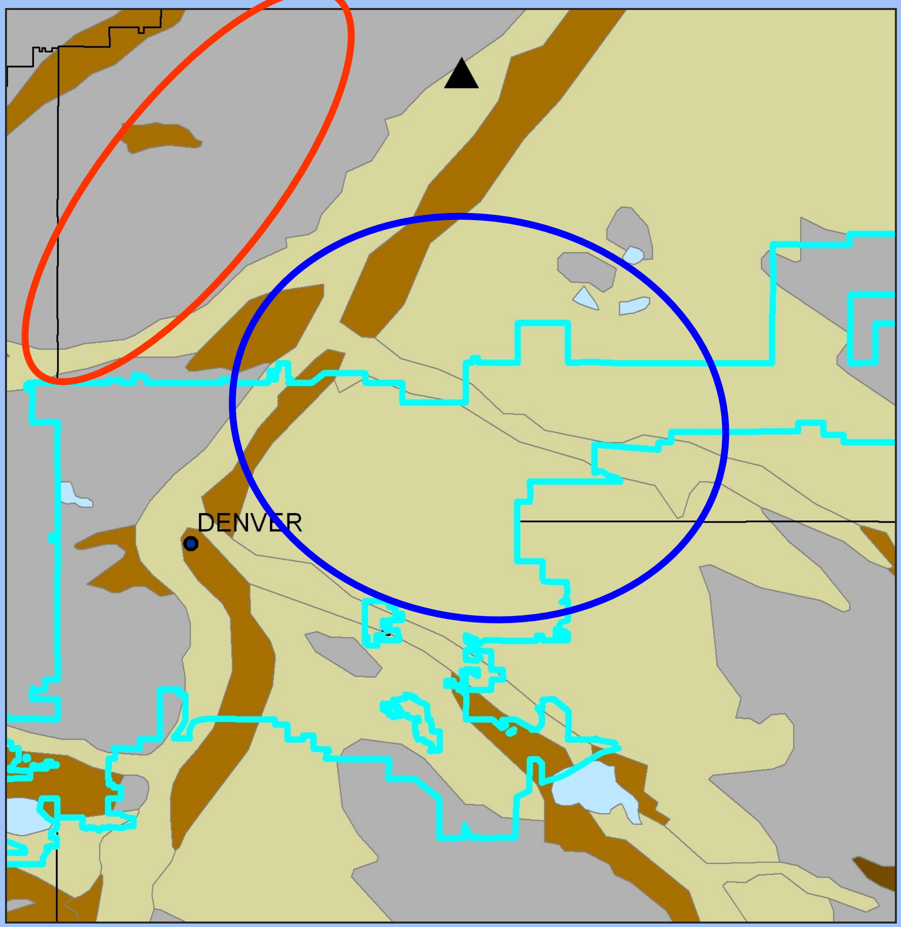

Williams Fork Fault
M 6.75 $ 3.5 billion
Selected Hazus
Scenario Results

Ground motion is highly affected by:

1) Soil Type

Rocky Mountain Arsenal M 6.0
School Functionality





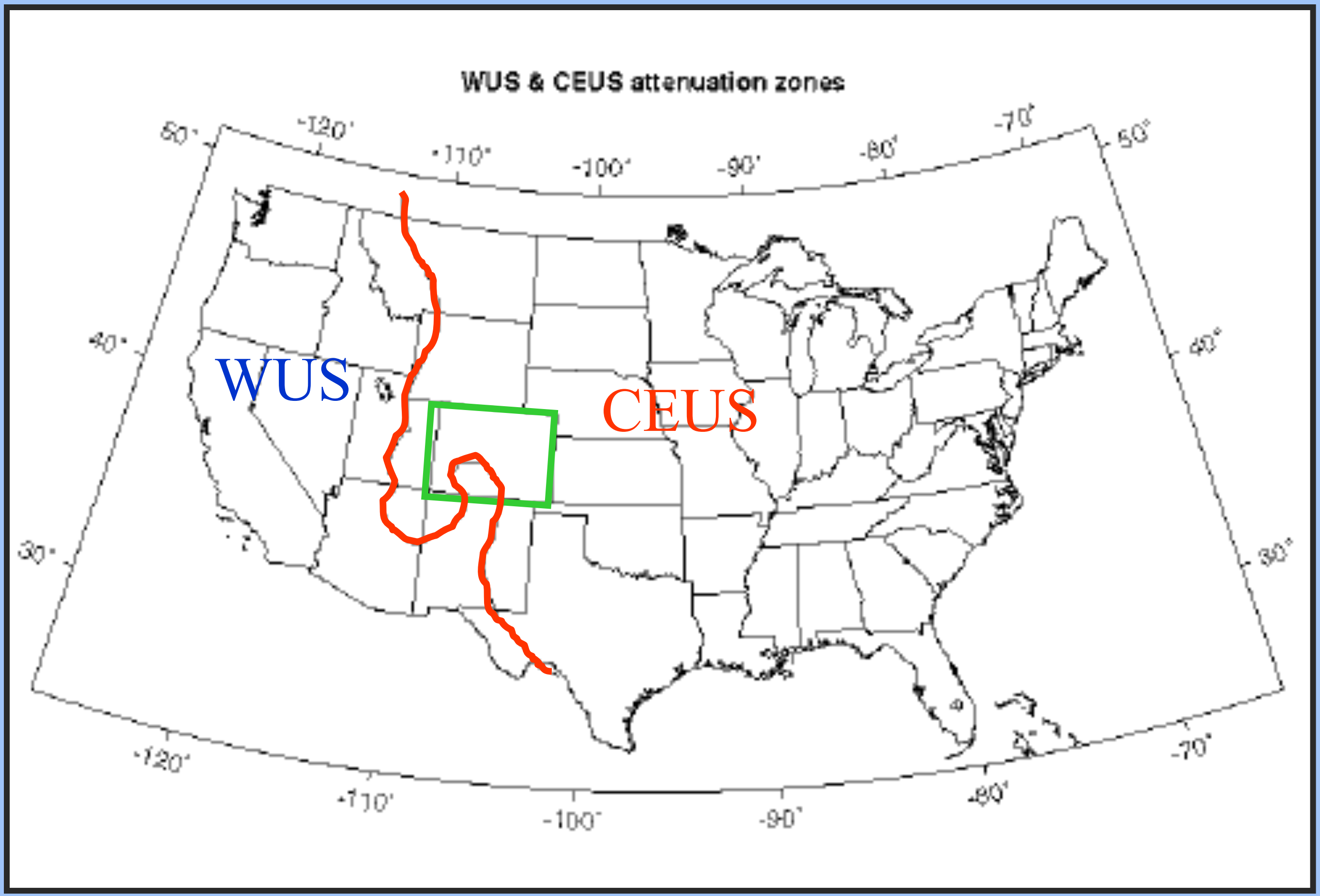
Ground motion is also highly affected by:

1) Soil Type

2) Attenuation Function

- Damping of seismic wave amplitude with distance from epicenter
- Q = 1/attenuation

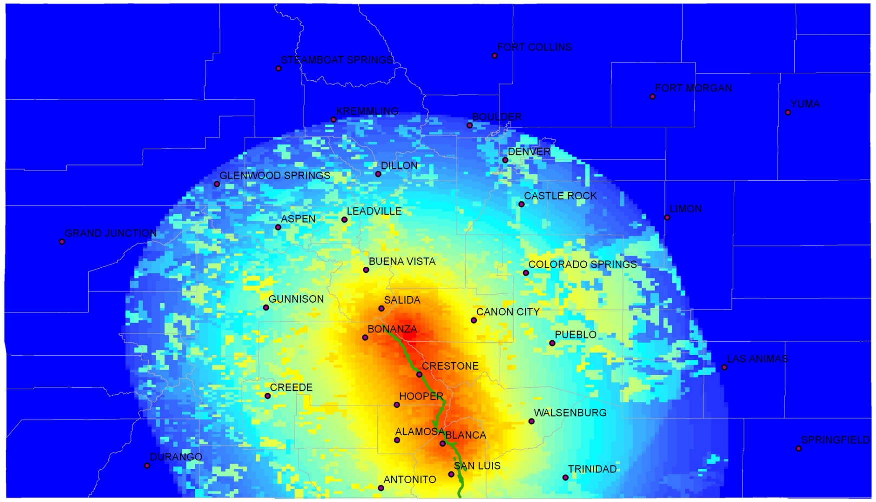
What Q is right for Colorado?



Hazus Economic Loss Results: CEUS = 3 or 4 x WUS

From USGS documentation for 1996 Seismic Hazard Maps

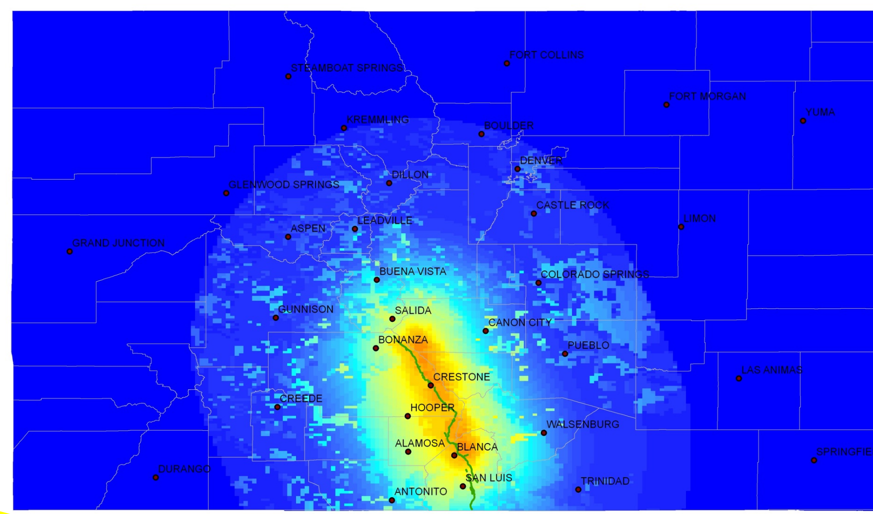
N Sangre de Cristo M7.5 Earthquake
CEUS Attenuation Function



Epicenter 37.9 N, -105.63 W
Fault Strike N19W, Dip 60 W
Maximum PGA = 1.87 g
$8.02 Billion, 335 fatalities

CEUS losses are 10.5 x greater than WUS

N Sangre de Cristo M7.5 Earthquake
WUS Attenuation Function



Epicenter 37.9 N, -105.63 W
Fault Strike N19W, Dip 60 W
Maximum PGA = 0.63 g
$767 Million, 17 fatalities

Improving Results

- Refine and update inventory
  - Add to default inventory
  - Missing utility pipelines and military facilities
- Include liquefaction and landslide maps
- Enlarge radius of ground shaking
- Run multi-state scenarios
- Use most appropriate attenuation function

Mitigation Uses

- Cost-Benefit analysis of retrofitting buildings, structures, and facilities

Specific buildings or entire city or region

Conclusions

- Earthquakes on a number of faults across the state with realistic magnitudes could cause losses of billions of dollars and hundreds of lives.
- Our results emphasize the need to increase the resources available for earthquake research in Colorado to better understand the actual risk and hazard that exists.

THE END

THE END

HAZUS:
Presentations

HAZUS Earthquake Scenarios for Quaternary Faults in Colorado

Matthew Morgan and Lauren Powell,
Colorado Geological Survey

Introduction to Hazus-MH

- FEMA's Risk Assessment Software Program, 2003 edition
- Multi-Hazard: Earthquakes, Floods, Wind
- Produces physical, economic, and social loss estimates
- Tool for government planning – preparedness, mitigation, response, and recovery

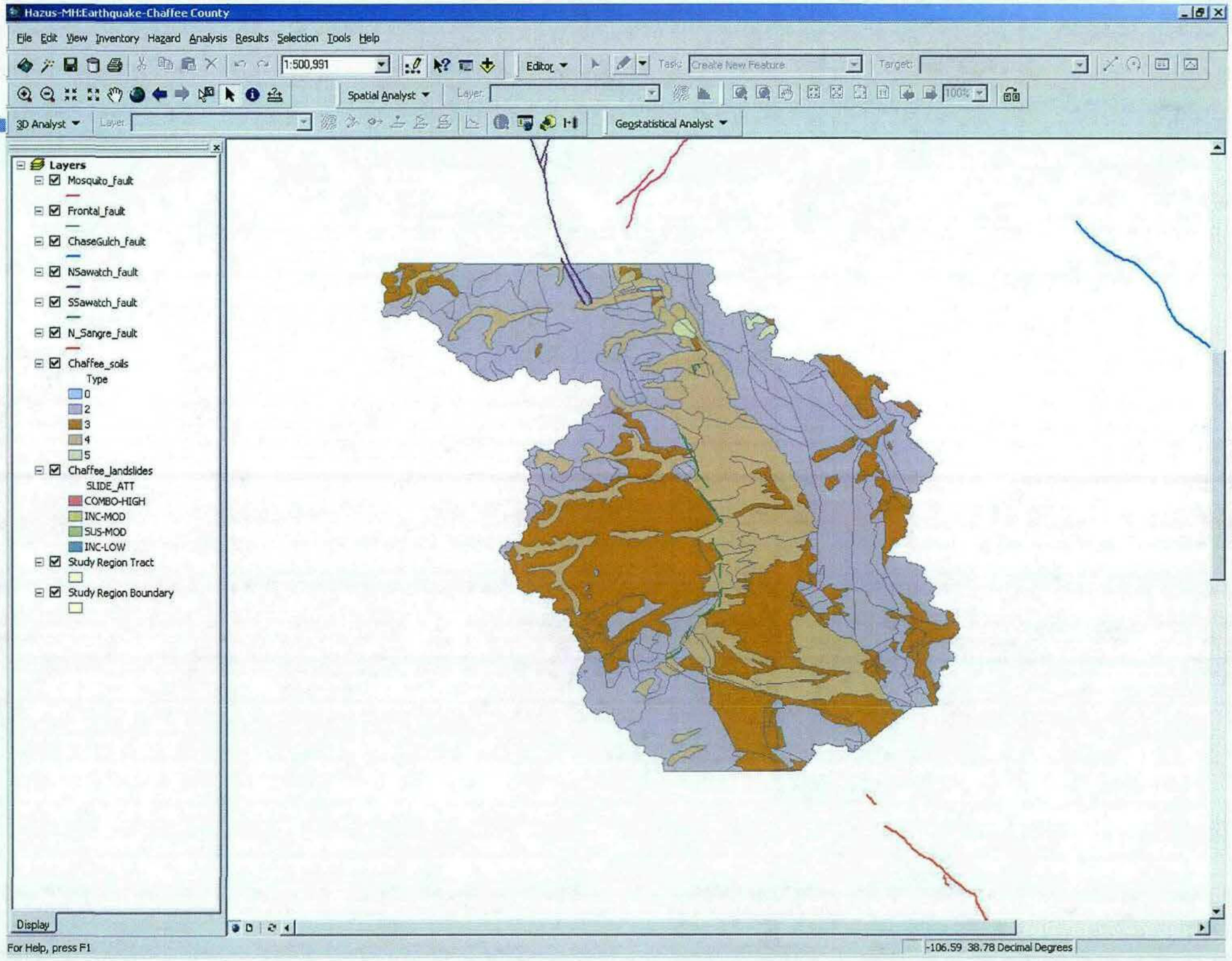
Hazus-MH and GIS

- Coupled with Geographic Information Systems (GIS) technology – ArcView and MapInfo
- Uses national databases including 2000 Census data, building inventories, transportation systems, utilities systems, and critical facilities
- Earthquake model incorporates attenuation functions and ground shaking models used by USGS in 2002 National Seismic Hazard Maps

User-Supplied Information

- Hazard maps
  - soil type
  - landslide susceptibility and incidence
  - liquefaction
- Additional inventory data specific to region
- Fault parameters: epicenter, strike, dip

Study Region Example: Chaffee County



Scenario Types

- Deterministic
  - Specific ‘what if’ situations and results
  - Multiple or single county regions
  - Several earthquake magnitudes for each epicenter
- Probabilistic
  - Probability of earthquake for given region
  - Results for specific time period return and magnitude or annualized results

Loss Estimate Results

- Physical Damage
  - Building, Transportation and Utilities
- Economic Loss
  - Total direct losses
  - Loss ratio = total losses/region inventory x 100
  - Indirect losses due to business interruption
- Social Impacts
  - Casualties at 2am, 2pm and 5pm
  - Displaced households
  - Employment impact
- Mapping
  - Ground shaking per census tract
  - Peak ground velocity or acceleration contours

Estimates are Estimates

- Future earthquakes are surrounded by high level of uncertainty
- Many assumptions and simplifications are inherent in loss estimation methodology

Faults Causing Greatest Economic Loss

1. Golden Fault - $22.08 Billion
2. Rampart Range Fault - $18.26 Billion
3. Ute Pass Fault Zone - $9.77 Billion
4. Frontal Fault - $1.72 Billion
5. Mosquito Fault - $1.52 Billion

Runners up: Walnut Creek and Cheraw

Golden Fault

- M6.5 Counties within 150km radius
  - $22.08 Billion, 719 fatalities, 7.3% loss ratio
- M6.5 Jefferson County
  - $8.14 Billion, 322 fatalities, 21.7% loss ratio
- M6.5 Denver County
  - $4.73 Billion, 164 fatalities, 11.8% loss ratio

Rampart Range Fault

- M7.0 Counties within 150km radius
  - $18.26 Billion, 671 fatalities, 5.7% loss ratio
- El Paso County M7.0
  - $8.15 Billion, 596 fatalities, -23.5% loss ratio
- El Paso County M6.0
  - $830 Million, 12 fatalities, -2.4% loss ratio

Highest Loss Ratio

1. South Sawatch M7.25 Chaffee County – 24.1%
2. Rampart M7.0 El Paso County – 23.5%
3. Golden M6.5 Jefferson County – 21.7%
4. Frontal M7 Summit County – 20.1%
5. Cheraw M7 Otero County – 18.2%

Probabilistic Scenarios

- State-wide scenarios
  - M6.5, 100-year period: $27.0 Million
  - M6.5, 500-year period: $1.5 Billion

HAZUS:
Questions & Communications

Heerschap, Lauren

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]

Sent: Sunday, April 23, 2006 2:59 AM

To: Heerschap, Lauren

Subject: RE: HAZUS wrap-up

Hi Lauren,

It's too bad your leaving CGS now that you know the model so well. Some of the questions have quick answers, but the annualized seems like you found an error. We'll have to see if it is in MR-2. The magnitude driving the event only has a slight impact on duration of shaking that causes a little more damage to URMs and more liquefaction (if a susceptibility map is provided) and does not change the actual ground motions. I think this interface needs to be changed since it confuses users and we should be able to include information from the USGS that the program would use as a default. The return periods are listed when you choose a probabilistic hazard, I can't remember them all off-hand. Landslide should be the next priority for Colorado losses. Were you using just the critical landslides? An immediate proxy could be developed by combining that product with the USGS national map. A better more detailed product can be developed using slope steepness and engineering properties from the geologic map statewide and using more detailed mapping when available. I recall that Matt figured out how to deal with the attenuation function limits. Another way is to ask Dave Wald at the USGS to produce some scenarios for our use and we bring the data in as user supplied.

Thanks,
Doug

From: Heerschap, Lauren [mailto:Lauren.Heerschap@state.co.us]
Sent: Monday, April 17, 2006 12:13 PM
To: Bausch, Douglas
Subject: HAZUS wrap-up

Hi Doug,

The CGS HAZUS computer is dutifully churning out earthquake scenarios once again! I returned to CGS in January as a 6-month temp (my last time, I am sorry to say), this time to complete our inital Hazus scenarios and tie this information together into something meaningful and hopefully useful. It has been a long process, but here's where we stand as of April 2006:

- The MR1 version is working well, and I have re-run most of our Build 31/36 scenarios to create a consistent, updated dataset. I have run state-wide deterministic scenarios for the 18 faults and 2 historical epicenters chosen by Vince at the onset of this project, with state-wide PGA maps for each. I have also run deterministic county scenarios for faults that could cause ground shaking in that county, selecting from those loss estimates one or more "worst-case scenario(s)" for each county. I have also run deterministic "random" earthquakes for each county, using a M6.5 event at an epicenter at the geographic center of the county, to address the uncertainties present in Colorado.

- I am currently supervising a GIS intern from Metro State College who is mapping all of the significant county-level results. Maps include probabilities of damage states for essential facilites, as well as building-related economic losses by census tract.

- The "final product" envisioned by me and Vince is a report that describes why and how CGS has run these earthquake scenarios and summarizes our results, with links to maps and tables. Vince hopes that these scenarios and maps will generate increased awareness and action amongst local governments and planners. If counties are interested in more detailed scenarios with region-specific inventories instead of the default data we have been using, perhaps higher-level Hazus analyses can be done in the future (although I won't be at CGS after June, so someone else will have to learn the ways...).

- Some final issues I am hoping to resolve before I leave:
---Probabilistic scenarios are still fuzzy in my mind in terms of the parameters that drive them. First of all, I tried running an Annualized Loss scenario but it seemed to just import the results from the previous result for the region I was in. Any ideas there? Next, I am wondering why probabilistic scenarios ask for an earthquake magnitude driving the event? This magnitude does not seem to affect results - only the return period does. And could you shed light on the 8 hazard maps that the technical manual says are used for probabilistic scenarios? The manual states that these hazard maps range from 39% probability of exceedance in 50 years (100-year return period) to 2% p.e. in 50 years (2500-year return). What are the specific values in between, and what is the correlation between the percent p.e. and the return period used by Hazus?
---Our importing of landslide maps has never produced any results. This was done several years ago, but I believe we imported a USGS landslide map to which I added a susceptibility field labeled 'type' so Hazus could recognize susceptibility numbers 1-10 I added in. Is there a way to produce meaningful landslide results within the month?
---The radius of ground shaking in the attenuation tables is 200km. Vince has been wondering if it would be possible to extend this radius to 250 or 300 km - is this possible?

As usual, please forward this to Jawhar or Pushpendra or anyone else who might prefer to address those final issues. Thanks for your help throughout this project!

- Lauren
****

Lauren Heerschap
Colorado Geological Survey
1313 Sherman St., Rm. 715
(303)866-3510
****

Heerschap, Lauren

From: Sares, Matt

Sent: Friday, March 03, 2006 10:28 AM

To: Heerschap, Lauren

Subject: FW: Discussion of Earthquake Hazards

Lauren,
Can you respond to TC about this. I expect that you do or will have HAZUS info for Colorado Springs. --Matt

-----Original Message-----
From: Wait, TC
Sent: Friday, March 03, 2006 9:05 AM
To: Berry, Karen; Sares, Matt; Greenman, Celia; Carlson, Jill; Gleason, Andy; White, Jonathan
Cc: Morgan, Matt
Subject: RE: Discussion of Earthquake Hazards

Does anyone know if a similar HAZUS model has been done for the Co Springs faults? I would be interested in seeing that!

TC

-----Original Message-----
From: Berry, Karen
Sent: Wednesday, March 01, 2006 1:18 PM
To: Sares, Matt; Greenman, Celia; Wait, TC; Carlson, Jill; Gleason, Andy; White, Jonathan
Cc: Morgan, Matt
Subject: Discussion of Earthquake Hazards

Dear All:

Every so often, the issue of what CGS should recommend, if anything, when building is proposed on or near a fault surfaces in land use. If I recall correctly, our last discussions resulted in no direction or policy. Again, I am discussing such issues with the City of Lakewood in conjunction with a new subdivision in the Rooney Valley just east of C470 and Morrison. The current filing (land use case) is located adjacent to but not on the approximate location of the Golden Fault.

However, the next filing will be located "on the fault" and the issue will need to be addressed, in particular, a 1977 hazards study done for the city states that commercial and multi-family housing should not be constructed on or near the fault. Of course, these types of uses are proposed.

Below is one of many informal discussions with the city engineering staff, in preparation for the next filing, but serves as a very brief outline on the issue. It is my hope that a discussion of issues and policy can take place, in the next six months or so, and I offer this example as a possible starting point.

"Attached is a FEMA HAZUS model for the Golden fault. It was run by CGS and is based on many assumptions. It is only to be used for very general planning purposes and not for risks on a specific site. Generally, it shows that a "big one" (mag. 6.5) on the fault would result in widespread regional damage. In addition, here are conclusions from a few reports on the fault:

Investigation of Golden Fault, Rocky Flats, Dames and Moore (1981):
-"no compelling evidence for tectonic activity of golden fault was identified."

Robert Kirkam, CGS Report, 1977

It is a complex fault; location is approximate.
-oldest period of movement is 750,000 years ago; youngest is less than 650,000 years, but older than 250,000 years ago.

Scott, USGS, 1970 Report

-concluded last movement is 650,000 years or younger."

Hope this helps.

Karen A. Berry

Karen A. Berry
Geological Engineer, PG, CPESC-SWQ, AICP

Heerschap, Lauren

From: Oliver S Boyd [olboyd@usgs.gov]
Sent: Friday, January 27, 2006 1:38 PM
To: Heerschap, Lauren
Subject: Re: Colorado Q

Hello Lauren,
I did measure attenuation in Colorado, or should I say beneath Colorado (50 to 400 km depth). I do not think the attenuation work I did would be applicable to seismic hazard. It may be worthwhile to look at results from seismology, reflection, refraction, and velocity and attenuation tomography, to determine where CEUS and WUS attenuation relations might be more appropriate. I am not sure what kind of data would be available to calculate an attenuation relationship for Colorado as I'm not sure there have been any recent large earthquakes and significant ground motions. The best person to talk to about the feasibility of attenuation relationships for Colorado would be Art Frankel (afrankel@usgs.gov). I'd be happy to continue this conversation, though my expertise in attenuation relationships is relatively limited.

I am currently working on time-independent and time-dependent seismic hazard in Alaska and related research. The work on Alaska should be done soon.

Oliver

"Heerschap, Lauren"
<Lauren.Heerschap@state.co.us>

01/27/2006 11:01 AM

To <olboyd@usgs.gov>
cc
Subject Colorado Q

Hi Oliver,

Your name was mentioned at a Colorado Earthquake Hazard Mitigation Council meeting this summer, and I remember running into you at the Warren Miller show this past fall. Life's timing is such that I haven't contacted you until now. After an experiment with public school teaching, I've returned to the Colorado Geological Survey and am working on a compilation of earthquake scenarios for the state. An obviously important factor in these scenarios is the attenuation function used. CEUS functions tend to result in damages 3 to 10 times greater than those calculated using WUS functions. To date, I have just used the WUS-CEUS boundary that USGS uses for hazard maps, with most of Colorado in the CEUS zone and only the San Luis Valley in the WUS zone. Was your dissertation related to Q in the Rockies/Colorado? If so, I would be interested in talking with you about a better way to calculate Q in Colorado.

What are you working on at the USGS?

Lauren
(was Lauren Powell at CU)

****

Heerschap, Lauren

From: SETH JACOB WITTKE [WittkeSJ@uwyo.edu]

Sent: Monday, June 06, 2005 8:23 AM

To: Heerschap, Lauren

Subject: RE: Hazus

Lauren,

Sorry it took so long to get back to you, I lost your email in a load of others. As far as the Western or Eastern model attenuation functions I'm pretty sure we used the Eastern models. This was because of the numerous basins in the state, where the majority of the population resides, and the fact that the majority of Wyoming is in the CEUS zone. Unfortunately the boundary is obscure across the entire rocky mountain region. We've really only run the probabilistic scenarios in Hazus MH. I have messed with some other the other models but I haven't really QC'd the results to make they are reasonable. We never got the MR1 version of Hazus to work properly. We spent a good couple of months working with FEMA Region 8 (Doug Bausch and Rich Hansen) as well as PBS&J out of Atlanta to try and get the flood model working but the grant we were working under expired so for now we have given up on the program. We were working with a modified version of Hazus which ran at the block level for both EQ and Flood instead of at the tract level. This caused a lot of new errors and unfortunately the program never ran smoothly for very long. I'm hoping to get the program up and running again, but until we can be assured that the problems we ran into are fixed I'm hesitant to rely on the results of Hazus. If I remember from Jen, you guys are running the stock version which doesn't have the same problems that our version had, and as far as I know provides reasonable results. Feel free to contact me with any other questions.

Seth Wittke
Research Geologist--Hazards Dept.
Wyoming State Geological Survey
(307)-766-2286

-----Original Message-----
From: Heerschap, Lauren [mailto:Lauren.Heerschap@state.co.us]
Sent: Thursday, May 26, 2005 3:19 PM
To: SETH JACOB WITTKE; >; SETH JACOB WITTKE
Subject: Hazus

Hi Seth and Jim,

I am using Hazus-MH at the Colorado Geological Survey to try to better understand our state's potential losses from earthquakes. Vince Matthews suggested I contact you both, since you have used Hazus for scenarios in Wyoming. Looking through piles of old emails, I couldn't tell if Jen McHarge contacted you last summer or fall with similar questions, so I apologize if I am reinventing the wheel. I was here before her last spring and now I am back again, so it has been a challenge to piece together the state of affairs with Colorado Hazus...

A brief overview of where we stand with our Hazus scenarios: We have run over 600 deterministic scenarios for various magnitudes on 18 of our better-documented Quaternary faults. We have done a few probabilistic scenarios as well, and we have made a handful of pretty good statewide PGA maps for many of our deterministic scenarios. Right now I am at a bit of a standstill because I'm in the midst of installing the newer MR1 version of Hazus, along with the necessary GIS bells and whistles. I will probably run most of our 'worst-case' scenarios again in the new version so our results are as accurate and consistent as possible.

The main reason I am contacting you is those tricky attenuation functions. There is a huge discrepancy in results between WUS and CEUS scenarios, sometimes with CEUS losses up to 9x greater than WUS. Most of our state belongs in the CEUS zone, according to the USGS documentation, but it seems like such a drastic difference across an unclear boundary between zones isn't quite accurate. Have you found an attenuation function that is more appropriate for the Rocky Mountain region? How have you resolved this in your scenarios?

Besides the Q issue, I am also curious to know more about what you have done with Hazus in Wyoming. Are you still using it or was it a former project?

I look forward to hearing from you!

Lauren

****
Lauren Heerschap
Geologist
Colorado Geological Survey
1313 Sherman St., 2nd Floor
(303)866-2082
****

Heerschap, Lauren

From: Matthews, Vince
Sent: Friday, May 13, 2005 6:07 PM
To: Heerschap, Lauren
Subject: FW: Sheep Mt. Fault, North Park/Walden area

Lauren,

Please generate an acceleration map with a 6.6 at this epicenter. Also, let's do a 7.1 at both the Piceance and Estes epicentral locations.

Vince

Vincent Matthews
State Geologist
Colorado Geological Survey
1313 Sherman Street, Room 715
Denver CO 80203
Phone: 303-866-3028
FAX: 303-866-4445
Cell: 303882-6580
http://geosurvey.state.co.us

-----Original Message-----
From: Jeff Unruh [mailto:unruh@lettis.com]
Sent: Friday, May 13, 2005 2:18 PM
To: vince.matthews@state.co.us
Subject: Sheep Mt. Fault, North Park/Walden area

Hi Vince,

As we discussed on the phone Wednesday, I reviewed our mapping of the Sheep Mountain fault in North Park to determine the lat and long location of the Quaternary scarp on the fault. The scarp, veg lineaments and springs are concentrated in the area around:

Lat 40° 47.5'

Long 106° 30'

The Sheep Mountain fault is along the base of a mini range of north-south-trending hills that includes Sheep Mountain and Delaney Butte. The full north-south extent of this mini range is about 20 km, but the tectonic-geomorphic features we saw and examined are limited to several km along the base of Sheep Mountain only. I assume that the earthquake(s) that produced the scarp was at least M 6.5 (the rule-of-thumb threshold magnitude for surface-rupturing events).

faults ~ 14 l
strike N19W
dip to E (-60)
type 2 soil
Jackson Co.

I am very curious to know if the Sheep Mountain fault (or something nearby in North Park) is a plausible candidate for the 1882 EQ in Colorado. If someone in your office has the time and is willing to test this hypothesis using your "1882 EQ screening" software, I would be very interested to know the results.

Please keep me on the distribution list for info on the CGS trenches across the Williams Fork Mountains fault this summer. If you folks have a trench party, I'll beg Bill Lettis to let me fly out and look at the fault.

Cheers,

WILLIAM LETTIS & ASSOCIATES, INC.

Heerschap, Lauren

From: Morgan, Matt
Sent: Thursday, May 05, 2005 9:50 AM
To: Heerschap, Lauren
Subject: FW: extracting data from Nat Map

-----Original Message-----
From: Mark D Petersen [mailto:mpetersen@usgs.gov]
Sent: Friday, April 15, 2005 1:06 PM
To: Morgan, Matt
Subject: Re: extracting data from Nat Map

Hi Matt,
\
Nice to hear from you. I hope that all is well with you. We have most of the information on Colorado on our website. It sounds like you are interested in the fault data. You can extract all the faults in Colorado from our database on the website: eqhazmaps.usgs.gov. Let me know if you have any problems. We will shortly have the consensus fault data also available on our website. Another thing that Vince may be thinking about is our ARCIMS server on our website that allows you to choose all of the 1996 fault information.

Please send my regards to Vince.

Take care,

Mark

Mark Petersen

U.S. Geological Survey
phone: (303) 273-8546
fax (303) 273-8600
e-mail: mpetersen@usgs.gov

mailing address: USGS, Denver Federal Center,
MS 966, Box 25046, Denver, CO 80225

USGS office (for overnight deliveries):
1711 Illinois Street, Golden, CO 80401

"Morgan, Matt" <Matt.Morgan@state.co.us> 04/15/2005 10:37 AM

To: "'mpetersen@usgs.gov'" <mpetersen@usgs.gov>
cc:
Subject: extracting data from Nat Map

Hi Mark:
I was talking with Vince Matthews the other day and he mentioned to me that you could "extract data" from the Nat Map for the faults listed for Colorado. He wants data that we can use for HAZUS to run some

scenarios with. Could you shed some let on this for me? Thanks a bunch!

****
Matt Morgan
Geologist
Colorado Geological Survey
1313 Sherman St. #715
Denver, CO 80203 USA
http://geosurvey.state.co.us

Heerschap, Lauren

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Friday, April 29, 2005 2:23 PM
To: 'Heerschap, Lauren'
Subject: RE: new hazus version

Hi Lauren,

Did you get the signature for training okay? Jawhar is one of the trainers and is also one of the main EQ model developers.

I just got back but will look into the attenuation change.

Thanks,
Doug

-----Original Message-----
From: Heerschap, Lauren [mailto:lauren.heerschap@state.co.us]
Sent: Wednesday, April 20, 2005 3:04 PM
To: 'Bausch, Douglas'
Subject: new hazus version

Hi Doug,

Thanks for sending the latest version. I have yet to install it because I am trying to produce some PGA maps with consistent data for Vince. So far so good.

I am curious to know what changes we ought to expect with the new Hazus build. You mentioned that building replacement costs are 10% less. Have inventories changed? Anything else that will change the results we see?

I spent some time comparing the scenarios that Jen, Matt, and I did last year with build 31 and those run with build 36. I did this because I am unable to duplicate results obtained with the older version. I can't put my finger on what is different between the two because the inventories are identical, but some regions show significantly greater damage and economic loss while some show significantly less. The "new" attenuation functions might be behind these changes (meaning they might have changed in more than just their naming), but one would expect results to swing either higher OR lower instead of doing BOTH. This might not be worth investigating since I will probably re-run most of our scenarios anyway in the newest version for consistency's sake. Just an observation...

As far as the EMI training course goes, I am still trying to get the state OEM officer's signature. I faxed an unsigned application to Lillian, so hopefully I will be able to attend.

Lauren

****
Lauren Heerschap
Colorado Geological Survey
1313 Sherman St., 2nd Floor
(303)866-2082
****

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Friday, April 15, 2005 10:09 AM
To: 'Heerschap, Lauren'
Cc: Virgil, Lillian; 'Marilyn Gally'
Subject: RE: hazus training

75-5.pdf

Hi Lauren,

I'm glad you are interested in the Advanced Earthquake course for the work the State Geological Survey is doing supporting OEM. I have cc'd Lillian who is the FEMA course manager and expert in the course logistics. We should get the ball rolling, because I have heard that time is running out.

I have attached the admissions form. As I mentioned the State OEM training officer signature is needed on the form, but I don't have any of her contact information and am hoping Marilyn can help, who I have also cc'd.

Since your work supports the State EM agency and you are a State employee, FEMA reimburses your travel expenses and provides lodging at EMI, as well as transport from the area airports. There is a meal ticket you have to buy, but the course is free. The weather should be nice and Gettysburg is nearby.

Thanks,
Doug

-----Original Message-----
From: Heerschap, Lauren [mailto:lauren.heerschap@state.co.us]
Sent: Friday, April 15, 2005 8:59 AM
To: 'Bausch, Douglas'
Subject: hazus training

Doug,

Thanks for the prompt reply! I am interested in the course, so I'll start filling out the necessary paperwork. Do the covered expenses include airfare and registration?

Lauren

-----Original Message-----
From: Bausch, Douglas [mailto:Douglas.Bausch@dhs.gov]
Sent: Thursday, April 14, 2005 1:53 PM
To: 'Heerschap, Lauren'
Cc: Hansen, Rich; 'Johari, Pushpendra'
Subject: RE: back at CGS

Hi Lauren,

Heerschap, Lauren

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Thursday, April 14, 2005 1:53 PM
To: 'Heerschap, Lauren'
Cc: Hansen, Rich; 'Johari, Pushpendra'
Subject: RE: back at CGS

Hi Lauren,

Welcome back. Weren't you in Europe? I can't recall. The new release that runs in 9.0 is now out. It is optimized (faster) and may solve the overload problems with the contour mapping. My understanding is that the attenuation functions are the same, but it appears the names have been modified and I did not know until now that the fault width is different.

I'll ask Rich to send you the new version with the new State data for CO. The building replacement costs have been adjusted downward by about 10%. I have also cc'd Pushpendra to confirm the attenuation functions are still the same and address why the fault width was changed.

Also we can likely get you into the course described below at our national training center in Maryland if you are interested. All your expenses are reimbursed by FEMA with the exception of the meal ticket ($75). Since this course is considered advanced and will be taught by model developers, I would recommend it for you. The url leads to the application information. You will have to get it signed by the State OEM training officer, as of tomorrow I'm on the road again, but you could work with Marilyn Gally to get the right signatures.

E174 Advanced HAZUS-MH FOR EARTHQUAKE   Dates: May 9 - 12, 2005   Apply now if you want to attend this course.
Provides in-depth instruction on the use of HAZUS-MH for advanced applications related to earthquake loss modeling. Prerequisites: Basic HAZUS-MH and a strong working knowledge of ArcGIS. Further information on national and regional HAZUS deliveries is available at http://www.fema.gov/hazus/tr_main.shtm

Emmitsburg, Maryland
(75 mi. N of D.C.)

Thanks,
Doug

-----Original Message-----
From: Heerschap, Lauren [mailto:lauren.heerschap@state.co.us]
Sent: Thursday, April 14, 2005 1:42 PM
To: 'Douglas.Bausch@dhs.gov'
Subject: back at CGS

L enrollment
Lillian Virgil
(301) 447-1490

Hi Doug,

Jen has moved on, and I am back to work here at CGS attempting to polish up our Hazus scenarios. This is only my second day back, so I am still trying to sort through what was changed and accomplished in my absence. Since we are now using MH build 36 instead of version 31 of last year, what changes can I expect to see in our results? Is there a need to redo important scenarios with the updated version?

I've noticed new attenuation functions and the absence of old ones: Is 'WUS Shallow Crustal Event - Ext' going to yield drastically different results compared to 'Project 2000 - Extensional' that was used for most of our scenarios? For some regions I can duplicate former results, suggesting that the Q factor is similar if not equal. But for other regions, I cannot tweak the scenario to yield equivalent results. What about the new 'CEUS' compared to the old 'Project 2000 East'?

PGA contour mapping has worked for only one scenario so far: Jen might have a secret for doing this, but it seems that Hazus overloads itself as soon as it starts to analyze and create the contours, even when only using a contour grid of 100. 50% of the time I have had to shut down the program because it crashes.

Fault width used to be 17.3 in the older build - now it is 10. What does this really represent? I know that the results are sensitive to this width parameter, so should I stick with the former 17.3 for consistency's sake?

Sorry to bombard you once again with so many questions! Thanks for your help!

Lauren

****
Lauren Heerschap
Colorado Geological Survey
1313 Sherman St., 2nd Floor
(303)866-2082
****

Jen McHarge

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]

Sent: Tuesday, February 01, 2005 11:00 AM

To: Jen McHarge; 'Ivan_Wong@URSCorp.com'

Cc: Hansen, Rich

Subject: RE: Hazus

Hi Jen/Ivan,

Jen, Ivan has significant expertise with attenuation functions, and if he has a chance, it would be great if he could look at this traffic and see if we are off base.

Ivan, We (CGS) are running HAZUS scenarios in Colorado using both CEUS and WUS for comparisons. All the scenarios seem to generate significantly larger losses for CEUS function as expected, with the exception of the El Paso County scenarios in the Colorado Springs area along Quaternary faults (Rampart Range and Ute Pass).

I believe the difference in El Paso is that the sources are very close to most the inventory (Colorado Springs). A way to test this theory is to look at the percent difference at similar distances to the other scenarios, such as a community in eastern El Paso County. But I can't explain why a M6 WUS would be greater than and M6 CEUS event. The PESH chapter of the technical manual (Chapter 4) has some tables that compare the attenuation functions that may be helpful (attached).

We don't have the full SQL server license here so I don't think we can assign the CEUS to Colorado sources, but we can export and import study regions that you have already run. We have migrated to the new HAZUS version (MR-1) and use ArcGIS 9.0, and the 8.3 study regions import fine, but we also can't go backwards. It appears that we would need 8 pre-run study regions from you to investigate the issue.

Jen, I also would not characterize the WUS has underestimating the CEUS has overestimating--more like Colorado is in a transition areas between the two and there is significant uncertainty in which to assign is some areas. However, the losses you are running illustrate the importance in resolving this issue.

I'll be in Florida next week and Utah the week after so hopefully we can work on this, this week. I have also cc'd Rich who can help in my absence.

Thanks,
Doug

→ export scenarios
setup window

-----Original Message-----
From: Jen McHarge [mailto:jmcharge@westerngas.com]
Sent: Tuesday, February 01, 2005 9:43 AM
To: Bausch, Douglas
Subject: Hazus

Hi Doug,
My internship at the Colorado Geological Survey has ended, but I may try and give a presentation on how we used Hazus to assess our level of awareness about earthquake hazards in Colorado. I remembered that CEUS tends to overestimate damage, while WUS tends to underestimate, and the relationship between the two is approximately WUS*3=CEUS.

We had an anomaly in El Paso County where for M6.0 WUS > CEUS, then M6.5 WUS = CEUS, M7.0 CEUS = 2*WUS, then M7.5 was CEUS = 3*WUS. (the magnitude values may not be exactly correct, I am working from memory) Does that make sense? Usually the relationship between CEUS and WUS damage values are fairly consistent, but not in El Paso County's case.

Lauren emailed Push about this oddity, and in the emails that I had to look through, there was never a response. I also emailed him about it, but his response didn't answer my question, instead he re-explained the relationship between WUS and CEUS. So, in order to give an accurate presentation, I feel I need to get to the bottom of this issue.

The state geologist has granted me access to the Hazus software, so I can .ftp all the necessary maps to you or Push and see if you get the same strange results I do. I would really appreciate your help on this. I can make my way over to the CGS someday this week after work and put the maps on the "easy ftp" floodmaps.net website and email you what they are called and when they are available, along with all the parameters necessary to run the program just like I did. Let me know if you want me to do anything different from what I have explained. And I will email you again later this week with all the information you need.
Thanks Doug!

Best Regards,
Jen

Jennifer McHarge
Geological Intern
Western Gas Resources, Inc.
1099 18th Street, Suite 1200
Denver, CO 80202
(303) 450-8431
jmcharge@westerngas.com

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Friday, October 29, 2004 12:16 PM
To: 'pjohari@pbsj.com'
Cc: 'McHarge, Jennifer'; Rich Hansen (E-mail)
Subject: RE: Alternate Landslide map

Hi Push,

We have been able to produce contour maps of ground motion when using user supplied hazard maps, but not PGD contours (we are currently using 36a). Although we see an impact on the losses using our WY, UT and CO ground failure susceptibility maps the contours of PGD is not produced. Do you know for certain that the PGD contours are functional? The other item is that MH is much more finicky than -99 regarding field types in hazard maps and we have to delete any unused attributes that might interfere.

Thanks,
Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Friday, October 29, 2004 10:45 AM
To: Rich Hansen (E-mail)
Cc: Douglas Bausch (E-mail)
Subject: Alternate Landslide map

Hi Rich,
We have been using a second landslide map to help us get a more complete picture of the hazard in Colorado. I uploaded it on the floodmaps site, and called it colton_landslides.zip. Doug helped us get this map into a form that we could use in Hazus, so I believe he has seen it before. We don't use this one as often as the USGS map, but I can't get contours to plot on this one either, so thought you may want to take a look.
Thanks!
<>*<>*<>*<>*<>
Jennifer McHarge
Geologist
Colorado Geological Survey
1313 Sherman St., 2nd Floor
Denver, CO 80203
303-866-2082
jennifer.mcharge@state.co.us

McHarge, Jennifer

From: Hansen, Rich [Rich.Hansen@dhs.gov]
Sent: Thursday, October 28, 2004 5:43 PM
To: Jennifer McHarge (E-mail)
Cc: Bausch, Douglas
Subject: CO Soils

Hi Jennifer,

We were successful in integrating the CO Soils map after cleaning up the data a bit. I've uploaded the CO_Soils.mdb to Floodmaps.net for you to download. There seems to be some additional problems with the Landslide integration and Contour Map production. We'll keep working on that and get back to you tomorrow.

Thanks,
Rich

Follow The Link Below To Download The File
http://www.floodmaps.net/eftp/checkfile.asp?file=CO_Soils.mdb

Sender: rich.hansen@dhs.gov

You can also retrieve the file manually from
http://www.floodmaps.net/eftp/
Retrieve the file:
CO_Soils.mdb
--------------------- End of Message ---------------------

McHarge, Jennifer

From:	Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent:	Monday, October 25, 2004 4:05 PM
To:	'McHarge, Jennifer'
Cc:	Hansen, Rich
Subject:	RE: Hazus build 36

Yes. Let's try it with the exact same files. They can be uploaded for us at www.floodmaps.net. Just zip them down first. Thanks, Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Monday, October 25, 2004 4:02 PM
To: Douglas Bausch (E-mail)
Subject: Hazus build 36

We have Hazus-MH MR1 Release 36. Would it be helpful to have the same data maps (soils and landslide) that we are using. They are faily large files (47,000 KB), but Matt said that you might have an address or website for me to send them if you need them.
Let me know, thanks Doug.
<>*<>*<>*<>*<>

Jennifer McHarge
Geologist
Colorado Geological Survey
1313 Sherman St., 2nd Floor
Denver, CO 80203
303-866-2082
jennifer.mcharge@state.co.us

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Monday, October 25, 2004 3:26 PM
To: 'McHarge, Jennifer'
Subject: RE: PGA Values for deterministic scenarios

elpasocontours.pdf

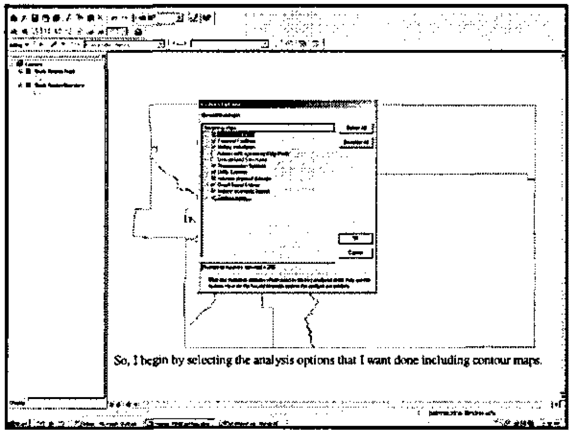
Hi Jennifer, Thanks for preparing the clear steps. I tested both an arbitrary and source event before responding this morning (source is attached). I ran into similar errors as you with build 35 but not 36a. Which are you running? I also did not test with the soils or landslide input, but did some WY runs that produced the contours fine. Please let me know which build you are running, and I will do a test with the soils and landslide data. Thanks, Doug

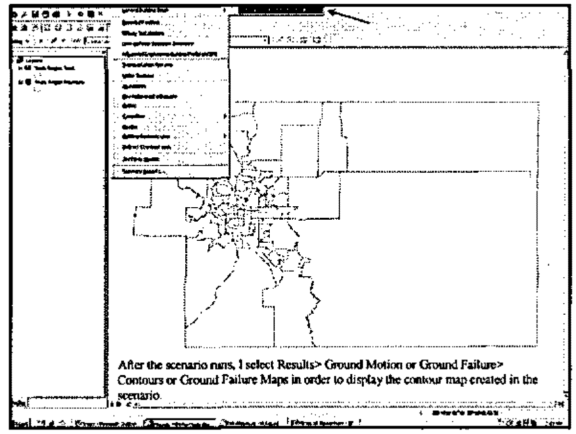
-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Monday, October 25, 2004 2:39 PM
To: 'Bausch, Douglas'
Subject: RE: PGA Values for deterministic scenarios

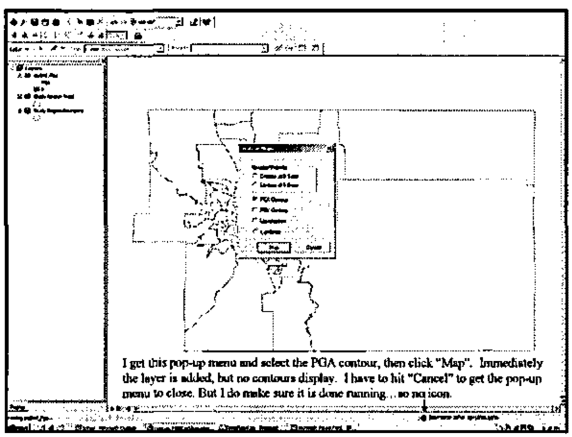
Doug,
I am having some problems getting the contours to show up on my maps. I am attaching an annotated powerpoint of the steps I took to get the contours to work. Would you please review it and enlighten me on the correct procedure, I am obviously doing something wrong!
Thanks so much for your time!
Jen

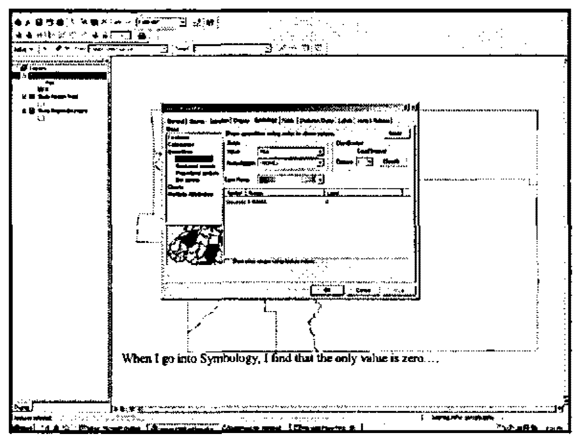
<>*<>*<>*<>*<>
Jennifer McHarge
Geologist
Colorado Geological Survey
1313 Sherman St., 2nd Floor
Denver, CO 80203
303-866-2082
jennifer.mcharge@state.co.us

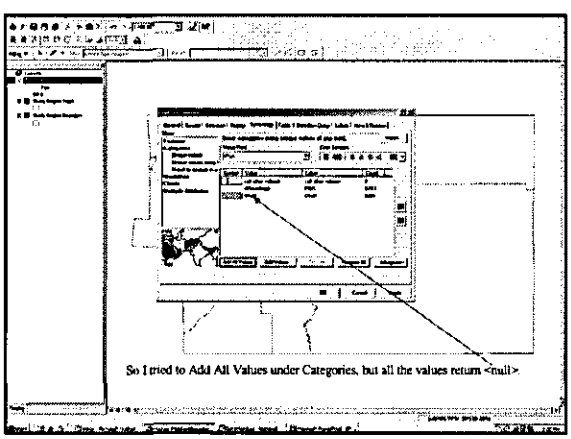
"Contours not plotting": ppt to Doug. Bausch
10/25/04

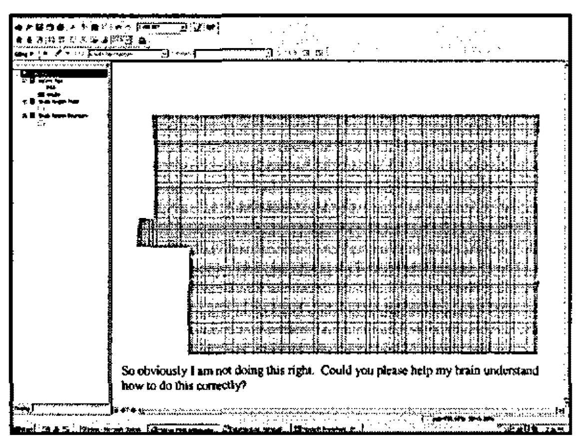


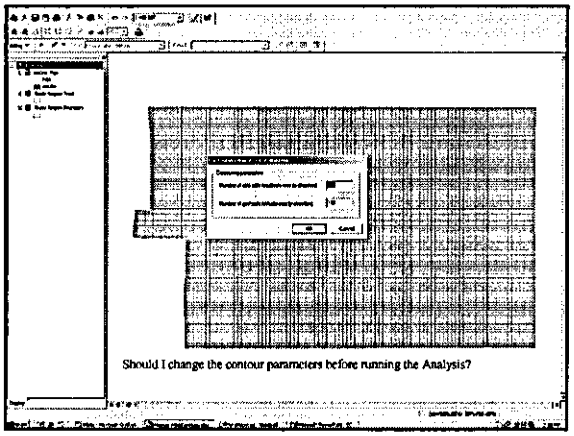











Should I change the contour parameters before running the Analysis?

* Probablistic ~~attenuation~~ WUS faults (Far West Wyo)

Confrence w/ JIM CASE

WUS | → CEUS

front range

strike-slip in eastern Wyo (diff. erosion fault line scarp)
40 mi 10-12 ft high
trend?

* N. Albany Co. 1984-85 large felt area
Lander, Wyo → problem SE fault system
Wind River Range (run both WUS-CEUS)
more weight

Individual faults: manually - hand calc.
applied series of attenuation functions
- loss ratios
- building damages

2500yr map at block level vs ~~tract~~ tract level
↑ census block
↑ census tract
1/2 day - 1 1/2 days

soils.lyr = Colorado soils (surfical features / deposits)
landslides.lyr = digitized ~~so~~ many
↳ attached 10 ~ ended up w/ some decreases

Basin & Range meeting: Teton Co. - acceleration values
many areas that a=0, wrong!
used by Hazus,
large church were
wrong!

modify ↓ 35-
W → build 36

* single building analysis
NOT WORKING!

User-defined ~ added in specific building specs

- acceleration values region folder
- region > geodatabase > USGS > acceleration w/in

PGA
PGV > bring into Arc & be mapped

perimeter 0's in grid = no accele.

Small tracts? - old build = bogus accel. values

By hand?:

- attenuation functions that were applicable
- Campbell & Art Frankel
- strike & dip ~~Esome~~ estimated at times - estimated most shallow rupture
- rupture depth - played with

GET BUILD 35 - 36?

Build 31 vs Build 36 building dataset the same? or better?

check building data bases → block WYO, tract CO

critical & essential facilities → ✓

~~✓~~ potential damage to state buildings.

on mitigation plan.

specific buildings = user-defined structures
building import tool

what build? → ~~[illegible]~~ 36

HAZUS →
moving building locations & shifting peak ground accel. → E. Wyo → Teton

★ print out PGA maps } look at, check data.
PGV

#census tracts HAZUS is using?

Call Sim Case after 1 week we get new build & run

loss RATIOS. ~ annualized loss, range of ratios wasn't right

Fema online
382-2

→ manual calculations → compare.

TO MAP PGA & PGV data:

open any region: Then add data from

C:\ ~~Program~~ Program files\Hazus-~~MH~~

open The folder for region that you opened in Hazus

open USGS database

add usgs shapefile!

use symbology to map PGA & V values
↳ quantities

Jim Questions (Wyo Geo Survey)

Done
- magnitudes for probabilistic scenarios (changes)
- annualized loss → won't run (crashes)
- El Paso county anomaly

new JIM CASE!
- Converting 1882 Hist. Intensity maps to accelerations (Ivan Wong)
- then, importing the acceleration map as an attenuation (Q) function
  may not be precise & accurate

→ 1882 Hist. NE trend vs. NW trend
503 – 881. $~~\$~~617 → $630 is difference true or an artifact of program.
– 1139

Specific Scenarios!
N Sangre 6.5 Denver county WUS = no damage — shaking supposed to be longer & hence higher return period.
" " " CEUS = $~5 million
" 7.0 " WUS = $~8 million
7.0 CEUS = $89 million

EQ sucept. => cutoff 150km in Hazus program could not be edited.

- RUN EQ scenarios
  - update all forms for each scen.

- Water well data
  - input?
- soil survey data

will help
Ivan Wong - URS
B. of Recl.
convert Intensities to accel.

1. 1882 Itensity map convert to accel
   how to talk to Ivan

Cheraw
N Sangre
N & S Sawatch

data beyond 150 km

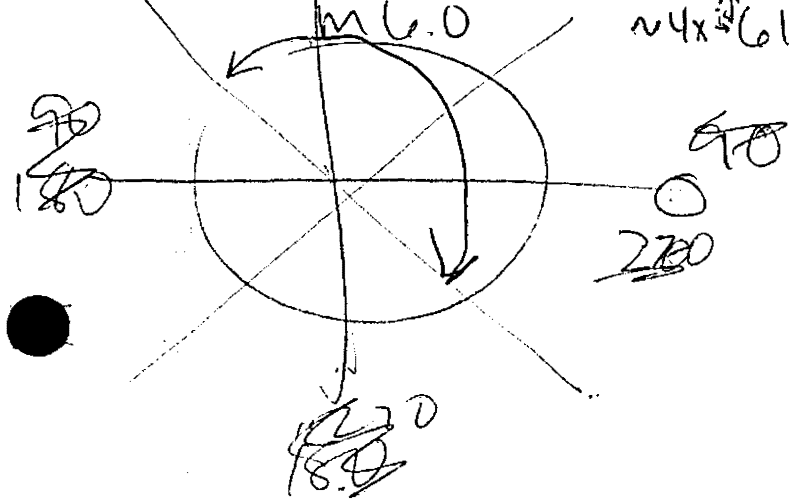
- tells physical properties

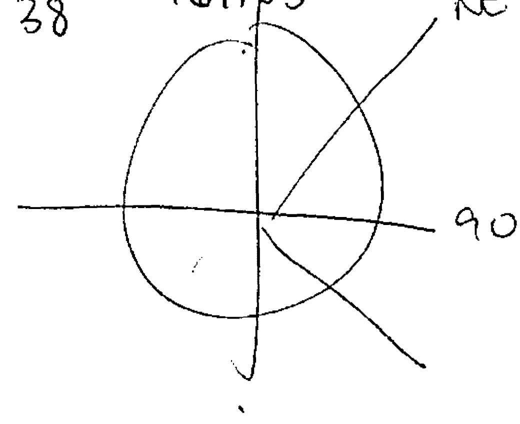
2. extracting from Nat'l hazard map.

	7	2839.48
CEUS	6.5	901.41 ~ 3.1
	6.0	280.81 ~x3.2

Rampart · Douglas Co

	M7	906.53	-675.62
WUS	M6.5	~ 4x → 230.91	0
	M6.0	~4x 61.38	-169.53





McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Monday, October 25, 2004 11:55 AM
To: 'McHarge, Jennifer'
Subject: RE: PGA Values for deterministic scenarios

Hi Jennifer, That should be an easy one. You just have to select contour maps for your run. They are only produced for looks since the actual analysis is either determining the ground motions at specific sites or the census tract centroid. You can also change the contour density under analysis>parameters>contours but it can slow down the analysis and create a very large file. The source will be in your study region folder: RegionBndry.mdb Feature Class: eqGrid, and can be mapped within the program under results>ground shaking maps. With this option you should also get a product that displays contours of permanent ground deformation in inches from the landslide susceptibility map. Thanks, Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Monday, October 25, 2004 10:16 AM
To: Douglas Bausch (E-mail)
Subject: PGA Values for deterministic scenarios

Hi Doug,

I hope all is well with you. I really appreciate all of your help and work you have done for us at the CGS. I feel like you work really hard for us

and it certainly doesn't go un-noticed! I have run across another question for you regarding the mapping of PGA and PGV vales for deterministic

scenarios. I have been in contact with Seth Wittke of the Wyoming Geological Survey. He helped me to map the PGA and PGV values for the 100-

2500yr probabilistic earthquake events. This was done by adding the USGS shapefile, in the USGS database, in the folder of the region of interest, in

the Hazus-MH folder. When you symbolize the shapefile by quantities, it gives you the 100-2500yr PGA and PGV values for that region.

For each deterministic scenario, the probability of the event occurring is 100%. We are telling Hazus that it has occurred (right?). Hazus must then

create specific PGA and PGV values for that scenario. Where does Hazus store that data? Is it something that we can map like the probabilistic data?

Basically we are trying to get a visual representation of the peak ground acceleration values for a deterministic event. Any suggestions?

<>*<>*<>*<>*<>
Jennifer McHarge
Geologist
Colorado Geological Survey
1313 Sherman St., 2nd Floor
Denver, CO 80203
303-866-2082
jennifer.mcharge@state.co.us

McHarge, Jennifer

From: McHarge, Jennifer
Sent: Tuesday, September 21, 2004 12:30 PM
To: Douglas Bausch (E-mail)
Subject: CGS Hazus Question

Hi Doug,
I apologize for my sparatic communication, (my email computer is also the "mapping" machine, and I fall to the bottom of the list of users when mapping geologists come in....)

To revisit the probabilistic scenario issue: I ran the 2500yr event for the state with and without the maps for magnitudes 5 and 7.

Scenario	**Total Damage** (millions)
M5 2500yr w/maps:	$13,209.83
M5 2500yr no maps:	$13,405.10
M7 2500yr w/maps:	$13,205.12
M7 2500yr no maps:	$13,404.88

There is a slight change with each scenario, so I believe it is working correctly, it was just too small of a change for me to see in the 100 and 500yr events.

I have also been trying to run the annualized loss for the state of Colorado without success. The first time, I let the program run for 7 days, before I decided that it was no longer responding. I have tried to run it everyday since (about 8 days) and it continues to crash and stop responding. This may have nothing to do with the program, possibly just the machine its running on. Have you had any issues with computing the annualized loss? Does it really take over 7 days to run or is my computer not tough enough?

My last question is the same as one Lauren asked a while back about the central-eastern US attenuation function generating results with 2-4 times greater damage than the western US function. This seems to hold true for most of the scenarios, except for the scenarios for the Rampart Range and Ute Pass faults in El Paso County.

Scenario	**Qualitative Damage Comparison**
M7 CEUS damage	= (1/2)*(M7 WUS damage)
M6.5 CEUS damage	= M6.5 WUS damage
M6 CEUS damage	= 2*(M6 WUS damage)
M5.5 CEUS damage	= 3*(M5.5 WUS damage)

I am still uncertain what is going on with these results. Any ideas?

Thanks so much for your time, if it's not too much trouble, could you copy your response to: jen_mcharge@hotmail.com, that way I can get back to you promptly.

Jennifer McHarge
jennifer.mcharge@state.co.us
Colorado Geological Survey
1313 Sherman St.
Denver, CO 80203
(303) 866-2082

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Friday, September 24, 2004 5:43 PM
To: 'McHarge, Jennifer'
Cc: 'jen_mcharge@hotmail.com'
Subject: RE: Hazus

annualized_loss.pdf

Hi Jennifer,

We were able to run annualized on the State in 3:40 (w-out the landslide map), I have attached our results by County. Please let me know if it continues not to work for you. Another option might be to run just the 2,500 year event. It provides a good way to prioritize jurisdictions and provides additional results than annualized.

Thanks,
Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Wednesday, September 22, 2004 11:19 AM
To: Douglas Bausch (E-mail)
Subject: Hazus

Hi Doug,
I just found another stack of emails that Lauren saved for me and it looks like you forwarded the question about El Paso county CEUS and WUS to Jawhar and Pushpendra. Pushpendra answered:

"In general the Question is why the results from CEUS attenuation did not grow with the same magnitude at the same proportion as the WUS attenuation function. The answer lies in the way the Ground Motion attenuates between WUS and CEUS. The long period of ground motion is much higher in WUS for higher return periods than for CEUS. That is why as the magnitude increases the damage increases more in WUS than CEUS."

We have found that, in general, WUS damages are 2-4 times less than damages in EQ of the same magnitude using CEUS. For example:
Rampart Range Fault; Douglas County

	CEUS damages	WUS damages (in millions of dollars)
M7.0	$2,839.48	$906.53
M6.5	$901.41	$230.91
M6.0	$280.81	$61.38

While the damage increases with magnitude at a higher rate in the WUS function than the CEUS function,
(i.e. M6.5 WUS $230 ~ four times greater monetary damage than M6.0 WUS $61 and M6.5 CEUS $901 is only three times greater monetary damage than M6.0 CEUS $280), the CEUS function causes greater monetary loss than WUS in equivalent scenarios.

This generalization seem to hold true in most of our scenarios, except for the Rampart Range Fault in El Paso County, which I explained in the previous email.

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Thursday, September 23, 2004 4:54 PM
To: 'McHarge, Jennifer'
Cc: 'jen_mcharge@hotmail.com'
Subject: RE: CGS Hazus Question

Hi Jennifer, I'll launch annualized for the State before I leave today. Could you double check the El Paso issue that all the parameter (magnitude, etc.) are the same with the CEUS and WUS comparison? I can't think of a reason there would be an issue with one county. If you still see the discrepancy, we should call Push (770) 933-0280 x. 758. I'm only back in town tomorrow. So I hope to touch base before leaving again. Thanks, Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Tuesday, September 21, 2004 12:30 PM
To: Douglas Bausch (E-mail)
Subject: CGS Hazus Question

Hi Doug,
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There is a slight change with each scenario, so I believe it is working correctly, it was just too small of a change for me to see in the 100 and 500yr events.

I have also been trying to run the annualized loss for the state of Colorado without success. The first time, I let the program run for 7 days, before I decided that it was no longer responding. I have tried to run it everyday since (about 8 days) and it continues to crash and stop responding. This may have nothing to do with the program, possibly just the machine its running on. Have you had any issues with computing the annualized loss? Does it really take over 7 days to run or is my computer not tough enough?

My last question is the same as one Lauren asked a while back about the central-eastern US attenuation function generating results with 2-4 times greater damage than the western US function. This seems to hold true for most of the scenarios, except for the scenarios for the Rampart Range and Ute Pass faults in El Paso County.

Scenario	Qualitative Damage Comparison
M7 CEUS damage	= (1/2)*(M7 WUS damage)
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M6 CEUS damage	= 2*(M6 WUS damage)
M5.5 CEUS damage	= 3*(M5.5 WUS damage)

I am still uncertain what is going on with these results. Any ideas?

Thanks so much for your time, if it's not too much trouble, could you copy your response to: jen_mcharge@hotmail.com, that way I can get back to you promptly.

So, my question is not why don't WUS and CEUS change with magnitude at the same rate because I understand that the Ground Motion is higher for the long period with higher return period in WUS than CEUS, but I don't understand why then our CEUS damages are higher everywhere except for the El Paso county scenarios. What do you think?

Jennifer McHarge
jennifer.mcharge@state.co.us
Colorado Geological Survey
1313 Sherman St.
Denver, CO 80203
(303) 866-2082

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Thursday, September 23, 2004 4:31 PM
To: 'McHarge, Jennifer'
Subject: RE: Hazus

Hi Jennifer,

You should always have greater losses for scenarios using CEUS functions rather than WUS. I think Push missed that part of the question. Are you certain that the CEUS function is being assigned and that all the other parameters (magnitude, etc.) are the same for the El Paso region? I don't have SQL here to duplicate your work, but if you could double check and if you find the same results we should give Push a call. I'm again leaving town this weekend, so would need to hear from you by Friday COB.

Thanks,
Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Wednesday, September 22, 2004 11:19 AM
To: Douglas Bausch (E-mail)
Subject: Hazus

Hi Doug,
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"In general the Question is why the results from CEUS attenuation did not grow with the same magnitude at the same proportion as the WUS attenuation function. The answer lies in the way the Ground Motion attenuates between WUS and CEUS. The long period of ground motion is much higher in WUS for higher return periods than for CEUS. That is why as the magnitude increases the damage increases more in WUS than CEUS."

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could you copy your response to: jen_mcharge@hotmail.com, that way I can get back to you promptly.

Jennifer McHarge
jennifer.mcharge@state.co.us
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Denver, CO 80203
(303) 866-2082

McHarge, Jennifer

From: Matthews, Vince
Sent: Wednesday, September 08, 2004 9:52 AM
To: Morgan, Matt; McHarge, Jennifer
Subject: FW: [SHMONet] EQ Hazard Analysis - State Buildings

Jim is a very dedicated geologist with WGS who has worked with HAZUS and the hazard maps a lot. He could be a great asset/ally for us. Let's get a list of questions for him. And then we can make a call from my office and vacuum his brain.

Vince

Vincent Matthews
Colorado State Geologist and Director
Colorado Geological Survey
1313 Sherman Street #715
Denver CO 80203
Phone: 303-866-3028
FAX: 303-866-4445
Mobile: 303-882-6580
http://geosurvey.state.co.us

-----Original Message-----
From: Marilyn Gally [mailto:Marilyn.Gally@state.co.us]
Sent: Wednesday, September 08, 2004 9:16 AM
To: vince.matthews@state.co.us
Subject: Fwd: [SHMONet] EQ Hazard Analysis - State Buildings

FYI.

>>> pbersi@state.wy.us 9/1/2004 3:47:46 PM >>>
** High Priority **

Dear fellow SHMOs:

Have any of you used HAZUS-MH to calculate building damage for individual state buildings? Please advise if you have. If so, we discovered an error in how HAZUS-MH is calculating damage for individual buildings. Comparing HAZUS-MH data with data in FEMA's Pub 386-2, Chapter 4, Building Damage Table, you come up with significantly different estimates. It appears the figures will have to be re-worked by hand until HAZUS-MH is corrected. If you have questions or comments, please contact Jim Case at Wyoming State Geological Survey. His phone number is 307-766-2286, Ext. 225. E-mail: jcase@uwyo.edu.

Thanks for your assistance.

Pat Bersie
All-Hazards Planner
Plans Division
Emergency Management Agency
WY Office of Homeland Security
Phone: 307-777-4917
FAX: 307-635-6017

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Friday, August 20, 2004 10:15 AM
To: 'Johari, Pushpendra '; "Bausch, Douglas ' '
Cc: '"McHarge, Jennifer' ' '
Subject: RE: CGS Hazus Question

Thanks Push, Before I left, I tried a probabilistic run with and without the landslide susceptibility map and saw no change. The same map used in deterministic scenarios does result in damages. Could there be a problem with the probabilistic scenarios seeing user supplied hazard maps? Doug

Y/n → change Landslide maps = same results

-----Original Message-----
From: Johari, Pushpendra
To: 'Bausch, Douglas '
Cc: ''McHarge, Jennifer' '
Sent: 8/19/04 12:19 PM
Subject: RE: CGS Hazus Question

HI Dough,

I have been in touch with Jennifer on this. She is using default conditions
for Ground failure that's where the maximum effect comes from. The only other place magnitude is used in identifying the earthquake duration. This
effects a paramerter in the building capacity curve, I think either fraction
or kappa. I am not sure how this will affect the damage state probabilities.

At this point I would like you to compare the damage state probabilities from the GBS\Damage State Probabilities dialog and also from the table eqTractDsBt that get saved to the study region sql server database. My guess
is they will be different but the difference will be very minor. That is why
its not reflecting in Losses and Casualties.

As far as our testing indicates all these parameters have been thoroughly
checked and the implementation is picking the correct values for the capacity curve based on the duration. Its possible that the change is so minor that it's not visible in the 2 decimal places of the damage state probabilities.

I will be back in office on Aug 24th and will look into this as will let you
know whatever I find out. In the mean time please let me know the region that is being used so that I test it on the same region.

While I am here I will try to test this on a couple of regions for which I
have data and will try to reproduce this.

Thanks,

Pushpendra.

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Wednesday, August 18, 2004 3:05 PM
To: 'McHarge, Jennifer'
Subject: RE: CGS Hazus Question

Thanks Jennifer, It could be that the contribution is also very minor at low levels of ground motion. Have you seen the same issues for the 2,500 year event? Or have you tried probabilistic without a landslide map to see if it is being used correctly? I'll take a look if I get a chance, but I'm heading to Florida in the morning. Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Wednesday, August 18, 2004 2:00 PM
To: 'Bausch, Douglas'
Subject: RE: CGS Hazus Question

Hi Doug,
We have incorporated the new (Colton) landslide data, and have seen a slight decrease in total economic loss with the Colton data verses the USGS landslide map in some of the deterministic scenarios. There has been no change in the probabilistic results. I also emailed Pushpendra around the same time I emailed you and he wrote:

"In case of Probabilistic scenario, the effect of magnitude could be noticed only if you have specified Liquefaction/landslide susceptibility maps. In other words in case of probabilistic scenario the magnitude is used to only in the calculation of Ground Failure values. SO if you are using the default conditions, that assume no liquefaction/landslide, then there will not be any difference in the results."

I still think that there should be some change because we are using specified landslide maps, and you would think that at higher eq magnitudes, landslides would be more widespread and damaging, hence a higher total economic loss with increasing magnitudes.

Let me know what you find out.
Thanks,
Jennifer McHarge
CGS
303-866-2082

Scenarios to try:
(1) State 2500 yr M5
M7
(2) with & w/o landslide maps] Doug tried w/ no change

Hi Jennifer,

The magnitudes requested is considered the "driving magnitude" of the probabilistic hazard (eg. the event considered most likely) The USGS national map website will let you deaggregate the hazard and determine the driving magnitude. What it does is change the duration of ground shaking and increases liquefaction probability if you have a liquefaction

.McHarge, Jennifer

From: Johari, Pushpendra [PJohari@pbsj.com]
Sent: Thursday, August 19, 2004 10:20 AM
To: 'Bausch, Douglas '
Cc: "McHarge, Jennifer' '
Subject: RE: CGS Hazus Question

HI Dough,

I have been in touch with Jennifer on this. She is using default conditions for Ground failure that's where the maximum effect comes from. The only other place magnitude is used in identifying the earthquake duration. This effects a paramerter in the building capacity curve, I think either fraction or kappa. I am not sure how this will affect the damage state probabilities.

At this point I would like you to compare the damage state probabilities from the GBS\Damage State Probabilities dialog and also from the table eqTractDsBt that get saved to the study region sql server database. My guess is they will be different but the difference will be very minor. That is why its not reflecting in Losses and Casualties. should be very small change 0.0001?

As far as our testing indicates all these parameters have been thoroughly checked and the implementation is picking the correct values for the capacity curve based on the duration. Its possible that the change is so minor that it's not visible in the 2 decimal places of the damage state probabilities.

I will be back in office on Aug 24th and will look into this as will let you know whatever I find out. In the mean time please let me know the region that is being used so that I test it on the same region. entire state of Colorado

While I am here I will try to test this on a couple of regions for which I have data and will try to reproduce this.

Thanks,

Pushpendra.

McHarge, Jennifer

From: Johari, Pushpendra [PJohari@pbsj.com]
Sent: Monday, August 09, 2004 8:26 PM
To: 'McHarge, Jennifer '
Subject: RE: CGS Hazus Questions

Hello Jennifer,

In case of Probabilistic scenario, the effect of magnitude could be noticed only if you have specified Liquefaction/landslide suscpetability maps. In other words in case of probabilistic scenairo the magnitude is used to only in the calculation of Ground Failure values. SO if you are using the default conditions, that assume no liquefaction/landslide, then there will not be any difference in the results.

Thanks,

Pushpendra.

-----Original Message-----
From: McHarge, Jennifer
To: 'PJohari@pbsj.com'
Sent: 8/9/04 10:28 AM
Subject: CGS Hazus Questions

Hi Pushpendra,
My name is Jennifer McHarge and I have been finishing up Lauren's work on
the Hazus program here at the Colorado Geological Survey. I have just begun
running the probabilistic scenarios for the entire state, and I have run into a snag. The probabilistic 100-yr scenario has been run at magnitudes
5.0 to 7.0 and every scenario I run on the entire state returns the exact
same results. (same number of casualties and total damages).
I am sure I don't have as firm of a grasp as Lauren had on the Hazus program, so maybe I 'm doing something really simple wrong, or maybe I shouldn't run the state as a whole? Any assistance or advice that you have
about this problem would be greatly appreciated.
Thanks,
Jennifer McHarge
jennifer.mcharge@state.co.us
Colorado Geological Survey
1313 Sherman St.
Denver, CO 80203
(303) 866-2082

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Wednesday, August 18, 2004 10:41 AM
To: 'Johari, Pushpendra'
Cc: 'McHarge, Jennifer'
Subject: RE: CGS Hazus Question

Hi Push,

Jennifer from the Colorado Geological Survey pointed out an issue that when changing the driving magnitude for a probabilistic event the losses don't change. I was able to replicate her findings using Build 36a for the 100-year probabilistic event for a statewide study region with driving magnitudes of 5 and 8. We see no change in the building losses or casualties. I know the effect is relatively minor, but we don't think it is working at all. Could you please take a look? If you are unable to fix it right away, could you let us know what magnitude it is defaulting to for the probabilistic events?

Thanks,
Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Monday, August 09, 2004 9:22 AM
To: 'Douglas.Bausch@dhs.gov'
Subject: CGS Hazus Question

Hi Doug,
My name is Jennifer McHarge and I have been finishing up Lauren's work on the Hazus program. I have just begun running the probabilistic scenarios for the entire state, and I have run into a snag. The probabilistic 100-yr scenario has been run at magnitudes 5.0 to 7.0 and every scenario I run on the entire state returns the exact same results. (same number of casualties and total damages).
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jennifer.mcharge@state.co.us
Colorado Geological Survey
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Denver, CO 80203
(303) 866-2082

McHarge, Jennifer

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Tuesday, August 17, 2004 11:01 AM
To: 'McHarge, Jennifer'
Subject: RE: CGS Hazus Question

Hi Jennifer,

The magnitudes requested is considered the "driving magnitude" of the probabilistic hazard (eg. the event considered most likely) The USGS national map website will let you deaggregate the hazard and determine the driving magnitude. What it does is change the duration of ground shaking and increases liquefaction probability if you have a liquefaction susceptibility map. In addition, it should introduce some additional building damage to vulnerable buildings such as Unreinforced Masonry. So there should be at least slight differences, especially when changing the magnitude so much. I'll try it here and see if I get the same results.

Have you been able to incorporate the landslide map?

Thanks,
Doug

-----Original Message-----
From: McHarge, Jennifer [mailto:Jennifer.McHarge@state.co.us]
Sent: Monday, August 09, 2004 9:22 AM
To: 'Douglas.Bausch@dhs.gov'
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Thanks,
Jennifer McHarge
jennifer.mcharge@state.co.us
Colorado Geological Survey
1313 Sherman St.
Denver, CO 80203
(303) 866-2082

Morgan, Matt

From: Johari, Pushpendra [PJohari@pbsj.com]
Sent: Tuesday, June 22, 2004 12:12 PM
To: Morgan, Matt
Subject: RE: building stock

Please give you phone number so that we can discuss this. Alternatively you may call me at 770-933-0280 x 758.

Thanks,

Pushendra.

-----Original Message-----
From: Morgan, Matt [mailto:Matt.Morgan@state.co.us]
Sent: Tuesday, June 22, 2004 12:40 PM
To: 'Johari, Pushpendra'
Subject: RE: building stock

Hello Pushpendra:
It will not let me edit any of the values under any of the tabs. I do have it set on "Start Editing".

Also I would like to know how to globally change these values, as the ones for Morgan County are missrepresented by 1,000 fold. I do have SQL server

Thanks,
Matt

-----Original Message-----
From: Johari, Pushpendra [mailto:PJohari@pbsj.com]
Sent: Tuesday, June 22, 2004 10:05 AM
To: Morgan, Matt
Subject: RE: building stock

Hello Matt,

Answer to Question 1.
For Exposure and Content Exposure the values are in thousands of dollars, i.e., 150 means 150,000.
Square Footage is in thousands of square feet, i.e., 250 mean 250,000 square feet.
Building count is in terms of number of buildings so 150 means 150 buildings.

Answer to Question 2.
It's not very clear what you mean by scenario.
1) If by scenario you mean changing the Earthquake Scenario on the same study region then you can just go to the Inventory/General Building Stock/ Dollar Exposure and launch the Dollar Exposure table. Select the TAB "Exposure by Specific Occupancy". Then right click and select "Start Editing". Just change whatever value you want to change and when you are done right click and select "Stop Editing". The application will ask you "Do you want to save the changes?", click yes and the modified values will be saved in the study region. After this if you change the earthquake scenario for this study region, you will still use the modified values.

2) If by scenario you mean a different study region then these changes will have to be made into the Default State data. This is a more complicated than the steps described above. In case this is what you mea n by a different scenario then please let me know I will tell you what all is involved in this.

Thanks,

Pushpendra.

-----Original Message-----
From: Morgan, Matt [mailto:Matt.Morgan@state.co.us]
Sent: Tuesday, June 22, 2004 11:16 AM
To: 'HAZUSQUAKEHELP@pbsj.com'
Subject: building stock

Hello:
We need to change a couple of the default building stock values for Morgan County, Colorado. Questions are 1. What value (in dollars) is given to the numbers in the HAZUS tables (i.e. is 1,500 1.5 million?) and 2. How can I change the default vaules so it takes effect for each scenario?
Thanks

~+~+~+~+~+~+~+~+~+~
Matt Morgan
Geologist
Colorado Geological Survey
1313 Sherman St. #715
Denver, Colorado 80203 USA
Web Site:
<http://geosurvey.state.co.us/programs/moe/morgan.asp>

Morgan, Matt

From: Johari, Pushpendra [PJohari@pbsj.com]
Sent: Tuesday, June 22, 2004 10:05 AM
To: Morgan, Matt
Subject: RE: building stock

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Thanks,

Pushpendra.

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Sent: Tuesday, June 22, 2004 11:16 AM
To: 'HAZUSQUAKEHELP@pbsj.com'
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Geologist
Colorado Geological Survey
1313 Sherman St. #715
Denver, Colorado 80203 USA
Web Site:
<http://geosurvey.state.co.us/programs/moe/morgan.asp>

Morgan, Matt

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Tuesday, June 01, 2004 5:39 PM
To: 'Morgan, Matt'
Subject: RE: landslide dataset

Hi Matt, I sent the landslide dataset to tech support to look at. When do you need it back? Also, we found a big valuation error in a tract in Morgan County that will throw off the losses. The building exposure and content values for COM1 in tract 08087000700 is $5 trillion. The values should be reduced to $5M (2.5M contents and 2.5M building exposure). Thanks, Doug

-----Original Message----- ours is 2.5 mil
From: Morgan, Matt [mailto:Matt.Morgan@state.co.us]
Sent: Friday, May 21, 2004 1:56 PM
To: Doug Bausch (E-mail)
Subject: landslide dataset

Hi Doug:
Have you had a chance to look at the Colton landslide dataset for Colorado?

~+~+~+~+~+~+~+~+~
Matt Morgan
Geologist
Colorado Geological Survey
1313 Sherman St. #715
Denver, Colorado 80203 USA
Web Site:
<http://geosurvey.state.co.us/programs/moe/morgan.asp>

HAZUSQuakeHelp@pbsj.com

2512904

Powell, Lauren

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Monday, April 19, 2004 11:50 AM
To: 'Bouabid, Jawhar'; Johari, Pushpendra; Powell, Lauren
Subject: RE: hazus questions

Thanks Jawhar, Many of the attenuation functions appear to be designed to go further than 200 km. How come we limited HAZUS-MH to 200km? Also has someone else done the editing, so we can provide Lauren with the new tables?
Thanks, Doug

-----Original Message-----
From: Bouabid, Jawhar [mailto:JBouabid@pbsj.com]
Sent: Monday, April 19, 2004 11:14 AM
To: Bausch, Douglas; Johari, Pushpendra; Powell, Lauren
Cc: Bouabid, Jawhar
Subject: RE: hazus questions

Doug,

~ able to access tables, but no idea how to edit!

In HAZUS-MH, PGA, PGV, Sa(0.30 an SA(1.0) values for distances up to 200 km and for magnitudes ranging from 5 to 8.5 are read from tables in SYHAZUS database.

Change cut-off to 250 km (Denver → to → Cheraw ≅ 211 km)

If you need more distances, you need to edit and expand these tables. By the way, these tables are conveniently names eqPGAvals, eqPGVvals, eqSa03vals, and eqSA10vals.

Jawhar
==

-----Original Message-----
From: Bausch, Douglas [mailto:Douglas.Bausch@dhs.gov]
Sent: Monday, April 19, 2004 1:08 PM
To: 'Johari, Pushpendra'; Powell, Lauren
Cc: Bouabid, Jawhar
Subject: RE: hazus questions

Hi Lauren,

It looks like you are giving the program a good workout. Hopefully, closing and opening the region will free up the RAM and let you map.

My understanding from the HAZUS '99 technical manuals is that there are cut-off distances for the attenuation functions. Most my experience with this is in running the New Madrid scenarios. Some extend fairly far (Frankel-350km), but the combination ones (Project 1997, 2000) seem to cut-off. When they are combined is the shortest cut-off being used? Jawhar isn't there a way to modify the cut-off distance? Is there any new technical documentation for HAZUS MH on the treatment of PESH?

Lauren, I'll be around all week and see what results I get for Denver with the Cheraw event and further test the mapping.

Thanks,
Doug

-----Original Message-----
From: Johari, Pushpendra [mailto:PJohari@PBSJ.COM]
Sent: Thursday, April 15, 2004 6:35 AM
To: Powell, Lauren

Cc: Bausch, Douglas; Bouabid, Jawhar
Subject: RE: hazus questions

Hello!

Yes I have answer for you for question number 4 below.

In general the Question is why the results from CEUS attenuation did not grow with the magnitude with the same proportion as the WUS attenuation function.

The answer lies in the in the way the Ground Motion attenuates between WUS and CEUS. The long period ground motion is much higher in WUS for higher return periods than for CEUS. That is why as the magnitude increases the damage increases more in WUS than in CEUS.

Regarding question number 2:
AS Cheraw fault is not there in the current HAZUS-MH fault database, you must be using Arbitrary event. You haven't mentioned the epicenter you used in case of Cheraw fault analysis run. If you could tell me the Epicenters you used for the two cases I could dig in to find the answer.

Regarding the Mapping: This is the first time I have heard that mapping is just not working. At times is misbehaves after generating contours but if one closes HAZUS-MH and launches it again it fixes the problem. Could you be very specific as to what you are trying to map, for example, which result menu options which table's which column.

Thanks,

Pushpendra.

-----Original Message-----
From: Powell, Lauren [mailto:Lauren.Powell@state.co.us]
Sent: Wednesday, April 14, 2004 4:29 PM
To: 'Johari, Pushpendra'
Subject: RE: hazus questions

Hi Pushpendra,

Any progress with the study regions I sent to you?

I am still unable to map data from the earthquake scenarios I run, so when you have a free minute could we address ways to achieve this in build 31 of Hazus?

Thanks!
Lauren

-----Original Message-----
From: Johari, Pushpendra [mailto:PJohari@pbsj.com]
Sent: Wednesday, April 07, 2004 9:41 AM
To: Powell, Lauren
Subject: RE: hazus questions

Hello Lauren,

I have received all the three notifications and we are starting to download the regions.

Just one question: Were you using any hazard maps: Soil or Liquefaction maps. If yes then please upload those maps also.

I will get back to you as soon as I have an update for you.

Thanks,

Pushpendra.

-----Original Message-----
From: Powell, Lauren [mailto:Lauren.Powell@state.co.us]
Sent: Wednesday, April 07, 2004 11:33 AM
To: 'Johari, Pushpendra'
Subject: RE: hazus questions

Pushpendra,

I just FTP'ed you two zip files through the FloodMaps.net web site as you mentioned below. If you have trouble opening them, let me know, because I had some errors while trying to compress the files.

The first region, 'CGS Denver CountyEQ' is in response to question #2 below. This is the situation where scenarios with large magnitude earthquakes along the Cheraw Fault (in eastern Colorado) do not seem to affect Denver, only 200 km from the fault. I have even run an M7.5 and M8.0, but they still result in 0 damage and 0 casualties. The fault parameters I am using are: Epicenter (38.28, -103.42), Strike = 44, Dip = +66, Width = 17.3, Attenuation function = Project 2000 East, Normal fault. I use a soil and landslide map, but I think in this case those will not make a huge difference in what we're trying to achieve. How can we get these Cheraw earthquakes to damage Denver?

The second region, 'CGS El Paso CountyEQ' is in response to question #4 below. The attenuation functions I have been comparing are Project 2000 West-Extensional and Project 2000 East. For the Rampart Range Fault, default parameters are: Epicenter (39.06, -104.92), Strike = 171, Dip = +60, Width = 17.3, Normal Fault. For comparison purposes, I will send you one more region, 'CGS Douglas CountyEQ' since Douglas County fits the normal pattern of higher damage with CEUS attenuation than with WUS functions.

Let me know if you need more information or if I omitted anything. Thank you for your help!

Lauren

-----Original Message-----
From: Johari, Pushpendra [mailto:PJohari@pbsj.com]
Sent: Tuesday, April 06, 2004 12:17 PM
To: Lauren.Powell@state.co.us
Cc: Bouabid, Jawhar; Bausch, Douglas
Subject: RE: hazus questions

Hello,

Jawhar forwarded me your email with Dough's responses. Here are my responses to your questions.

1) If you are using build 34 then you should not face this problem. This happens sometimes in Build 31.

2) If you could export your study region and send it to me I could try to reproduce it. To send the exported region you may use FloodMaps.net web site's Easy FTP facility.

3) Dough has already clarified this.

4) It's very hard for me to say anything about this behavior unless I study this very closely myself. If you could export your study region and send it to me I could try to reproduce it and then will share with you whatever our findings are.

Thanks,

Pushpendra.

-----Original Message-----
From: Bouabid, Jawhar
Sent: Tuesday, April 06, 2004 12:31 PM
To: Johari, Pushpendra
Subject: FW: hazus questions

Please reply ASAP and Cc me

Thanks!

==
-----Original Message-----
From: Bausch, Douglas
To: 'Powell, Lauren'
Cc: 'Bouabid, Jawhar'
Sent: 4/6/04 11:34 AM
Subject: RE: hazus questions

Hi Lauren,

Sounds like you are busy. I can answer some of these and have cc'd Jawhar
to help with the others, below:

-----Original Message-----
From: Powell, Lauren [mailto:Lauren.Powell@state.co.us]
Sent: Tuesday, April 06, 2004 8:13 AM
To: 'Bausch, Douglas'
Subject: hazus questions

Hi Doug,

I have run over 100 scenarios to this point and am still only scratching the
surface of what we want to learn about CO earthquakes. Once we ironed out
with Jawhar how to import central-eastern US attenuation functions, things
have been running smoothly with Hazus. More often than not, I'm using a trial-and-error method to see how different hazard maps, attenuation functions, and epicenter locations affect results.

-This is really a good approach, so you can see how the model is most sensitive and get a handle on uncertainty.

Several questions have arisen, though:
1) When I try to map PGA or PGV once an analysis has been run, the program
gives me an error message "field cannot be mapped." How do I tell the computer to map these results?

-If you did not skip the production of a contour map (grid) when running it
should map. You can also use the add data button and map the fields from
the eqGrid geodatabase in the study region folder. Also, under Analysis-->Parameters-->Contour you can set the size of the contours. A small size slows processing, but can produce a nice final map. So it is best to do this when you think the run is final.

2) I'm often interested in seeing how a remote earthquake such as on the Cheraw or Sangre de Cristo faults affects Denver county or a similar high
population county. The epicenter I chose for a M7.5 on the Sangre de Cristo
fault is 205km from the closest point in Denver county, and results showed
significant damage depending on the attenuation function. But when I ran a
M7.0 on the Cheraw fault with an epicenter 200km from Denver, it showed no
damage of any kind. (This is a problem they had with Hazus99 and the Cheraw
fault - certainly Denver would feel a M7!) Is this a magnitude-distance relationship built into Hazus, such that a M7.5 would "reach" Denver but a
M7.0 will not?

-I don't have any experience here. I know there is a cutoff in the attenuation functions, but thought Jawhar provided some guidance to get around it. I would suggest trying a 7.5 on the Cheraw to see if it is related solely to magnitude. Also, the USGS National Map web page allows
you to deaggregate the hazard for a given area, and you can see which sources are contributing to the Denver hazard. In addition, the National
Map folks (Mark Peterson) can provide the ground shaking contribution of individual sources and produce a scenario map that you would import as a user-defined hazard.

3) Epicenter soil types appear to have a large impact on scenario results.
If type 2 and type 4 are close together, moving the epicenter from 2 to 4
increases damage significantly. This might be due to my ignorance of earthquake mechanics, but does Hazus only "see" soil type at the epicenter
or does it recognize variety over the entire region?

-The soil types should be letters (A-E), and amplify or deamplify ground shaking at each inventory item or census tract. The amplification parameters are under analysis-->parameters-->hazard and actually vary by acceleration. Low accelerations have higher amplification factors. The model is sensitive to soil type, but mainly in cases where lots of inventory
are on softer soils and exposed to relative low levels of ground motion.

4) For most regions, a central-eastern US attenuation function results in
2-4 times greater damage than with a western US function. When I ran scenarios for the Rampart Range and Ute Pass faults in El Paso county, however, a pattern results that produces M7 CEUS damage half that of WUS,
M6.5 CEUS damage approximately equal to WUS, M6.0 damage twice that with WUS, and M5.5 damage three times that with WUS. What's going on here?

--I can't explain this one, other that trying to duplicate these results

to
see if there was something else. Perhaps Jawhar can help here.

Sorry to bombard you with questions - I look forward to hearing from you when you get the chance.

Lauren

(Is there still going to be Hazus training April 13-15 as you mentioned last
month? Matt Morgan and I are still interested, if so.)

-The April 13-15 course filled up so we added a April 27-29 session. Your
earthquake skills are beyond the materials that will be covered in the earthquake portion, but you might be interested in the other hazards. I have attached the flyer and agenda.

Good luck, and I am very interested in your progress so please don't hesitate asking questions.

Thanks,
Doug

<<April 27-29 HAZUS-MH Introduction Course-Denver.doc>> <<Denver Course Outline-April 27-29.doc>>

Powell, Lauren

From: Johari, Pushpendra [PJohari@pbsj.com]
Sent: Wednesday, April 07, 2004 2:58 PM
To: lauren.powell@state.co.us
Subject: RE: Floodmaps.net eFTP Download Available

Hello!

The study regions that you sent me cannot be used with HAZUS-MH as they are incomplete. This is because you just zipped the study region folders. This way several databases in use did not get zipped.

→ Startup wizard • export/backup region

Please use the HAZUS-MH Export facility to export the region. This will generate a CGS Denver CountyEQ.hpr file. Then send this hpr file to me via floodmaps.net. You will have to export all the 3 study regions from HAZUS-MH and then send those to me. ✓

Thanks,

Pushpendra.

-----Original Message-----
From: lauren.powell@state.co.us [mailto:lauren.powell@state.co.us]
Sent: Wednesday, April 07, 2004 11:10 AM
To: PJohari@pbsj.com
Subject: Floodmaps.net eFTP Download Available

A file has been submitted to Floodmaps.net eFTP for you to download:

Follow The Link Below To Download The File
http://www.floodmaps.net/eftp/checkfile.asp?file=CGS Denver CountyEQ.zip

Notes: Attached is the Denver County study region to experiment with sensitivity to the Cheraw Fault. I will email details to you.

Recipients: PJohari@pbsj.com;

Sender: lauren.powell@state.co.us

You can also retrieve the file manually from
http://www.floodmaps.net/eftp/
Retrieve the file:
CGS Denver CountyEQ.zip
--------------------- End of Message ---------------------

Powell, Lauren

From: Johari, Pushpendra [PJohari@pbsj.com]
Sent: Tuesday, April 06, 2004 12:17 PM
To: Lauren.Powell@state.co.us
Cc: Bouabid, Jawhar; Bausch, Douglas
Subject: RE: hazus questions

Hello,

Jawhar forwarded me your email with Dough's responses. Here are my responses to your questions.

1) If you are using build 34 then you should not face this problem. This happens sometimes in Build 31. — Release 28D ?error

2) If you could export your study region and send it to me I could try to reproduce it. To send the exported region you may use FloodMaps.net web site's Easy FTP facility. Cheraw defaults → Denver County region 4/7 ✓ zip file: PowellLa\My Documents\ CGS Denver County EQ

3) Dough has already clarified this.

4) It's very hard for me to say anything about this behavior unless I study this very closely myself. If you could export your study region and send it to me I could try to reproduce it and then will share with you whatever our findings are. → El Paso County – Rampart + Ute Pass settings

4/7 ✓ zip file: PowellLa\My Docs\ CGS El Paso County EQ

Thanks,

Pushpendra.

4/7 zip file: PowellLa\My Docs\ CGS Douglas County EQ

✓ also FTP'd soil and landslide maps

-----Original Message-----
From: Bouabid, Jawhar
Sent: Tuesday, April 06, 2004 12:31 PM
To: Johari, Pushpendra
Subject: FW: hazus questions

Please reply ASAP and Cc me

Thanks!

==

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To: 'Powell, Lauren'
Cc: 'Bouabid, Jawhar'
Sent: 4/6/04 11:34 AM
Subject: RE: hazus questions

Hi Lauren,

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From: Powell, Lauren [mailto:Lauren.Powell@state.co.us]
Sent: Tuesday, April 06, 2004 8:13 AM

Powell, Lauren

From: Bausch, Douglas [Douglas.Bausch@dhs.gov]
Sent: Tuesday, April 06, 2004 10:35 AM
To: 'Powell, Lauren'
Cc: 'Bouabid, Jawhar'
Subject: RE: hazus questions

April 27-29 AZUS-MH Introduct. Denver Course Outline-April 27...

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Several questions have arisen, though:
1) When I try to map PGA or PGV once an analysis has been run, the program gives me an error message "field cannot be mapped." How do I tell the computer to map these results?

Results - Grnd Motion/Failure Contours/Grnd Fail Maps Layers-Tables Empty!

-If you did not skip the production of a contour map (grid) when running it should map. You can also use the add data button and map the fields from the eqGrid geodatabase in the study region folder. Also, under Analysis-->Parameters-->Contour you can set the size of the contours. A small size slows processing, but can produce a nice final map. So it is best to do this when you think the run is final.

not there

difault = 100 grid cells
-how small is small?

2) I'm often interested in seeing how a remote earthquake such as on the Cheraw or Sangre de Cristo faults affects Denver county or a similar high population county. The epicenter I chose for a M7.5 on the Sangre de Cristo fault is 205km from the closest point in Denver county, and results showed significant damage depending on the attenuation function. But when I ran a M7.0 on the Cheraw fault with an epicenter 200km from Denver, it showed no damage of any kind. (This is a problem they had with Hazus99 and the Cheraw fault - certainly Denver would feel a M7!) Is this a magnitude-distance relationship built into Hazus, such that a M7.5 would "reach" Denver but a M7.0 will not?

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Good luck, and I am very interested in your progress so please don't hesitate asking questions.

Thanks,
Doug

Powell, Lauren

From: Bouabid, Jawhar [JBouabid@pbsj.com]
Sent: Friday, March 19, 2004 11:13 AM
To: 'Powell, Lauren'
Subject: RE: attenuation functions

If you want to use eastern attenuation function with eastern mechanism, keep DisttoUse as 1. All other values correspond to different types of distances to fault plane rupture.

In the FltMechanism field, E (means eastern fault mechanism), I and F for subduction events.

===

-----Original Message-----
From: Powell, Lauren [mailto:Lauren.Powell@state.co.us]
Sent: Friday, March 19, 2004 12:37 PM
To: 'Bouabid, Jawhar'
Subject: RE: attenuation functions

In the FltMechanism field, what do E, I, and F stand for?

Also, what do the specific values in the DisttoUse field stand for?

The eastern attenuation functions appear in HAZUS once we change FltMechanism to N, S, or R AND when we change DisttoUse to something greater than 1 (4 is what the other western functions mostly use).

-----Original Message-----
From: Bouabid, Jawhar [mailto:JBouabid@pbsj.com]
Sent: Friday, March 19, 2004 10:11 AM
To: 'Powell, Lauren'; Bouabid, Jawhar; Bausch, Douglas
Cc: Brush, Sara
Subject: RE: attenuation functions

You need also to set the FltMechanism to "S", "R" or "N" (strike-slip, reverse, or normal)

In this case, whatever value you use does not really matter unless you change the "DisttoUse" value to something else other than 1.

"DisttoUse" value of 1 means the shortest distance (to use in the lookup table) from epicenter to site of interest (no dependency on how the fault ruptures).

===

Powell, Lauren

From: Bouabid, Jawhar [JBouabid@pbsj.com]
Sent: Friday, March 19, 2004 10:11 AM
To: 'Powell, Lauren'; Bouabid, Jawhar; Bausch, Douglas
Cc: Brush, Sara
Subject: RE: attenuation functions

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==

-----Original Message-----
From: Powell, Lauren [mailto:Lauren.Powell@state.co.us]
Sent: Friday, March 19, 2004 12:02 PM
To: 'Bouabid, Jawhar'; Powell, Lauren; Bausch, Douglas
Cc: Brush, Sara
Subject: RE: attenuation functions

Jawhar,

We accessed the server and found the table eqAttenFunct. We changed the "E" to "W" to make the eastern functions applicable, but they did not appear in the dropdown menu in the Hazus scenario wizard. Is there something else we need to do?

Thanks!
Lauren

-----Original Message-----
From: Bouabid, Jawhar [mailto:JBouabid@pbsj.com]
Sent: Thursday, March 18, 2004 7:07 AM
To: 'Powell, Lauren'; Bouabid, Jawhar; Bausch, Douglas
Cc: Brush, Sara
Subject: RE: attenuation functions

Lauren,

Under HAZUSPLUSSRVR, there is a database named "SYHAZUS". In this database, there are 6 tables that define all attenuation functions and ground shaking values. These tables are:

(1) eqAttenFunct. This is where you add additional attenuation functions or modify existing ones (e.g., make East attenuation function applicable to West
(2)eqAttneDepend. You will only edit this table if you are creating new cocktail functions or modifying existing ones (i.e., the weights)

(3) eqPGAVals. This table is where you population with new PGA values.

(4) eq Sa03Vals. This table is where you population with new SA(0.3sec) values.

(5) eq SA10Vals. This table is where you population with new SA (1.0 sec) values.

(6) eq PGVVals. This table is where you population with new PGV values.

A lot of upfront data pre-compiling, but that's it.

Jawhar
==

-----Original Message-----
From: Powell, Lauren [mailto:Lauren.Powell@state.co.us]
Sent: Wednesday, March 17, 2004 3:31 PM
To: 'Bouabid, Jawhar'; Bausch, Douglas
Cc: Brush, Sara
Subject: RE: attenuation functions

Hi Jawhar,

It looks like we have the SQL server installed on this computer where Hazus scenarios are being run. If you could email me instructions about adding attenuation functions that would be great. That way several of us can refer back to the instructions instead of trying to reach each other by phone.

Thanks!
Lauren

-----Original Message-----
From: Bouabid, Jawhar [mailto:JBouabid@pbsj.com]
Sent: Monday, March 15, 2004 8:47 AM
To: Bausch, Douglas; 'Powell, Lauren'; Bouabid, Jawhar
Cc: Brush, Sara
Subject: RE: attenuation functions

Lauren,

If you have the full version of SQL, then you can "easily" do what you want.

If you do, then call me and I will tell you what tables you need to edit.

Jawhar
==

-----Original Message-----
From: Bausch, Douglas [mailto:Douglas.Bausch@dhs.gov]
Sent: Monday, March 15, 2004 10:53 AM
To: 'Powell, Lauren'; 'Bouabid, Jawhar'
Cc: Brush, Sara
Subject: RE: attenuation functions

Hi Lauren,

It was my understanding that HAZUS-MH would have some flexibility to add and modify attenuation functions. The technical documentation does not explain how to do this, so I am turning this over to Jawhar Bouabid who did the development. Jawhar's direct phone is (770) 933-0280 ext. 754. I would like to stay in the loop on this one. Jawhar is also working on the source database issue (eg. the missing Cheraw fault). I'll be back in town next week and will follow-up.

Thanks,
Doug

-----Original Message-----
From: Brush, Sara
Sent: Thursday, March 11, 2004 12:15 PM
To: 'Powell, Lauren'; Bausch, Douglas

Subject: RE: attenuation functions

Hi Lauren, I have to point you to Doug to answer this question. Sara

-----Original Message-----
From: Powell, Lauren [mailto:Lauren.Powell@state.co.us]
Sent: Thursday, March 11, 2004 9:14 AM
To: 'Brush, Sara'
Subject: attenuation functions

Hi Sara,

To continue with my stream of random Hazus questions, I was wondering if it would be possible to merge some of the Central-Eastern US attenuation functions with those already built into the software for the Western US zone that Colorado is in. We're thinking that a more realistic function for the eastern half of Colorado will produce more realistic results. Would this kind of merge/import be possible?

Lauren

Specific Limitations HAZUS

Limitations of the HAZUS-MH Software

Hazard specific limitations are repeated in the "Message to Users" in the hurricane, flood and earthquake user manuals. A copy of this readme.txt file is copied to the selected HAZUS-MH folder.

Installation
* Users who plan to operate HAZUS-MH in a network environment are advised to contact technical support immediately for advice if any difficulty is encountered in installing to a particular system.
* HAZUS-MH must be uninstalled only with the Windows Add/Remove Programs utility. For details on uninstalling, please consult the User Manuals.

Study Region Size
* The database management system of HAZUS-MH is SQL Server MSDE. This system has a size limit of 2 GB per database, which limits the size of the regions to 2,000 census tracts for a hurricane or earthquake analysis, 90,000 census blocks for a riverine flood analysis and one county for a coastal flood analysis. Two thousand census tracts and 90,000 census blocks are equivalent to an area with a population of about 9 million. For a multi-hazard study region that includes data for all three hazards, the 2 GB limit will permit an even smaller study region. To work around this, the full version of Microsoft SQL Server 2000 must be used.

* Multihazard loss analysis capability is limited to the 22 states that experience hurricane, flood and earthquake hazards and requires that the user first run annualized losses for each of the three hazards.

* To maximize the size of a study region that may be analyzed, set the virtual memory size from a minimum of 2048 MB to a maximum of 4096 MB. For the earthquake model, the virtual memory size may be increased from a minimum of 1024 MB to a maximum of 2048 MB for optimal operation.

* To speed up the study region aggregation process, the database can be copied to the local hard-disk. The process is as follows:

- Copy one or more of the state data folders (e.g., NC1) and the both the DVD identification files (e.g., D1.txt ^ 1.txt) to a folder on your hard drive (e.g., D:\HAZUS-Data\).

- Copy the file "syBoundary.mdb" from the Boundary CD to the same folder on your hard drive.

- Next, you'll need to point the program to your new data folder. To do this, click on the Start button, select "Run", type "regedit" and then click OK. Next, navigate through the folder down to the following location:

  HKEY_LOCAL MACHINE | SOFTWARE | FEMA | HAZUS-MH | General

- Now look at the right side of the window and find the entry called "DataPath1". Double click on "DataPath1" and enter the full name of the folder on your hard drive that contains the data you copied from the DVDs.

C:\Program Files\Hazus-Data\

(CO1, Earthquake, Landslide Data, Flood
Critical Landslides, Geology, syBoundary, and txt files 1-6, A1-F1 (empty?))

Specific Limitations HAZUS

- IMPORTANT: Make sure the path ends with a "\" and do not change any of the other registry settings.

Individual Versus Regional Analyses

* While HAZUS-MH may be used to estimate losses for individual buildings, the results must be considered as average for groups of similar buildings. For example, it has frequently been observed that nominally similar buildings have experienced vastly different damage and losses during hurricanes.

Earthquake Model

* Rapid loss estimates for large study regions of 1000-2000 census tracts might require 4 to 8 hours analysis time.
* Transferring data from HAZUS99, HAZUS99-SR1 or HAZUS99-SR2 to HAZUS-MH will require the assistance of technical support.
* Based on several initial studies, the losses from small magnitude earthquakes (less than M 6.0) centered within an extensive urban region appear to be overestimated.
* Because of approximations in modeling faults in California, there may be discrepancies in motions predicted within small areas immediately adjacent to faults.
* There is considerable uncertainty related to the characteristics of ground motion in the Eastern U.S. The embedded attenuation relations in the earthquake model, which are those commonly recommended for design, tend to be conservative. Hence, use of these relations may lead to overestimating losses for scenario events and when using probabilistic ground motion.
* Additional testing is needed for the indirect economic loss model.

Coastal Flooding Model

* Users should be aware that the current coastal flood model requires more processing time than the riverine flood model. However, the coastal model is now being optimized for smoother and faster operation in the first service release planned for Spring 2004.
* Annualized loss analysis for coastal flooding will be available in the first service release planned for Spring 2004.

Hurricane Model

* The Hurricane hazard is available to 22 states in the Gulf and Atlantic coast and the state of Hawaii.
* Loss estimates for large study regions of 2,000 census tracts or blocks might require 4 hours analysis time.
* The hurricane model contains definitions and assumptions regarding building strengths that represent what is typical for construction in hurricane zones and are defined in the Technical Manual. Where construction quality is known to be different, larger uncertainties occur in loss projections.

Lifelines in the Earthquake and Flood Models

* When using embedded inventories, accuracy of losses associated with lifelines might be less than the accuracy associated with the general building stock. The lifelines databases in HAZUS-MH and the assumptions used to characterize these systems are incomplete and simplified.

User Manuals

* The user manuals contain screen shots of the software that are not up to date.

Specific Limitations HAZUS
These will be edited in the first service release planned for Spring 2004.

Technical Support
* Technical support is available via telephone, e-mail, or FAX. The numbers and addresses are listed on the CD sleeve and under the Help menu in the software.

Information on HAZUS-MH updates, software patches, and FAQs are available at www.fema.gov/hazus/ <http://www.fema.gov/hazus/>.

☆ Convert all databases to geodatabases for Hazus MH
└ add 'Type' field with numerical attributes

☆ To get Geoprocessing Wizard – rt. click on toolbar –
Customize – Commands – Tools – Geoprocessing Wizard –
drag + drop on toolbar
(same for any other menu / tool)

HAZUS:
PUBLICATIONS &
RESOURCES

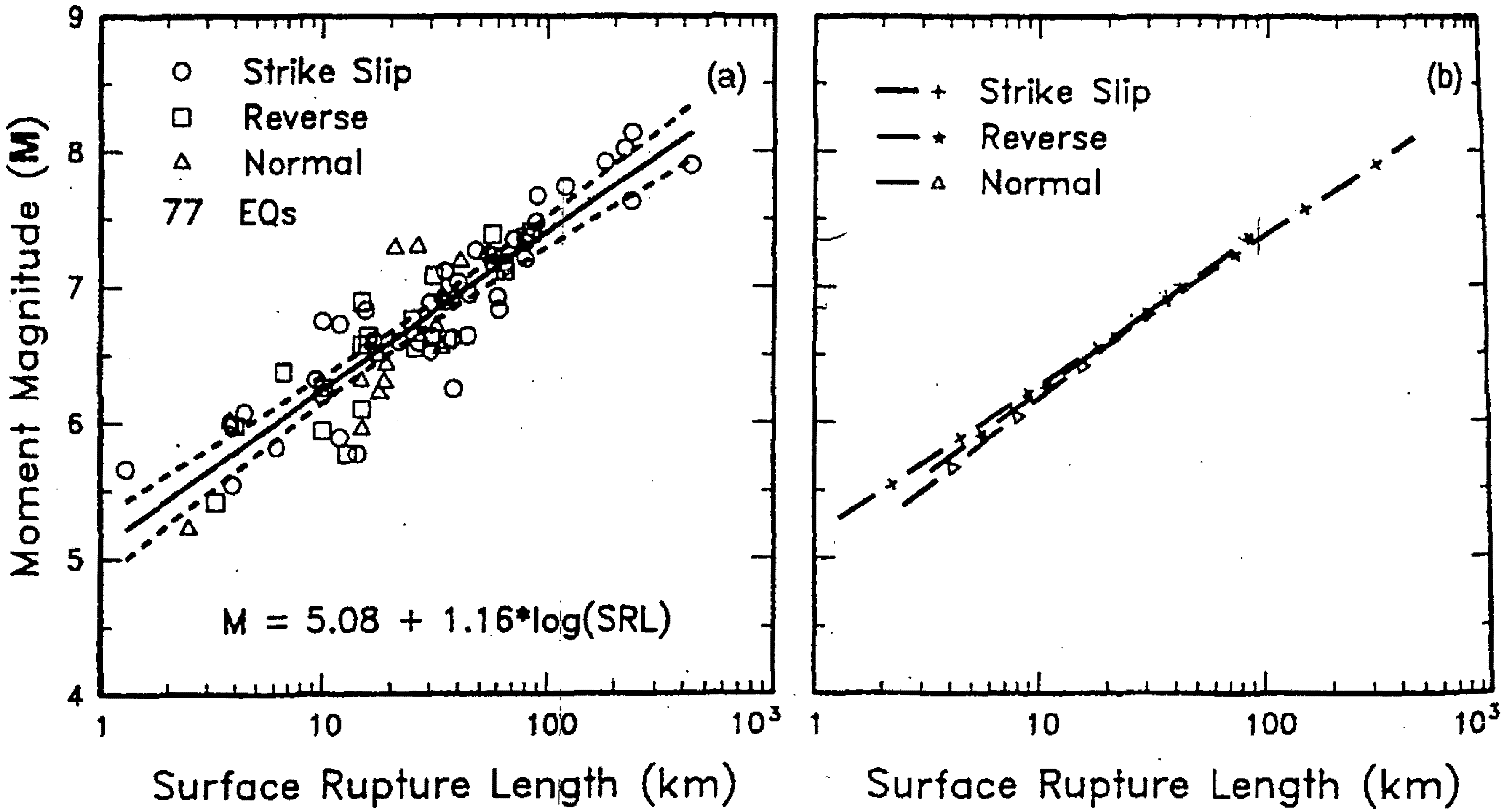


Figure 13–2. Regression of surface rupture length on magnitude for worldwide earthquakes of all slip types. Solid line is ordinary least-squares fit. Dashed lines indicate 95-percent confidence intervals. From Wells and Coppersmith (1994).

From Silva, Darragh, + Gregor (et al...), Reassessment of Site Coefficients and Near-Fault Factors for Building Code Provisions

Table 1

SITE CLASSIFICATIONS

Average shear-wave velocity to a depth of 30m (≈ 100 ft) is:

NEHRP 1994	UBC 1997
A = > 1,500 m/s	5,000 ft/sec
B = 760 - 1,500 (1,130)*	2,500 - 5,000 (3,750)*
C = 360 - 760 (560)*	1,200 - 2,500 (1,850)*
D = 180 - 360 (270)*	600 - 1,200 (900)*
E = < 180	600 ft/sec

Soil Profile Type	Description
A	Hard rock with measured shear-wave velocity, $\overline{v}_s > 5{,}000$ ft/sec (1,500 m/sec)
B	Rock with 2,500 ft/sec < $\overline{v}_s \leq$ 5,000 ft/sec (760 m/sec < $\overline{v}_s \leq$ 1,500 m/sec)
C	Very dense soil and soft rock with 1,200 ft/sec < $\overline{v}_s \leq$ 2,500 ft/sec (360 m/sec < $\overline{v}_s \leq$ 760 m/sec) or with either $\overline{N} > 50$ or $\overline{S}_u \geq$ 2,000 psf (100 kPa)
D	Stiff soil with 600 ft/sec < $\overline{v}_s \leq$ 1,200 ft/sec (180 m/sec < $\overline{v}_s \leq$ 360 m/sec) or with either $15 \leq \overline{N} \leq 50$ or 1,000 psf $\leq \overline{S}_u \leq$ 2,000 psf (50 kPa $\leq \overline{S}_u \leq$ 100 kPa)
E	A soil profile with $\overline{v}_s <$ 600 ft/sec (180 m/sec) or any profile with more than 10 ft (3m) of soft clay defined as soil with $PI > 20$, $\omega \geq 40\%$, and $\overline{S}_u <$ 500 psf (25 kPa)
F	Soil requiring site-specific evaluations: i. Soil vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clayss, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H >$ 10 ft (3m) of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H >$ 25 ft (8m) with $PI > 75$) 4. Very thick soft/medium stiff clays ($H >$ 120 ft (36m)) Exception: When the soil properties are not shown in sufficient detail to determine the Soil Profile Type, Type D shall be used. Soil Profile Types E or F need not be assumed unless the regulatory agency determines that Types E or F may be present at the site or in the event that Types E or F are established by the geotechnical data.

*Mid-range values adopted for amplification factors

Table 1 (Cont.)			
1997 UBC NEAR-SOURCE FACTOR, N_V			
Seismic Source	Closest Distance to Active Source		
	≤ 2 km	5 km	10 km
Type A	2.0	1.6	1.2
Type B	1.6	1.2	1.0
Type C	1.0	1.0	1.0

1997 UBC Seismic Source Types			
Seismic Source	Seismic Source Description	Source Properties	
		Maximum Moment Magnitude, M	Slip Rate, SR (mm/year)
Type A	Capable of Producing Large Magnitude Events and High Rate of Seismic Activity	M ≥7.0	SR ≥ 5
Type B	Not Type A or Type C Seismic Source		
Type C	Not Capable of Producing Large Magnitude Events and Low Rate of Seismic Activity	M < 6.5	SR ≤ 2

Table 3 **F_A and F_V VALUES**					
Soil Profile Type	F_A For Shaking Intensity Levels				
	$A_a \leq 0.1$	$A_a = 0.2$	$A_a = 0.3$	$A_a = 0.4$	$A_a \geq 0.50^a$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	b
F	b	b	b	b	b
Soil Profile Type	F_V For Shaking Intensity Levels				
	$A_V \leq 0.1$	$A_V = 0.2$	$A_V = 0.3$	$A_V = 0.4$	$A_V \geq 0.50^a$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	b
F	b	b	b	b	b

Fa: Evaluated over the frequency range of 2 to 10 Hz.
Fv: Evaluated over the frequency range of 0.5 to 2.5 Hz.

Note: Use straight line interpolation for intermediate values of A_a and A_V

[a] Values for A_a, A_V > 0.4 are applicable to the provisions for seismically isolated and certain other structure

[b] Site specific geotechnical investigation and dynamic site response analyses shall be performed.

Table 5 NEHRP B WUS $\kappa = 0.04$ sec									
Target Outcrop PGA(g)	Median Outcrop PGA(g)	Median Outcrop PGV(cm/sec)	Median Outcrop PGD(cm)	Median Outcrop V/A (cm/sec/g)	Median Outcrop AD/V^2 ($gcm/cm/sec^2$)	Dist. (km)	Depth (km)	M	$\Delta\sigma$ (bars)
0.05	0.05	5.72	2.58	113.06	3.91	40.00	8.00	6.5	64
0.10	0.10	10.72	4.74	106.96	4.06	21.50	8.00	6.5	64
0.20	0.19	19.80	8.67	103.54	4.15	10.00	8.00	6.5	64
0.30	0.31	31.91	13.89	101.94	4.19	1.00	8.00	6.5	64
0.40	0.39	39.98	17.80	103.71	4.21	3.00	6.00	6.5	64
0.50	0.51	52.88	23.49	103.09	4.23	1.00	5.00	6.5	64
0.75	0.74	76.98	34.78	104.38	4.25	1.00	3.50	6.5	64

Q(f) = 275 $f^{0.6}$ (Los Angeles; based on regional inversions, Silva et al., 1997)
Kappa = 0.04 sec

NEHRP B CEUS $\kappa = 0.04$ sec									
Target Outcrop PGA(g)	Median Outcrop PGA(g)	Median Outcrop PGV(cm/sec)	Median Outcrop PGD(cm)	Median Outcrop V/A (cm/sec/g)	Median Outcrop AD/V^2 ($gcm/cm/sec^2$)	Dist. (km)	Depth (km)	M	$\Delta\sigma$ (bars)
0.05	0.05	3.99	1.50	81.40	4.53	70.00	8.00	6.5	110
0.10	0.10	8.17	2.99	78.90	4.56	35.00	8.00	6.5	110
0.20	0.20	15.50	5.64	77.90	4.58	18.00	8.00	6.5	110
0.30	0.31	24.27	8.80	77.45	4.59	10.00	8.00	6.5	110
0.40	0.41	31.31	11.34	77.24	4.60	6.00	8.00	6.5	110
0.50	0.51	39.03	14.12	77.09	4.60	1.00	8.00	6.5	110
0.75	0.78	59.92	21.63	76.78	4.61	1.00	5.20	6.5	110

Q(f) = 351 $f^{0.84}$ (based on Saguenay inversions, Silva et al., 1997)
Kappa = 0.040 sec

Table 6 PROFILE DEPTH CATEGORIES	
Category (ft)	Depth Range (ft)
125	80 - 180
250	180 - 400
500	400 - 750
1,000	750 - 1,500
Base Cases	
Categories C and D	100 - 1,000
Category E	100 - 650

Abstract in SRL
1996

WHAT'S BEEN HAPPENING AT THE ROCKY MOUNTAIN ARSENAL?

BOTT, J.D.J. and WONG, I.G., Woodward-Clyde Federal Services, 500 12th Street, Suite 100, Oakland, CA 94607, igwongx0@wcc.com; AKE, J., U.S. Bureau of Reclamation, Denver Federal Center, Denver, CO 80225; BUTLER, D., Microgeophysics Corporation, 10900 W. 44th Avenue, Wheat Ridge, CO 80033

Beginning in April 1962, seismicity was observed near a 3671-m deep well at the Rocky Mountain Arsenal (RMA) near Denver, Colorado. This activity resulted from the injection of waste fluids into the well and continued up through at least 1981 despite cessation of the fluid injection in 1966. During this 20-year period, over 30 events of $m_b \geq 4.0$ occurred, 12 of which were damaging (MM > VI). A number of studies were performed to investigate this induced seismicity, the most recent being an analysis of a damaging m_b 4.3 earthquake and its aftershocks in 1981 (Bollinger *et al.*, 1983). Based on these studies, the source of the RMA seismicity appeared to be a northwest-striking Precambrian basement fault zone which was reactivated between the depths of 3 to 10 km.

Recently, due to an increased awareness of seismic hazards in Colorado, there has been a renewed interest in the RMA seismicity. Thus as part of a safety evaluation for several dams along the Front Range, we have attempted to evaluate whether the RMA fault zone is currently active and its maximum earthquake potential. We reanalyzed the available data from a microearthquake network which has been operated by Microgeophysics Corp. (MGC) in the Front Range since 1983. The focus of our study was seismicity that occurred east of the Front Range from 1983-1993 in the Denver area. Unfortunately, because the MGC stations were all located west of Denver, event locations were hindered by poor azimuthal coverage. Despite location uncertainties, our relocations of selected events using a master event technique indicate activity is still occurring at least up through 1993 at the RMA. The northeast-southwest-trending T-axes of previously determined RMA focal mechanisms (Herrmann *et al.*, 1981) are generally consistent with mechanisms of tectonic earthquakes that we have determined in the past decade in western and central Colorado. Although observations to date do not indicate that a single rupture plane is solely responsible for the RMA seismicity, conservative estimates of a maximum length of 13 km and a width of 7 km are consistent with a maximum earthquake of M_w 6. This value has been used in our seismic hazard studies for ground motion estimation.

1) Ivan Wong, Woodward-Clyde Federal Services, 500 12th Street, Oakland, CA 94607; (510) 874-3014
2) Wong 12141
3) N/A
4) Poster or oral acceptable
5) None

H:\ADMIN\WONG\ABSTRACT\SSA96.IGW

TABLE 4-3

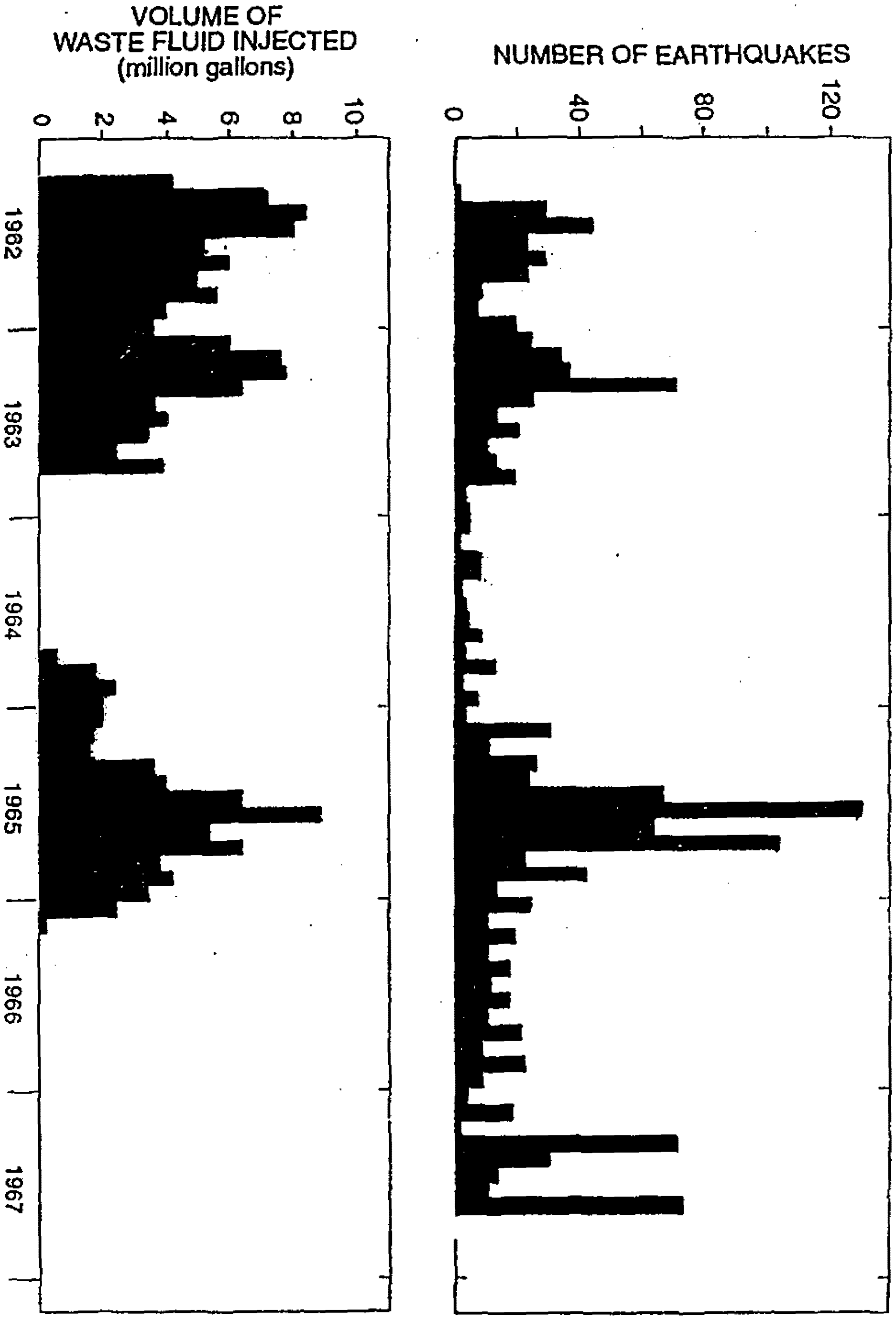
SIGNIFICANTLY DAMAGING RMA EARTHQUAKES*

Date	Magnitude	Maximum MM Intensity	Felt Area (km^2)	Region of Maximum MM Intensity	Damage
4 December 1962	M_L 3.5	VI	12,000	Dupont, Irondale and west Denver	Broken Windows
5 December 1962	M_L 3.8	VI	16,400	Derby, Dupont	Cracked Wall and Plaster
16 February 1965	M_L 3.0 m_b 4.9	VI	700	Northglenn	Cracked Walls
14 September 1965	M_L 3.6 m_b 4.7	VI	2,700	Commerce City, Broomfield, Derby and Denver	Cracked Plaster and Chimneys; Broken Dishes and Windows
29 September 1965	M_L 3.6 m_b 4.7	VI	3,700	Northglenn, Commerce City and Denver	Cracked Plaster and Windows
21 November 1965	M_L 3.8 m_b 4.5	VI	6,900	Commerce City, Hudson, Louisville, Northglenn, Thornton and Westminister	Broken Windows and Cracked Plaster
14 November 1966	M_L 3.5 m_b 4.4	VI	3,900	Commerce City, Eastlake	Cracked Plaster
10 April 1967	m_b 4.9 m_{bLg} 4.3 M_S 4.2	VI	16,000	Denver Metro Area	Cracked Plaster, Windows, Chimneys and Foundations; Broken Pipes
27 April 1967	M_L 3.8 m_b 4.5	VI	3,800	Commerce City, Boulder	Cracked Walls and Ceiling Tiles
9 August 1967	M_S 4.4 m_b 5.3 m_{bLg} 4.9 ?	VII	50,000	Northglenn	Broken Windows; Cracked Ceilings, Walls, Foundations and Concrete Floors; Merchandise Destroyed in Businesses
27 November 1967	m_b 5.2 m_{bLg} 4.6	VI	56,000	Twenty Locations in Denver and Boulder Areas	Cracked Plaster
2 April 1981 ?	m_b 4.3 M_L 3.8 M_N 4.5	VI	7,000	North Denver	Cracked Plaster, Drywall, and Cinder Block Walls

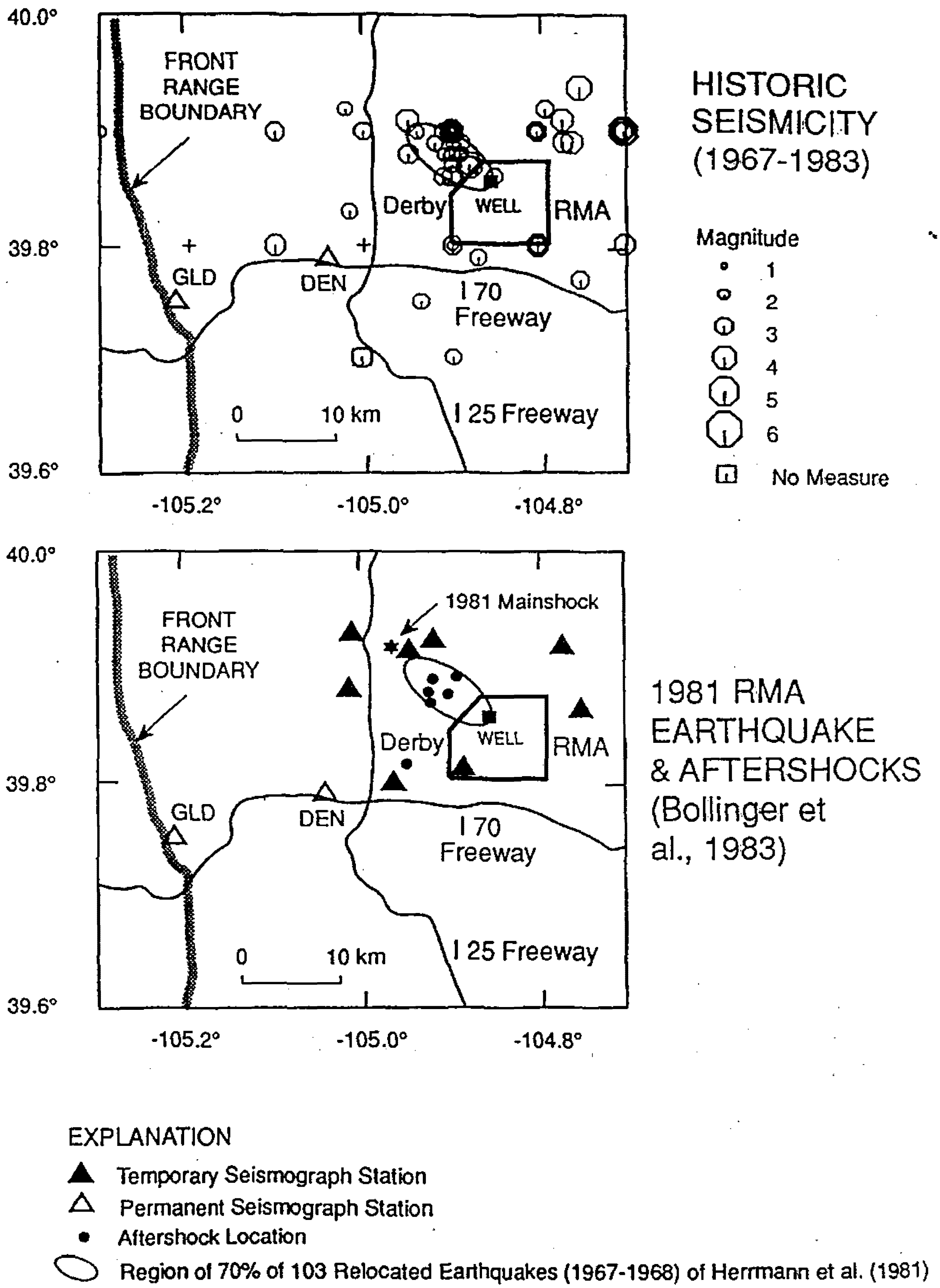
* Compiled from Kirkham and Rogers (1985)

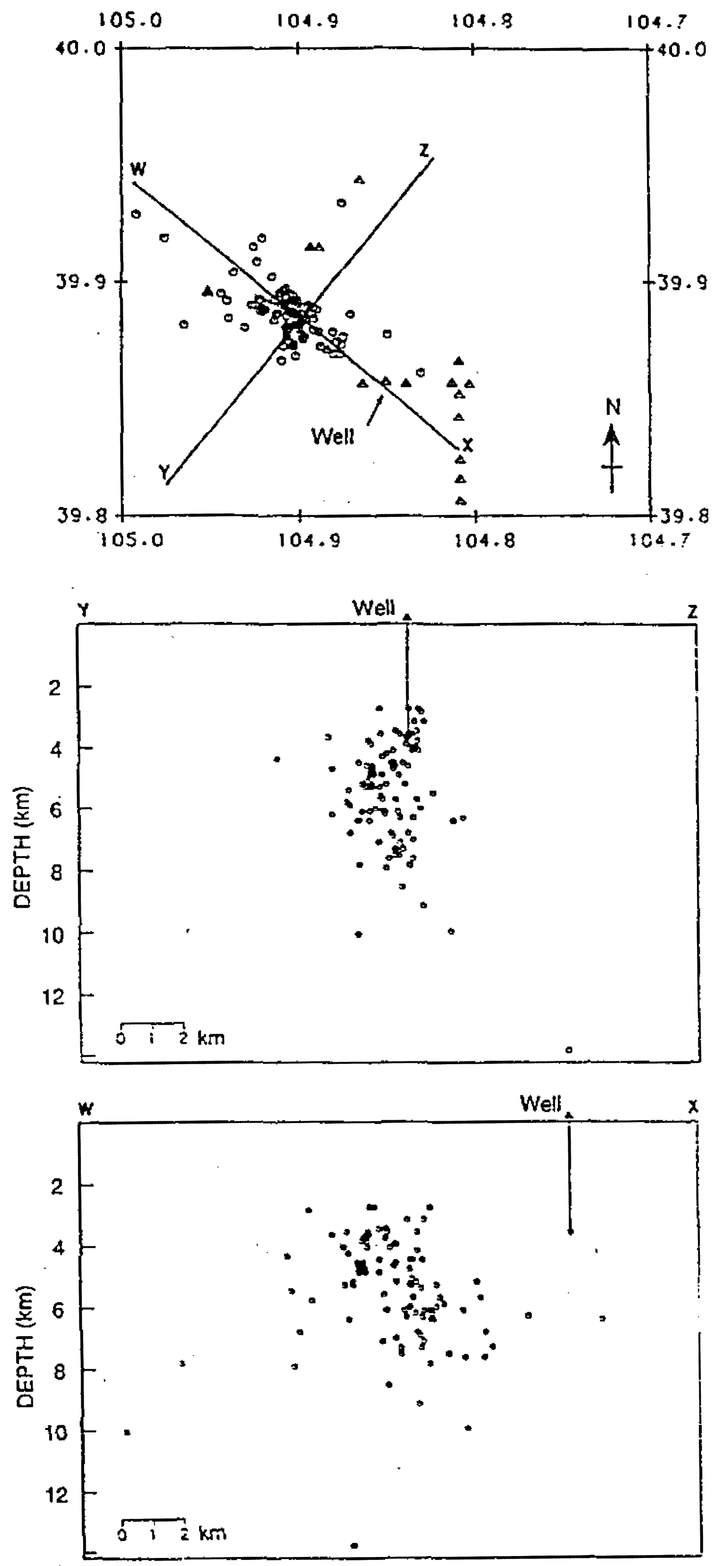
M_L = Richter
m_b = body-wave (P-wave)
M_S = surface-wave

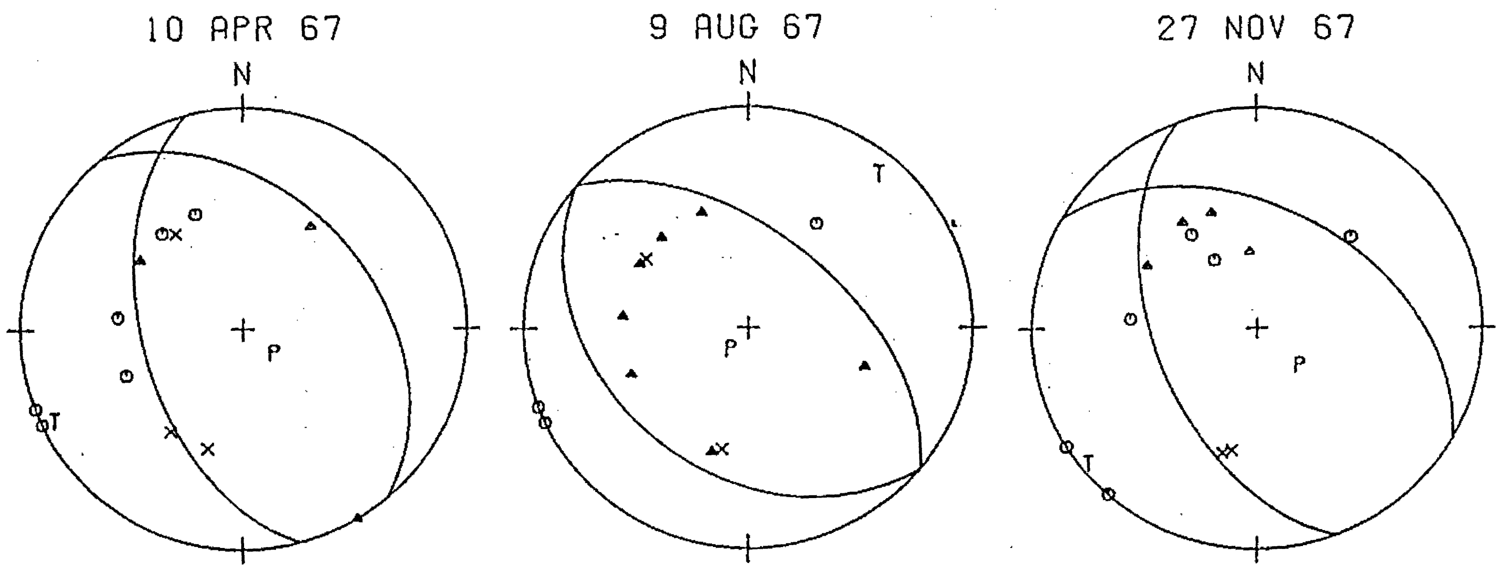
m_{bLg} = body wave magn. using Lg wave ?



VOLUME OF
WASTE FLUID INJECTED
(million gallons)
NUMBER OF EARTHQUAKES
0
2
4
6
8
10
0
40
80
120
1962
1963
1964
1965
1966
1967


40.0°
39.8°
39.6°
-105.2°
-105.0°
-104.8°
FRONT RANGE BOUNDARY
GLD
DEN
Derby
WELL
RMA
I 70 Freeway
I 25 Freeway
0
10 km
HISTORIC SEISMICITY (1967-1983)
Magnitude
1
2
3
4
5
6
No Measure
1981 Mainshock
1981 RMA EARTHQUAKE & AFTERSHOCKS (Bollinger et al., 1983)
EXPLANATION
Temporary Seismograph Station
Permanent Seismograph Station
Aftershock Location
Region of 70% of 103 Relocated Earthquakes (1967-1968) of Herrmann et al. (1981)


105.0
104.9
104.8
104.7
40.0
39.9
39.8
W
Z
Y
X
Well
N
Y
Z
Well
DEPTH (km)
2
4
6
8
10
12
0 1 2 km
W
X
Well
DEPTH (km)
2
4
6
8
10
12
0 1 2 km

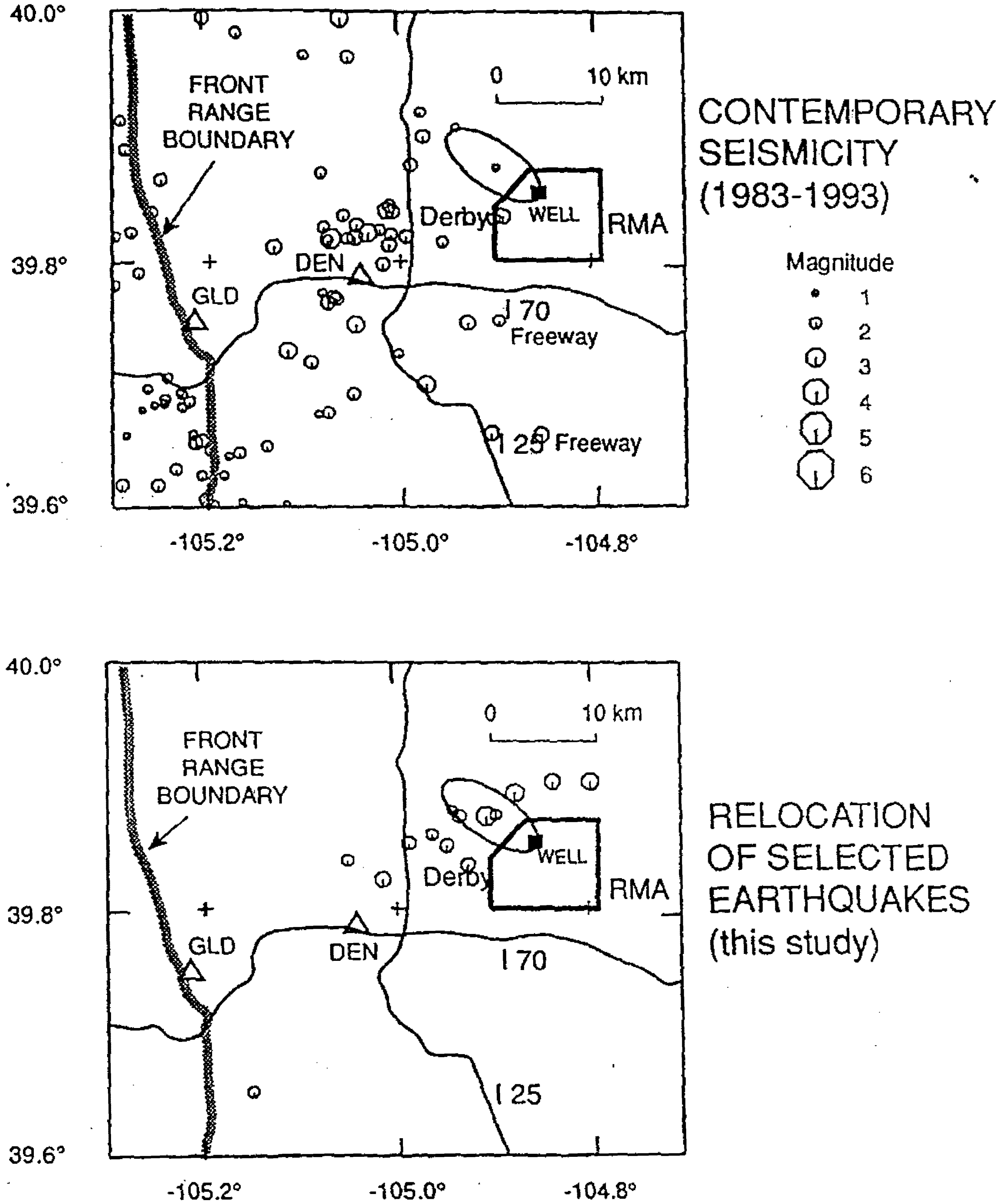


EXPLANATION

△ Dilatational

o Compressional

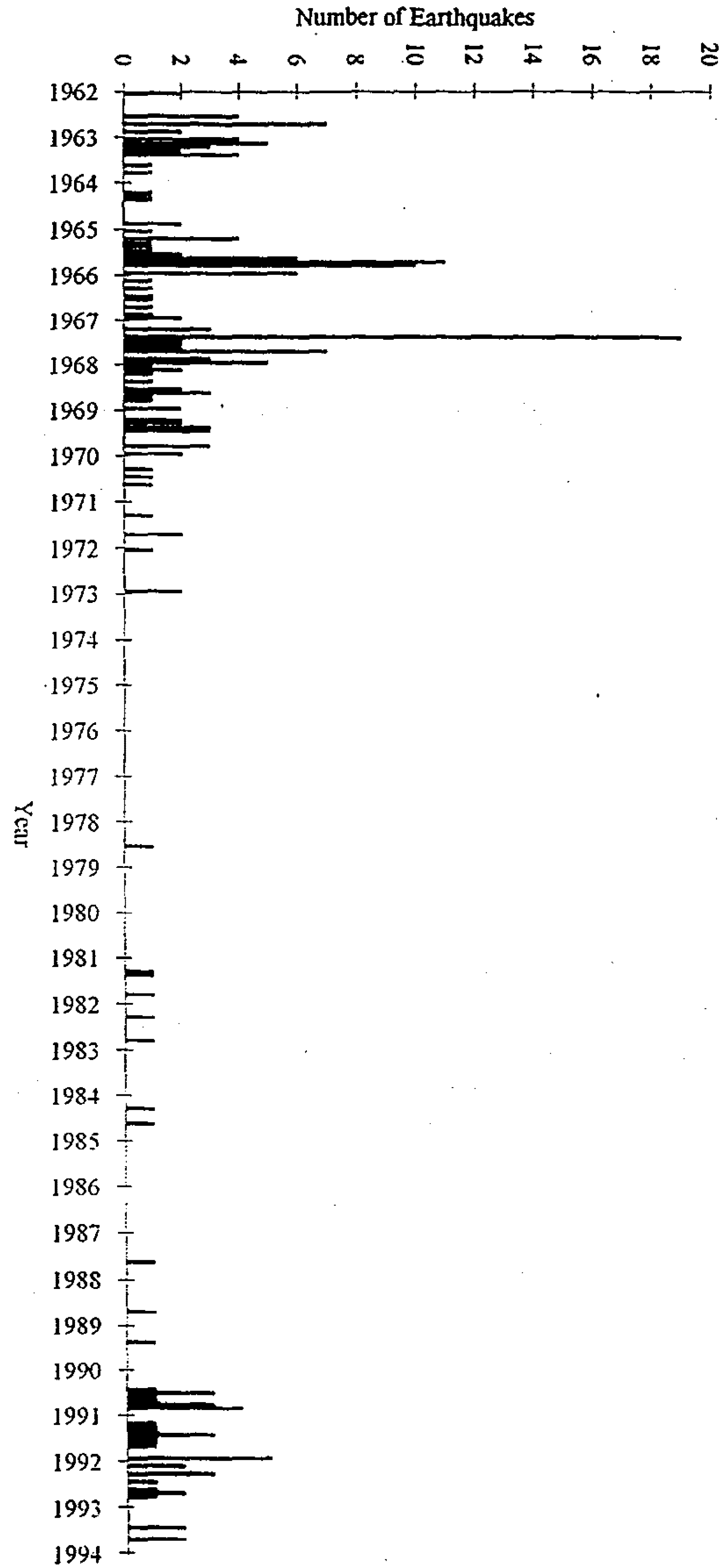
x Nodal



EXPLANATION

△ Seismograph Station

⬭ Region of 70% of 103 Relocated Earthquakes (1967-1968) of Herrmann et al. (1981)


Number of Earthquakes
0
2
4
6
8
10
12
14
16
18
20
Year
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994

SUMMARY

- Beginning in April 1962, seismicity has been observed at the RMA near Denver resulting from waste fluid injection into a 3671-m-deep well.

- Activity has continued up through at least 1981 despite cessation of the fluid injection in 1966.

- During this 20-year period, over 30 events of $m_b \geq 4.0$ have occurred, 12 of which were damaging (MM > VI).

- The source of the RMA seismicity appears to be a northwest-striking Precambrian basement fault zone which has been reactivated between the depths of 3 to 10 km.

- We reanalyzed the available data from the MGC microearthquake network which has operated in the Front Range since 1983.

SUMMARY (CONT.)

- Despite location uncertainties, our relocations of selected events using a master event technique indicate activity is still occurring at least up through 1993 at the RMA.

- The northeast-southwest-trending T-axes of previously determined RMA focal mechanisms are generally consistent with mechanisms of tectonic earthquakes in western Colorado.

- Although observations to date do not indicate that a single rupture plane is solely responsible for the RMA seismicity, conservative estimates of a maximum length of 13 km and a width of 7 km are consistent with a maximum earthquake of M_W 6.

Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California

David J. Wald, M.EERI, Vincent Quitoriano, Thomas H. Heaton, M.EERI, and Hiroo Kanamori, M.EERI

We have developed regression relationships between Modified Mercalli Intensity (I_{mm}) and peak ground acceleration (PGA) and velocity (PGV) by comparing horizontal peak ground motions to observed intensities for eight significant California earthquakes. For the limited range of Modified Mercalli intensities (I_{mm}), we find that for peak acceleration with V $\leq I_{mm} \leq$ VIII, $I_{mm} = 3.66\ log(PGA) - 1.66$, and for peak velocity with V $\leq I_{mm} \leq$ IX, $I_{mm} = 3.47\ log(PGV) + 2.35$. From comparison with observed intensity maps, we find that a combined regression based on peak velocity for intensity > VII and on peak acceleration for intensity < VII is most suitable for reproducing observed I_{mm} patterns, consistent with high intensities being related to damage (proportional to ground velocity) and with lower intensities determined by felt accounts (most sensitive to higher-frequency ground acceleration). These new I_{mm} relationships are significantly different from the Trifunac and Brady (1975) correlations, which have been used extensively in loss estimation.

INTRODUCTION

Seismic intensity has traditionally been used worldwide as a method for quantifying the shaking pattern and the extent of damage for earthquakes. Though derived prior to the advent of today's modern seismometric instrumentation, it nonetheless provides a useful means of describing, in a simplified fashion, the complexity of ground motion variations found on instrument recordings. Seismic intensity is still often the only observed parameter from which to quantify the level of ground shaking following damaging earthquakes in much of the world. In the United States, it has been used historically, and will very likely be used after future earthquakes. While advances in loss estimation in recent years now allow for the direct use of recorded ground motion parameters (e.g., Kircher et al., 1997; NIBS, 1997), seismic intensities will continue to be of value for post-earthquake analyses. As an example, seismic intensity maps for the 1994 Northridge, California earthquake have provided perhaps the most detailed descriptions of the variations of shaking and damage available (e.g., Dewey et al., 1995; Thywissen and Boatwright, 1998; Hales and Dengler, 1998).

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We have developed regression relationships between Modified Mercalli intensity (I_{mm}, Wood and Neumann, 1931, later revised by Richter, 1958) and PGA or PGV by comparing the recorded peak ground motions to observed intensities for eight significant California earthquakes. The eight events, the 1971 (M6.7) San Fernando, the 1979 (M6.6) Imperial Valley, the 1986 (M5.9) North Palm Springs, the 1987 (M5.9) Whittier Narrows, the 1989 (M6.9) Loma Prieta, the 1991 (M5.8) Sierra Madre, the 1992 (M7.3) Landers, and the 1994 (M6.7) Northridge earthquakes, were chosen because they were well recorded by regional strong motion networks in addition to having numerous intensity observations (Dewey, written communication, 1997).

Since the earlier studies (e.g., Trifunac and Brady, 1975), there is now substantially more strong motion data available, particularly at larger ground motion amplitudes, for such a comparison. Also, in earlier studies, these relations were derived based on taking the intensity value from a map at the location of the strong motion station when no observation was available near the strong motion site. Yet I_{mm} maps are typically simplified representations of a spatially variable field, and the true I_{mm} value at the strong motion recording site is not usually known, so there is no guarantee that the I_{mm} at the strong motion station location corresponds with the I_{mm} value on the contour map. Here, we chose to correlate only those values where the strong motion station is near (within 3 km) an I_{mm} observation. For each station, the nearest intensity observation is chosen; if it is not within 3 km, however, then the strong motion data at that site is not used for correlation purposes. Although ground motions can vary significantly over this distance, futher reducing the correlation distance significantly reduces the available pairing of data.

Earlier comparisons of peak ground motions and intensities were also based primarily on regressions of intensity against peak acceleration, or in a few cases, against peak velocity and displacement. Part of our goal is to derive a relationship that can be used to estimate seismic intensity rapidly given instrumental recordings of ground motions (see Wald et al., 1999a). For this reason, one significant difference from previous studies is that here we chose to use both peak acceleration and velocity jointly, recognizing the saturation of PGA at high intensities, and the frequency and amplitude-dependent nature of the intensity scale as manifested by both felt shaking descriptions and actual damage.

REVISED PEAK GROUND MOTION VERSUS INTENSITY RELATIONS

We summarize the correlation of I_{mm} values and PGA for each of the individual earthquakes analyzed in Figure 1; Figure 2 shows a similar plot for PGV. The correlation and regressions of I_{mm} versus PGA and PGV for the data from all eight earthquakes combined are shown in Figures 3 and 4, respectively.

While there is no fundamental reason to expect a simple relationship between Modified Mercalli intensity (I_{mm}) and recorded ground motion parameters, over a range of accelerations and velocities a simple power-law representation is adequate and convenient. We find that for PGA in the limited range of V $\leq I_{mm} \leq$ VIII,

$$I_{mm} = 3.66\ log(PGA) - 1.66 \quad (\sigma = 1.08) \tag{1}$$

and for peak velocity (PGV) within the range V $\leq I_{mm} \leq$ IX,

$$I_{mm} = 3.47\ log(PGV) + 2.35 \quad (\sigma = 0.98) \tag{2}$$

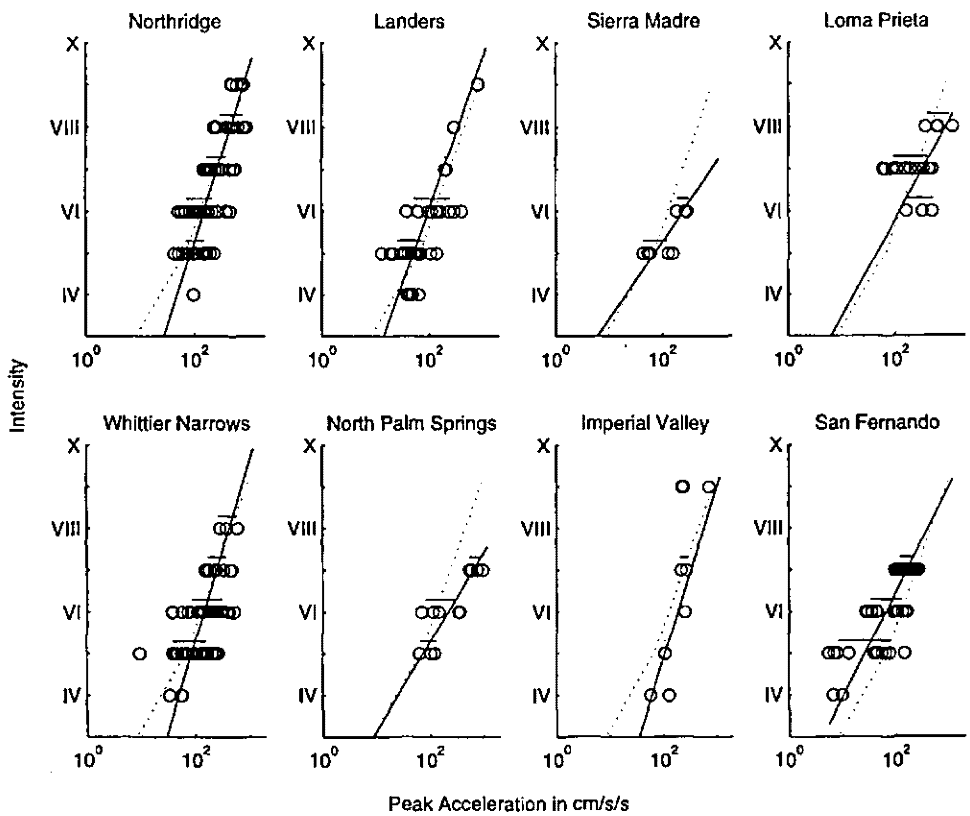

Figure 1. Modified Mercalli intensity plotted against peak ground acceleration for individual earthquakes. Circles denote data, horizontal lines above data depict the range of the geometric mean, plus and minus one standard deviation. Solid line is the regression for individual events; dotted line is regression for events combined.

The correlation coefficients (r) for Equations 1 and 2 are 0.597 and 0.686, respectively. Here the regressions are made on the geometric mean of the peak horizontal ground motion values for a given intensity unit. For acceleration, I_{mm} IX is not used in the regression since the peak acceleration values appear to saturate, and hence a simple power-law relation will not suffice. Likewise at I_{mm} IV, PGA and PGV are biased high due to lack of digitization of data from stations with lower values and hence they are not used in the regression. For I_{mm} IV, peak velocities do not continue decreasing, suggesting perhaps not only the above-mentioned bias, but also that a higher noise level (likely introduced in the integration of digitized recordings) may be controlling the peak values.

Requiring that the ground motion recording sites and I_{mm} observation points have similar surface geology, in addition to the maximum distance requirement, did not significantly reduce the scatter shown in Figures 3 and 4. However, this may be a limitation of the map scale used in the geology classification (1:750,000; Park and Ellrick, 1998), and a more detailed association of the geology at the strong motion sites and intensity

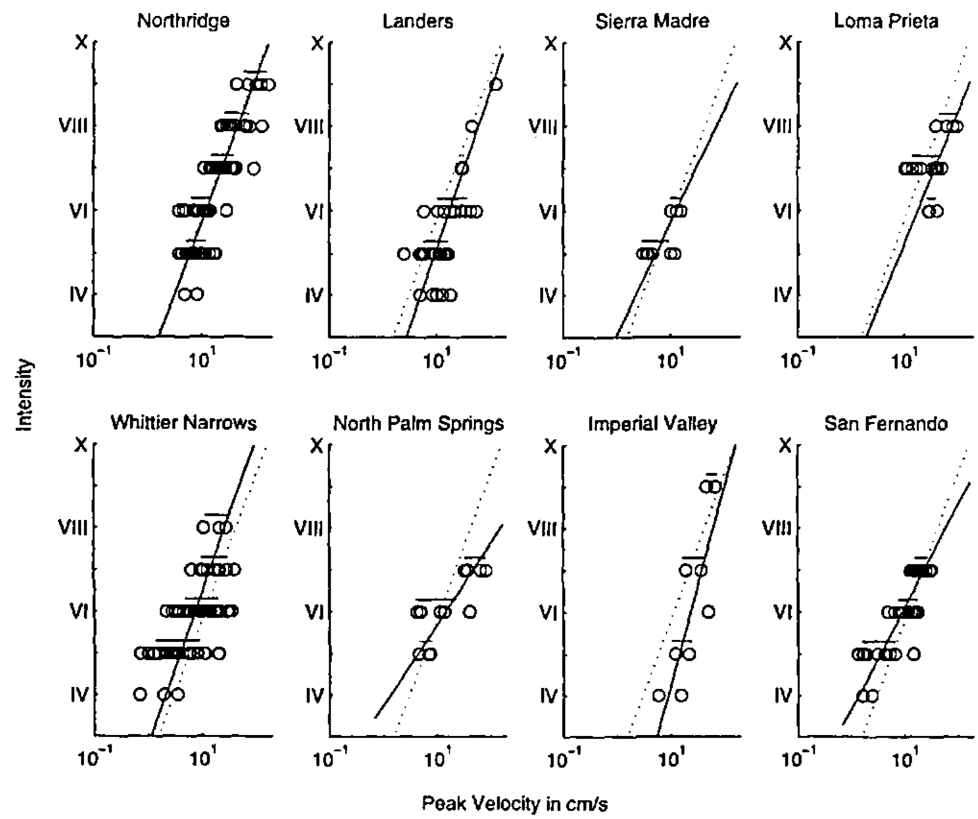

Figure 2. Modified Mercalli intensity plotted against peak ground velocity for individual earthquakes. Circles denote data, horizontal lines above data depict the range of the geometric mean, plus and minus one standard deviation. Solid line is the regression for individual events; dotted line is regression for events combined.

observations may be useful. Naturally, though, the association of an instrumental, point measurement of ground motion with an intensity observation defined as the maximum or average over a designated areal extent would be expected to show substantial scatter, particularly if the area does not contain the point measurement. This is a fundamental limitation originating from the definition of seismic intensity which requires an (unspecified) area be assigned a given intensity value based on the representative or average level of damage in the region; any single point observation in that area is not sufficient to satisfy such a definition.

As seen in Figures 3 and 4, low levels of shaking intensity correlate fairly well with both PGA and PGV, while high intensities correlate best with peak velocity. Basically, peak acceleration levels off at high intensity while peak velocity continues to grow. In contrast, the ground velocities, derived by integration of digitized analog accelerograms, are noisier at low levels of motion and the scatter is somewhat larger. By comparing maps of instrumental intensities with I_{mm} for the eight above-mentioned earthquakes, we have found that a relationship that follows acceleration for I_{mm}<VII and follows velocity

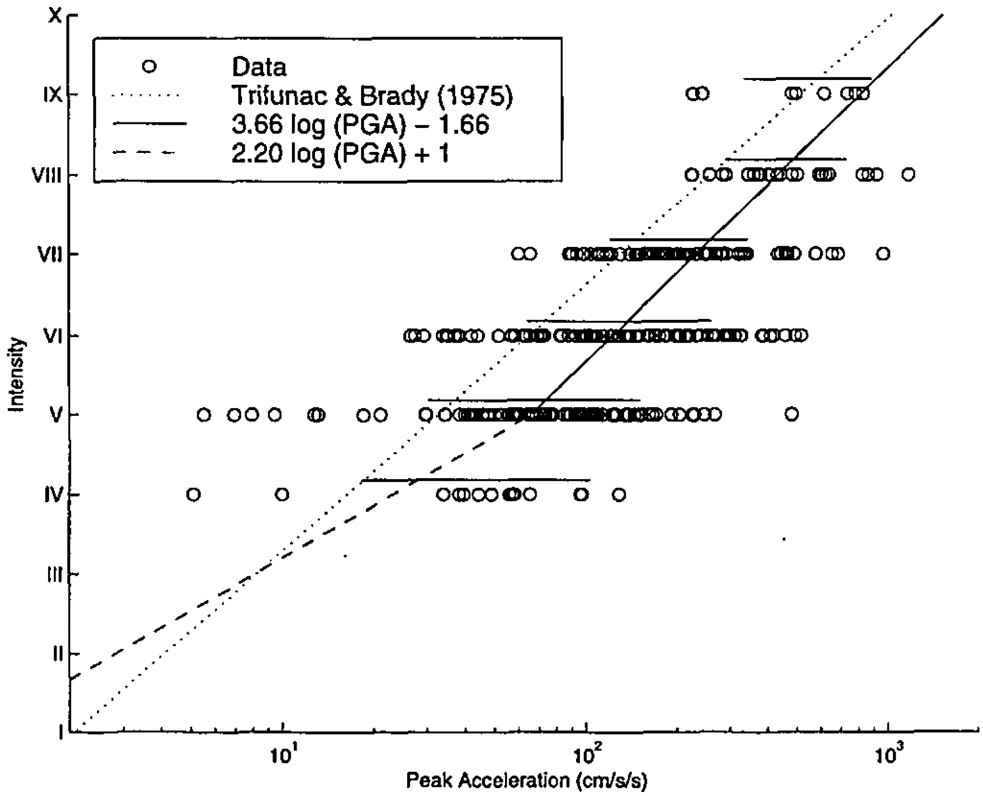

Figure 3. Modified Mercalli intensity plotted against peak ground acceleration for all events combined. Circles denote data; horizontal lines above data depict the range of the geometric mean, plus and minus one standard deviation. The solid line is regression from this study, the dashed line is assigned (see text for details). The dotted line is that of Trifunac and Brady (1975).

for I_{mm}>VII works fairly well in reproducing the observed I_{mm}.

Using peak acceleration to estimate low intensities is intuitively consistent with the notion that lower (<VI) intensities are assigned based on felt accounts, and people are more sensitive to ground acceleration than velocity. Higher intensities are defined by the level of damage; the onset of damage at the intensity VI to VII range is usually characterized by brittle-type failures (masonry walls, chimneys, unreinforced masonry, etc.) which are sensitive to higher-frequency accelerations. With more substantial damage (VII and greater), failure begins in more flexible structures, for which peak velocity is more indicative of failure (e.g., Hall et al., 1995). Our assumption is consistent with the recent analysis of Sokolov and Chernov (1998) which showed that seismic intensities correlate well for rather narrow ranges of Fourier amplitude spectra of ground acceleration, with 0.7-1.0 Hz being most representative of I_{mm} > VIII, while the 3-6 Hz range best represents I_{mm} V to VII; the 7-8 Hz range best correlates with the lowest I_{mm} range. In addition, Boatwright et al. (1999) have found that for the Northridge earthquake, PGV and the 3-0.3 Hz averaged spectral velocity are better correlated with intensity (VI and greater) than peak acceleration, and their correlation with intensity and peak spectral

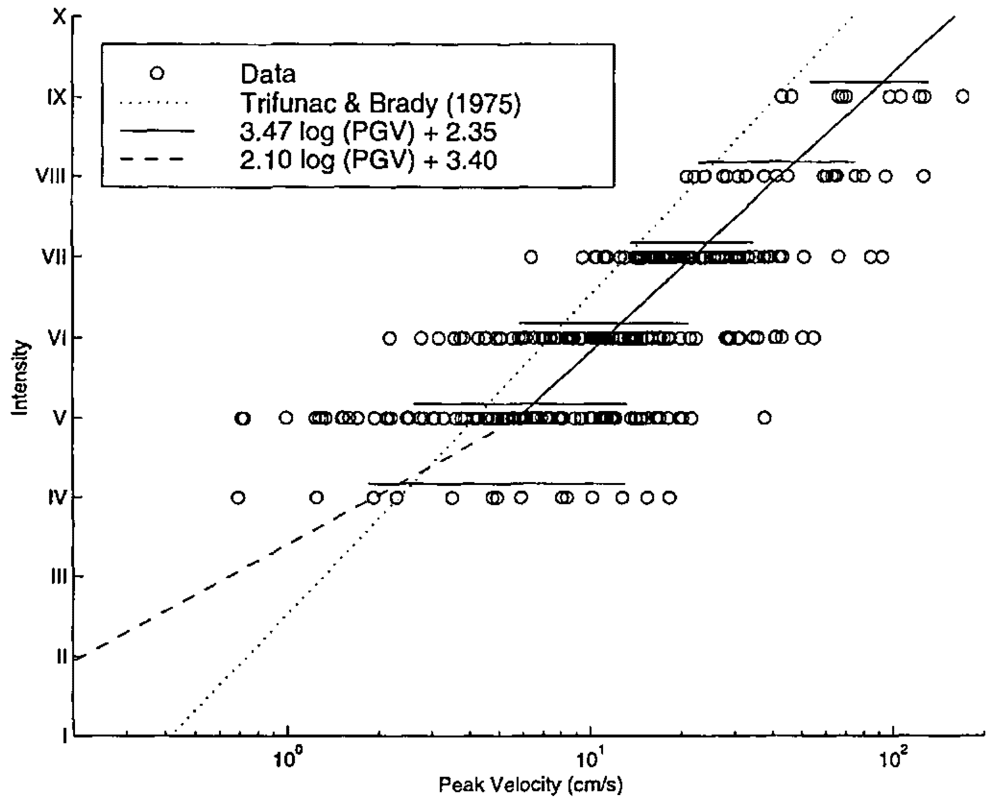

Figure 4. Modified Mercalli intensity plotted against peak ground velocity for all events combined. Circles denote data; horizontal lines above data depict the range of the geometric mean, plus and minus one standard deviation. The solid line is regression from this study, the dashed line is assigned (see text for details). The dotted line is that of Trifunac and Brady (1975).

velocity is strongest at 0.67 Hz.

While the range of $I_{mm}>$ V is well fit by a power law relation, this trend does not hold for lower intensities. Since we are also interested in estimating intensity at lower values with the peak ground motions, and our current collection of data from historical earthquakes does not provide constraints for lower intensity, we have imposed the following relationship (shown as a dashed line in Figure 3) between PGA and I_{mm}:

$$I_{mm} = 2.20\ log(PGA) + 1.00 \tag{3}$$

The basis for the above relationship comes from correlation of TriNet peak ground motions recordings for recent magnitude 3.5 to 5.0 earthquakes with intensities derived from voluntary response from Internet users (Wald et al., 1999b) for the same events. We determined that the boundary between "not felt" and "felt" (I_{mm} I and II, respectively) regions corresponds to approximately one-to-two cm/sec/sec, at least for this range of magnitudes. We then assigned the slope such that the curve would intersect the relationship in Equation (1) at I_{mm} equal to V. We plan to refine this relationship as more digital data become available. The corresponding equation for PGV and I_{mm} (shown as a dashed line in Figure 4) is:

$$I_{mm} = 2.10\ log(PGV) + 3.40 \tag{4}$$

Table 1 gives the peak ground motion ranges that correspond to each unit Modified Mercalli intensity value according to our regression of the observed peak ground motions and intensities for California earthquakes.

Table 1. Ranges of ground motions for Modified Mercalli Intensities

Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+
Peak Accel. (% g)	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
Peak Velocity (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116

DISCUSSION

For a given ground motion level, our intensities are lower than the commonly used relationships of Trifunac and Brady (1975), which are also displayed on Figures 3 and 4. Only data from the 1971 San Fernando earthquake are common; our data are from 1971 forward, while that of Trifunac and Brady (1975) contains data from the San Fernando and prior earthquakes. In general, the main differences are due to the addition of new data since the Trifunac and Brady (1975) study. However, for acceleration, part of the difference is that we do not include the intensity IX (or larger) values in the regression, due to the evidence of amplitude saturation, whereas Trifunac and Brady (1975) used an intensity X value. Likewise, for velocity, we did not use lower intensity values ($I_{mm} \leq$ IV) for the regression whereas Trifunac and Brady (1975) did so.

It is notable that the relationship of Trifunac and Brady (1975) indicated lower intensities for a given ground motion level than most earlier estimates (see Trifunac and Brady, 1975, Figure 3), and now our relationship indicates yet lower intensity levels associated with the same peak ground motion. There are a number of factors that may influence this trend, and certainly more densely spaced recordings in the near-fault region of the recent events, particularly for the Northridge earthquake, do presumably favor a more accurate portrayal of the relationship. However, building practices have certainly improved since the earlier events, altering the association of shaking and damage, and there are fewer brittle structures that are easily damaged at moderate levels of ground acceleration. Hence, it may be natural that such empirical relationships change with time, though further examination of this trend is in order.

The relationships we have developed are now used to generate maps of estimated shaking intensities within a few minutes of the event based on the recorded peak motions (see Wald et al., 1999a). In practice, we compute the I_{mm} from the I_{mm} verses PGA relationship; if the intensity value determined from peak acceleration is $\geq$ VII, we then use the value of I_{mm} derived from the I_{mm} verses PGV relationship. These maps provide a rapid portrayal of the extent of potentially damaging shaking following an earthquake and can be used for emergency response, loss estimation, and for public information through the media.

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Loss-Estimation Modeling of Earthquake Scenarios for Each County in Nevada Using HAZUS-MH

Ronald H. Hess
Craig M. dePolo

This information should be considered preliminary.
It has not been edited or checked for completeness
or accuracy

Loss-Estimation Modeling of Earthquake Scenarios for Each County in Nevada Using HAZUS-MH

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One of the first pieces of information needed in disaster planning, preparedness, and response is a general estimate of potential damage and costs of an event, such as an earthquake. Nevada has a relatively high level of earthquake hazard, but that hazard is not evenly distributed throughout the state. The characteristics of the population, infrastructure, and societal resources vary dramatically across the state as well. In order to understand the potential consequences of earthquakes in Nevada, we have run an earthquake loss-estimation model (Level 1 of the Federal Emergency Management Agency's HAZUS-MH computer program) for each county seat. A fault that is a likely source of an earthquake was selected near each community. How often such an earthquake may occur, a parameter that varies from thousands to tens of thousands of years, was not considered in this study. In all cases we do not know when the next earthquake will occur, only that it will happen sometime. The earthquake scenario allows us to see what could happen when an earthquake does occur nearby.

HAZUS-MH is a standardized, nationally recognized software program that was designed for the Federal Emergency Management Agency to estimate losses from potential earthquakes and other disasters. It is used for exercises, planning efforts, and disaster declarations. HAZUS-MH estimates losses at three levels of accuracy, Levels 1, 2, and 3.

Level 1: A rough estimate based solely on data from national databases included in the HAZUS-MH software distribution. The national databases that come with HAZUS-MH include Census 2000 demographic data, building stock estimates, earthquake fault data, historical earthquake information, and national transportation and infrastructure data layers.

Level 2: A more accurate estimate based on professional judgment and detailed information on local geology, more up-to-date demographic data, and greater detail on the buildings and other infrastructure within the community that are input into HAZUS-MH at the local level.

Level 3: The most accurate estimate based on detailed engineering and geotechnical input into HAZUS-MH that develops into a customized methodology designed to the specific conditions of a community.

This report summarizes HAZUS-MH Level I analyses, which use the default national data set within the computer model. Level 1 analyses are crude, order-of-magnitude estimates that should be used for risk communication, conceptual preparation, and generalized planning (e.g., on a state level or for a disaster mitigation plan). For more detailed disaster or mitigation planning, a Level 2 or 3 analysis is needed. All county scenarios in this report were run using the WUS shallow crustal event-extensional attenuation function, an option within HAZUS-MH that is applicable in Nevada.

Table 1 lists the counties and county seats analyzed in this study. Table 2 shows the results of the HAZUS-MH runs for each county seat. This table shows both county-specific damage estimates as well as regional estimates. As expected, the potential losses vary dramatically across the state. Earthquakes considered range in magnitude from 6.5 to 7.5, the general range of historical damaging earthquakes in Nevada. Possible economic losses range from about $280,000 in Goldfield to $8.8 billion in Las Vegas.

Keep in mind these are only crude, order-of-magnitude estimates. That is, any given number may be off by a factor of as much as 10, although HAZUS runs for real earthquakes in recent years have been within a factor of two. Significant potential economic losses, on the order of tens of millions of dollars, are indicated for most communities in Nevada. Potential major building damage per event ranges from four buildings (in the Goldfield region) to 30,000 buildings (in the Las Vegas area). Unfortunately, an accurate inventory of building stock is not available for the Level 1 analysis and statistical estimates are usually used. Fatalities are extremely difficult to predict because they are dependent on time of day, what buildings or structures people are in, and how people behave. These factors can vary wildly and dramatically affect the number of casualties listed for a potential earthquake. There is no record of anyone being killed during a historical Nevada earthquake, but this is going to be a hard record to keep in the future. Possible fatalities in future earthquakes range from none to as many as 800 people. The number of people needing shelter, a critical issue in some weather situations in Nevada, ranges from none to 11,000. The different levels of potential earthquake consequences require different levels and types of preparedness across the state, and it is this needed visualization that makes these county seat scenarios of immediate value for the local communities and for state contingency planning.

Table 2 also includes, in the last two fields, the probability of experiencing an earthquake of a given size or greater over a 50-year period within 50 kilometers (31 miles) of the county seat. These data come from maps that were generated using the U.S. Geological Survey PSHA (Probabilistic Seismic Hazard Analysis) Model, which is presented at http://eqint.cr.usgs.gov/eq/html/eqprob.html. The actual maps that the values were taken from can be viewed online at www.nbmg.unr.edu/eqprob/eqprob.htm.

The attached reports include, for each county, a HAZUS-MH produced Pga (peak ground acceleration) ground motion map that shows the location of the selected scenario event for each county; a one-page summary estimating anticipated damages that would occur if the earthquake struck in the early afternoon; and a detailed summary listing the population, building stock, and infrastructure inventory that is at risk and the various impacts that the designated earthquake might have on these resources. The county Pga ground motion maps, located at the beginning of each county section, show the maximum acceleration (a measure of the intensity of shaking) that would be expected during the course of the earthquake, generally decreasing with distance from the hypocenter (initial rupture point of the earthquake). The hotter or redder colors on the map are the areas of strongest shaking from the scenario earthquake, and the cooler colors (blue, green, and gray) are areas of less shaking.

It is important to understand that while the summaries contained in this report are county specific, i.e., only showing the impacts that an earthquake will have on a single county; large earthquakes generally have regional effects that can cover many counties. So, in addition to the individual county summaries contained within this report, there are several regional summaries depicting the multi-county effects of an earthquake from a regional perspective. These include multi-county scenarios for events in Douglas County, Storey County, Washoe County and Carson City. The multi-county scenarios are located immediately following the single county scenario for each of the respective counties. Table 2 provides a quick comparison of the expected losses in the county alone versus the multi-county region.

"A Guide to Using HAZUS for Mitigation" is located at the end of this report. This guide, produced by the National Institute of Building Sciences for the Federal Emergency Management Agency, will help you understand and interpret the various types of information that HAZUS-MH produces. It also identifies various ways that communities can use this information for earthquake mitigation planning.

Table 1: List of Nevada County Seats.

CARSON CITY - STATE CAPITAL
CLARK COUNTY - Las Vegas
CHURCHILL COUNTY – Fallon
DOUGLAS COUNTY – Minden
ESMERALDA COUNTY – Goldfield
HUMBOLDT COUNTY – Winnemucca
LYON COUNTY - Yerington
WHITE PINE COUNTY – Ely
NYE COUNTY - Tonopah
ELKO COUNTY – Elko
EUREKA COUNTY – Eureka
LANDER COUNTY - Battle Mountain
LINCOLN COUNTY – Pioche
MINERAL COUNTY – Hawthorne
PERSHING COUNTY – Lovelock
STOREY COUNTY - Virginia City
WASHOE COUNTY - Reno

Table 2: Summary of loss-estimation output for earthquake scenarios that may affect counties in Nevada, using FEMA's HAZUS model.

County	County Seat	Earthquake Scenario Magnitude	Economic Loss (estimated in multi-county region) In billions of $	Building-Related Economic Loss (estimated in county alone)	Buildings with Major Damage (estimated in multi-county region)	Buildings with Major Damage (estimated in county alone)	Fatalities (estimated in multi-county region)	Fatalities (estimated in county alone)	Number of People Needing Public Shelter (estimated in multi-county region)	Number of People Needing Public Shelter (estimated in county alone)	Earthquake Magnitude (for comparison with probabilities)	Estimated Probability of Occurring within 50 years within 50 km (1)
Carson City	Carson City	6.5	0.6 to 2.2	$665 million	~3,900	~2,800	30 to 110	20 to 100	170 to 700	140 to 600	6.5 6.0	50-55% ~70%
Churchill	Fallon	6.5	0.0 to 0.2	$85 million	~400	~400	< 20	1 to 3	10 to 50	10 to 50	6.5 6.0	20-25% 30-40%
Clark	Las Vegas	6.6	4.4 to 17.7	$8.8 billion	~30,000	~30,000	200 to 800	200 to 800	3,000 to 11,000	3,000 to 11,000	6.5 6.0	<5% 10-20%
Douglas	Minden	7.1	0.6 to 2.5	$471 million	~3,600	~1,300	30 to 120	10 to 50	150 to 600	50 to 190	7.0 6.5 6.0	10-12% 50-60% 60-70%
Elko	Elko	6.5	0.1 to 0.4	$224 million	~900	~900	10 to 40	10 to 40	40 to 150	40 to 150	6.5 6.0	6-8% 10-15%
Esmeralda	Goldfield	6.7	< 0.1	$280 thousand	~4	~2	none	none	none	none	6.5 6.0	5-10% 20-30%
Eureka	Eureka	7.2	< 0.1	$4.1 million	~100	~50	none	none	none	none	7.0 6.5 6.0	<0.5% 4-6% 10-15%
Humboldt	Winnemucca	6.5	0.0 to 0.1	$56 million	~600	~600	< 20	1 to 3	10 to 30	10 to 30	6.5 6.0	5-10% 15-20%
Lander	Battle Mountain	7.5	0.0 to 0.1	$74 million	~1,200	~1,200	< 20	3 to 6	10 to 20	10 to 20	7.5 7.0 6.5 6.0	0.1-0.2% ~1.5% ~10% 15-20%
Lincoln	Pioche	6.5	< 0.1	$5.6 million	~40	~40	none	none	none	none	6.5 6.0	2-3% 6-10%
Lyon	Yerington	6.9	0.0 to 0.2	$88 million	~800	~800	< 20	1 to 3	10 to 30	10 to 30	7.0 6.5 6.0	12% 40-45% ~60%
Mineral	Hawthorne	7.5	0.0 to 0.2	$78 million	~700	~700	< 20	2 to 4	10 to 40	10 to 40	7.5 7.0 6.5 6.0	<0.5% 10-12% 30-40% ~60%
Nye	Tonopah	7.0	< 0.1	$440 thousand	~140	~1	none	none	none	none	7.0 6.5 6.0	<1% 5-10% 20-30%
Pershing	Lovelock	7.3	0.0 to 0.1	$61 million	~800	~800	< 20	2 to 4	10 to 20	10 to 20	7.5 7.0 6.5 6.0	~0.1% 1-2% ~10% 10-20%
Storey	Virginia City	6.5	0.6 to 2.5	$8.5 million	~3,500	~70	20 to 90	none	200 to 800	none	6.5 6.0	50% 65-70%
Washoe	Reno	6.9	1.9 to 7.6	$2.9 billion	~12,000	~8,200	120 to 500	80 to 300	800 to 3,000	600 to 3,000	7.0 6.5 6.0	12-15% ~50% 65-70%
White Pine	Ely	6.8	0.0 to 0.2	$79 million	~400	~400	< 20	1 to 4	10 to 30	10 to 30	7.0 6.5 6.0	<0.5% 1.5-2% 4-6%

(1) Please refer to http://www.nbmg.unr.edu/eqprob/eqprob.htm for details on earthquake probabilities estimated by the U.S. Geological Survey.

Questions for Hazus Earthquake Training

May 9-12, 2005

Questions

1. Fault Width: What is fault width, how is the default value measured, and why does it sometimes affect results but not always? → EQ book (Hough) says width is thickness of seismogen. crust that ruptures...
   (Rampart Scenarios #662-663; Ute Pass #28-30; Valmont #460-462; Williams Fork #649,658,659,656-657)

arctoolbox spatial stat. tool - area

need to add transp. + util. → new field Join

2. Mapping Losses: Is there a way to map **total** economic loss? Right now it appears we can only map total **building-related** economic loss.
   (map 'wf_bldloss_4-21-05.jpg' in Williams Fork Scenarios folder)

or map loss ratios - in 9.0 better - arc Toolbox compute ct. area first then ÷ by A

* normalize by area! (census tract) - county ok! - also casualties/sq. mile (density maps) or casualties per total population

3. PGA Contours: What is the maximum contour grid value that can be entered? We have tried 100 and 200, but our ground shaking maps are still very blocky. How can we smooth these maps for better visual results?

√ 4. What are the Hazus units for PGA and PGV? – look in metadata

√ 5. Mapping Functionality: What is a reasonable confidence value to enter when trying to map functionality of essential facilities? Are the functionality values in the tables a percentage? 60-70 conf. value is good – functionality is % chance of structure being functional at given time after EQ

6. Landslide Maps: Entering a landslide map seems to **decrease** the loss estimates but not the casualties for a region. If the default landslide value is zero (no susceptibility) when no map is added, shouldn't the addition of a landslide map **increase** the loss estimate since it includes values with higher susceptibility?
   (Rampart #604,606; N Sangre #9-11; Williams Fork #636-638, 635,639)

* review how to edit db's in SQL server

7. Attenuation Functions: Are the Build 36 attenuation functions (WUS-Shallow Ext. and CEUS Normal) different from the Build 31 functions (Project 2000 West and East)? Their names have been changed, but it appears that they are also affecting results. Usually both WUS and CEUS produce slightly smaller loss estimates. What functions are present in the 2005 version? Is it possible to use a combination? YES! (see notes)
   (Cheraw #88/628; Golden #517/629; Rampart #49/661, 7/662; Williams Fork #208/623, 585/639, 189/590/620/626/630 (strange results); 1882 EQ #565/668; exception: RM Arsenal #589/603 – same results new vs. old)

√ 8. Hazus Analysis: We hardly ever check the analysis boxes for 'Advanced engineering building mode' or 'User-defined structures'. Would these change our results? Are there structures we should add in certain regions to make our results more accurate (i.e. ski areas, NORAD)? (yes, if data that's important is missing from inventory)

9. Soil Maps: The presence of a soil map decreases loss estimates, similar to input of a landslide map. Default soil value is Type D 4 (stiff soil), while adding a soil map causes much of the region to have higher density soils and rock at the surface (type 3 and 2). For reasons unknown to me, a new soil map ('cosoils_region_1') was added to our files

in late 2004 that **sometimes** decreases loss estimates. It looks identical to the older soil map ('cosoils_region'). How is this map different? Where is this soil map from, originally? (Tweto Colorado geology map) Would the Statsgo soil map from the NRCS website be a better option?

(Williams Fork #620/621, 624/631, 648/656, 659b/658)

— 10. A strange error message has appeared several times when trying to run a new scenario. It has squares instead of text or squares then an 'N'. What is this and why does it appear? A related error appears once I close Hazus saying 'The instruction at "0x69620590" referenced memory at "0x00000004". The memory could not be "written".' Is this just a sign of an overworked computer?

11. Large M Event Cutoff Distance: The cutoff distance for Build 31 was 150km, buffered around the fault's entire length instead of just the epicenter. In Build 36 it now appears to be 200km. This obviously affects PGA maps and the total damage and loss estimates. How can we make large magnitude events "reach" further to produce more realistic results? Can we extract 'Disaggregated Seismic Hazard' data from the USGS website [http://eqint.cr.usgs.gov/eq/html/deaggint2002.html] for the Cheraw and Sangre de Cristo faults and import it into Hazus? (a text file, graph, and map are produced for each interactive deaggregation)

change in SQL server database

12. Is there a direct correlation between PGA and MMI?

✓ 13. Does event magnitude in Hazus change the radius of the affected region? no...
(Q set up for M 5.0 - 8.5, radius 0 - 200 km)

14. Is it possible to run multi-state scenarios for large earthquakes or those near state borders? (ex.: 1882 Historical EQ with two possible epicenters)

15. Ground Shaking along Fault: The PGA maps show ground accelerations within a 200km buffer of the fault. This affected region appears to be elliptical along the strike direction of the fault, indicating that Hazus has taken the entire fault length into account. Are ground shaking values calculated assuming the entire fault ruptures or are they focused around the epicenter only?

✓ 16. Epicenter and Soil Type: It appears that the soil type of the epicenter affects results, even when that epicenter is moved only slightly along the fault to a new soil type region. The PGA maps and facility damage maps follow patterns that closely parallel those of the soil maps, suggesting a region-wide correlation of ground shaking and soil type. Why would a slight change in epicenter affect results when seismic waves, in reality, radiate from a hypocenter in a manner that has nothing to do with surface geology?

(S Sawatch #669-671) distance to epicenter affects ground shaking amplification

17. To my knowledge, we have not yet tried to map probabilistic scenario results. Is this possible, and what can we expect?

18. Other Hazard Maps: Most of our scenarios are run with a landslide and soil map activated, which have both affected results to produce what we assume are more accurate results. The other two parameters, 'water depth' and 'liquefaction' have always been kept at their default values (liquefaction = 0, water depth = 5 ft.). Are there maps or values that we could add that would improve our results? — ask Doug – CO data?

19. Fault Dip Angle: Several early scenarios on the Ute Pass fault experimented with the effects of fault dip angle. Results indicated that a shallower dip angle caused more damage. The 'depth' field remained the same default value of 10km for all scenarios. Why does dip angle affect results?

(Ute Pass #31-33)

20. Fault Orientation: The strike of the fault trace also appears to affect results. Is this simply due to slight changes in affected regions and inventories due to the elliptical buffer around the fault?

(1882 EQ #593,594)

21. Mapping Results: I have attempted to map a variety of results for different scenarios, but data is often confusing or missing. For example, a state-wide scenario for a M7.5 on the Sangre de Cristo fault showed hospitals and police stations with reduced (<=70%) functionality in the far corners of the state, well beyond the radius shown in my PGA map. When I tried to map utilities damage, the tables were all empty even though I ran that parameter during the analysis. The map of highway segment damage looked like ALL of the segments were damaged. How can I produce better visualizations of what these deterministic scenarios are telling me?

22. Newest Hazus Version: What changes can I expect with the 2005 version? Is it likely we will have to re-run most of our scenarios due to significant changes in loss estimates? What will compatibility with ArcInfo9.0 do for the program? (We have been using ArcMap8.3 until now)

worked with MRI in class – probably best to update, check inventories, get best hazard maps, learn how to use multiple Q's, then re-run our worst-case deterministic and several probabilistic scenarios

SQL Server Table - Attenuation

EqAttenFunct

eqAttenFunctId	Description	FltMechanism	EorW	DistToUse	PorD	Display	MinMag	MaxMag
1	Abrahamson and Silva (1997) Hanging Wall	N	W	4	P		5	8.5
2	Abrahamson and Silva (1997) Foot Wall	N	W	4	P		5	8.5
3	Abrahamson and Silva (1997) Hanging Wall	S	W	4	P		5	8.5
4	Abrahamson and Silva (1997) Foot Wall	S	W	4	P		5	8.5
5	Abrahamson and Silva (1997) Hanging Wall	R	W	4	P		5	8.5
6	Abrahamson and Silva (1997) Foot Wall	R	W	4	P		5	8.5
7	Atkinson and Boore (1995)	E	W	2	P		5	8.5
8	Toro et al. (1997)	E	W	1	P		5	8.5
9	Sommerville (2002)	E	W	1	P		5	8.5
10	Frankel (1996)	E	W	2	P		5	8.5
11	Campbell (2002)	E	W	2	P		5	8.5
12	Boore, Joyner and Fumal (1997)	N	W	3	P		5	8.5
13	Boore, Joyner and Fumal (1997)	S	W	3	P		5	8.5
14	Boore, Joyner and Fumal (1997)	R	W	3	P		5	8.5
15	Sadigh et al. (1997)	N	W	4	P		5	8.5
16	Sadigh et al. (1997)	S	W	4	P		5	8.5
17	Sadigh et al. (1997)	R	W	4	P		5	8.5
18	Campbell & Bozorgnia (2003)	N	W	5	P		5	8.5
19	Campbell & Bozorgnia (2003)	S	W	5	P		5	8.5
Utah Shake Maps → 20	Spudich et al. (1999)	N	W	3	P		5	8.5
21	Youngs et al. (1997)	F	W	6	P		5	8.5
22	Youngs et al. (1997)	I	W	6	P		5	8.5
23	Munson and Thurber (1997)	N	W	3	P		5	8.5
24	CEUS Event	E or N?	W	10	D		5	8.5
25	WUS Shallow Crustal Event - Extensional	S	W	10	D		5	8.5
26	WUS Hawaiian Event	S	W	10	D		5	8.5
27	WUS Cascadia Subduction Event	F	W	10	D		5	8.5
28	WUS Deep Event	I	W	10	D		5	8.5
29	WUS Shallow Crustal Event - Non Extensional	R	W	10	D		5	8.5
30	Atkinson and Boore (2002)	F	W	4	P		5	8.5
? 31	Atkinson and Boore (2002) - Global ?	I	W	4	P		5	8.5
32	Atkinson and Boore (2002) - Cascadia	I	W	4	P		5	8.5
33	WUS Shallow Crustal Event - Extensional	N	W	10	D		5	8.5
34	CEUS Characteristic Event	E	W	10	D		5	8.5

test spud...

eqAttenDepend

eqAttenDependId	eqAttenFunct1	eqAttenFunct2	Multiplier
1	24	7	0.286
2	24	8	0.286
3	24	10	0.286
4	25	3	0.2
5	25	16	0.2
6	25	13	0.2
7	26	23	0.5
8	26	13	0.5
9	27	21	0.5
10	28	22	0.5
11	28	31	0.25
14	24	11	0.143
15	25	20	0.2
16	25	19	0.2
17	27	17	0.5
21	29	5	0.25
22	29	17	0.25
23	29	14	0.25
24	29	18	0.25
25	28	32	0.25
26	33	3	0.2
27	33	16	0.2
28	33	13	0.2
29	33	20	0.2
30	33	19	0.2
31	34	7	0.25
32	34	8	0.25
33	34	9	0.125
34	34	10	0.25
35	34	11	.125

Ext = to surface
Non-Ext = "blind", not to surface

N = normal
R = reverse
S = strike-slip
E = East coast
I = intraslab
F = subduction inter-face

↑ enables use in an area, changed highlighted cells from 'E' to 'W'

?

D = dependent
P = primary

#24 CEUS Event is dependent on # $\underbrace{7, 8, 10}_{\times .286}$, 11 (.143)

34 CEUS Characteristic Event: # $\underbrace{7, 8}_{\times .25}$, 9, 10, 11 (.125, .25, .125)

#25, #33 WUS Shallow-Ext: # $\underbrace{3, 16, 13, 20, 19}_{\times .2}$

Attenuation Info

Attenuation Tests

#	Date	Region	M	Attenuation Function	Q #	Casualties	Loss Estimate ($Mil)	Q Function Dependencies	Rank
691	2-Jun-05	RMA Denver County	6.25	Abrahamson & Silva (1997) HW	1	1597, 408, 92, 122	$2,532.19	none	18
692	2-Jun-05	RMA Denver County	6.25	Abrahamson & Silva (1997) FW	2	1029, 237, 54, 66	$1,899.04	none	20
685	2-Jun-05	RMA Denver County	6.25	Atkinson & Boore (1995)	7	1640, 384, 64, 107	$3,702.94	none	10
687	2-Jun-05	RMA Denver County	6.25	Toro et al. (1997)	8	2745, 708, 120, 213	$4,477.67	none	7
688	2-Jun-05	RMA Denver County	6.25	Sommerville (2002)	9	1459, 331, 50, 91	$3,252.10	none	13
689	2-Jun-05	RMA Denver County	6.25	Frankel (1996)	10	6182, 1812, 358, 587	$8,502.42	none	2
690	2-Jun-05	RMA Denver County	6.25	Campbell (2002)	11	2003, 490, 86, 142	$3,912.97	none	8
693	2-Jun-05	RMA Denver County	6.25	Boore, Joyner and Fumal (1997)	12	1585, 372, 64, 104	$3,088.31	none	14
694	2-Jun-05	RMA Denver County	6.25	Sadigh et al. (1997)	15	1894, 460, 79, 132	$3,314.80	none	12
695	2-Jun-05	RMA Denver County	6.25	Campbell & Bozorgnia (2003)	18	1607, 388, 72, 112	$2,767.49	none	16
683	2-Jun-05	RMA Denver County	6.25	Spudich et al. (1999)	20	1135, 254, 44, 69	$2,223.86	none	19
696	2-Jun-05	RMA Denver County	6.25	Youngs et al. (1997)	21	2899, 748, 127, 224	$4,959.21	none	6
697	2-Jun-05	RMA Denver County	6.25	Munson & Thurber (1997)	23	9191, 2846, 563, 951	$9,536.18	none	1
686	2-Jun-05	RMA Denver County	6.25	CEUS Event	24	3249, 861, 157, 262	$5,557.58	7(.286), 8(.286), 10(.286), 11(.143)	4
684	2-Jun-05	RMA Denver County	6.25	WUS Shallow Crustal Event - Ext.	25	1626, 390, 70, 111	$2,830.22	3, 13, 16, 19, 20 x (.2)	15
698	2-Jun-05	RMA Denver County	6.25	WUS Hawaiian Event (strike-slip only)	26	5044, 1451, 279, 467	$6,190.20	13, 23 x (.5)	3
699	2-Jun-05	RMA Denver County	6.25	WUS Cascadia Subduction Event	27	1980, 481, 81, 138	$3,589.13	17, 21 x (.5)	11
700	2-Jun-05	RMA Denver County	6.25	WUS Deep Event	28	1293, 285, 40, 76	$2,720.15	22(.5), 31(.25), 32(.25)	17
701	2-Jun-05	RMA Denver County	6.25	WUS Shallow Crustal Event - NonExt.	29	2326, 591, 109, 176	$3,832.34	5, 14, 17, 18 x (.25)	9
702	3-Jun-05	RMA Denver County	6.25	Atkinson & Boore (2002)	30	365, 63, 7, 13	$951.66	none	22
703	3-Jun-05	RMA Denver County	6.25	Atkinson & Boore (2002) - Global	31	757, 147, 18, 35	$1,801.25	none	21
704	3-Jun-05	RMA Denver County	6.25	Atkinson & Boore (2002) - Cascadia	32	20, 2, 0, 0	$38.36	none	23
682	2-Jun-05	RMA Denver County	6.25	CEUS Characteristic Event	34	2997, 783, 141, 236	$5,272.81	7(.25), 8(.25), 9(.125), 10(.25), 11(.125)	5

"New CEUS" without Frankel (1996) = $3,836.43 (.25 x #7,8,9,11)

C:\Program Files\HAZUS-DATA\Earthquake\User Manual
(Technical Draft in same folder)

9.5 Running the Direct Social and Economic Loss Modules

The **Direct social and economic loss** modules are used for estimating casualties, displaced households due to loss of housing habitability, short-term shelter needs, and direct economic impacts resulting from damage to buildings and lifelines. Clicking on the **Direct Social Losses** option in the window shown in Figure 9.34 will cause the following menu to appear.

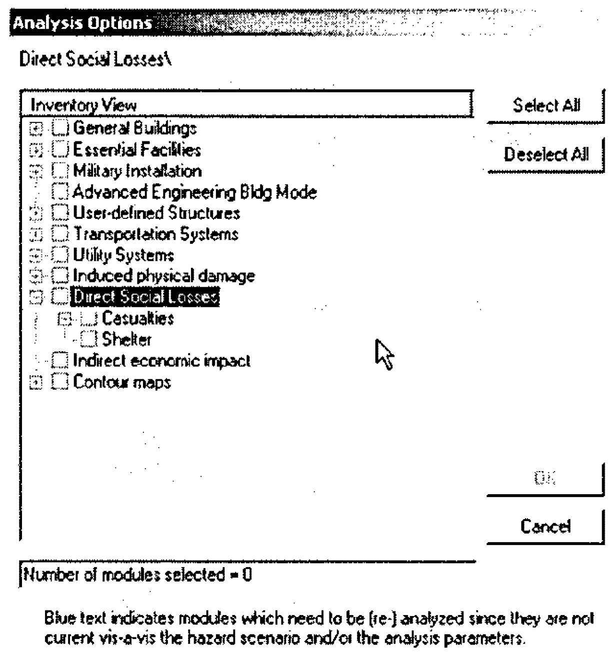


Figure 9.34 Direct economic losses

The direct economic loss option can be selected for each inventory type (general buildings, essential facilities, etc.) Select the types of analyses you wish to run, click on the **Close** button and then click on the **OK** button shown in the window in Figure 9.34. These social and economic analyses can only be run if the **direct physical damage** module is either run simultaneously, or if it has previously been run.

9.5.1 Casualty Estimates

The casualty module calculates the following estimates for each census tract at three times of day (2 AM, 2 PM and 5 PM):

- Single family dwelling (RES1) casualties (Severity 1, 2, 3 and 4)
- Residential (other than RES1) casualties (Severity 1, 2, 3 and 4)
- Commercial casualties (Severity 1, 2, 3 and 4)
- Industrial casualties (Severity 1, 2, 3 and 4)
- Education casualties (Severity 1, 2, 3 and 4)
- Hotel casualties (Severity 1, 2, 3 and 4)
- Commuting casualties (Severity 1, 2, 3 and 4)
- Total casualties (Severity 1, 2, 3 and 4)

The following inputs are needed to obtain estimates of casualties:

- Population distribution by census tract
- Population distribution within census tract
- Building stock inventory
- Damage state probabilities
- Time of day of estimate (2 AM, 2 PM or 5 PM)
- Casualty rates by damage state of model building
- Collapse rates due to collapse of model building/bridge type
- Number of commuters on or under bridges in the census tract

All of this information has already been provided by other modules or is available as a default.

9.5.1.1 Injury Classification Scale

The output from the module consists of a casualty breakdown by injury severity, defined by a four-tier injury severity scale (Coburn, 1992; Cheu, 1994). Table 9.8 defines the injury classification scale used in **HAZUS**®*MH*.

Table 9.8 Injury Classification Scale

Injury Severity	Injury Description
Severity 1	Injuries requiring basic medical aid without requiring hospitalization
Severity 2	Injuries requiring a greater degree of medical care and hospitalization, but not expected to progress to a life threatening status
Severity 3	Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. The majority of these injuries are a result of structural collapse and subsequent collapse or impairment of the occupants.
Severity 4	Instantaneously killed or mortally injured

Other, more elaborate casualty scales exist. They are based on quantifiable medical parameters such as medical injury severity scores, coded physiologic variables, etc. The selected four-tier injury scale used in **HAZUS®MH** is a compromise between the demands of the medical community (in order to plan their response) and the ability of the engineering community to provide the required data. For example, medical professionals would like to have the classification in terms of "Injuries/Illnesses" to account for worsened medical conditions caused by an earthquake (e.g., heart attack). However, currently available casualty assessment methodologies do not allow for a finer resolution in the casualty scale definition.

9.5.1.2 Casualty Rates

In order to estimate the number and severity of the casualties, statistics from previous earthquakes were analyzed to develop relationships that reflect the distribution of injuries one would expect to see resulting from building and bridge damage. These casualty rates were developed for each casualty severity and are multiplied by the exposed population to estimate the number of casualties. An example of a calculation of casualties follows:

Severity 1 casualty rate for low rise Unreinforced masonry buildings (URML) with slight structural damage = 1 in 2,000

Number of people in the study region who were in slightly damaged URML buildings = 50,000

Severity 1 casualties = 50,000* 1/2,000 = 25 people

The following default casualty rates are defined by **HAZUS®MH** and can be found in the *Technical Manual*:

- Casualty rates by model building type for slight structural damage
- Casualty rates by model building type for moderate structural damage
- Casualty rates by model building type for extensive structural damage
- Casualty rates by model building and bridge types for complete structural damage with no collapse
- Casualty rates after collapse by model building type.

Note that a separate set of casualty rates was developed for entrapped victims, and that collapse is only considered in the case of complete structural damage. It is assumed that in the cases of slight, moderate and extensive structural damage, collapses do not occur and building collapse is unlikely. Casualty rates for both buildings and bridges can be viewed and modified in the window shown in Figure 9.35. Selecting the Analysis|Parameters|Casualties menu accesses this window. These default casualty rates can be modified if improved information is available. To modify values, type in the new numbers and click on the **Close** button. You will be asked to confirm your changes.

It should be noted that complete data does not exist for all model building types and injury severity. Missing data were inferred from reviewing previous studies. Collection of better and more complete casualty statistics would involve a major research study.

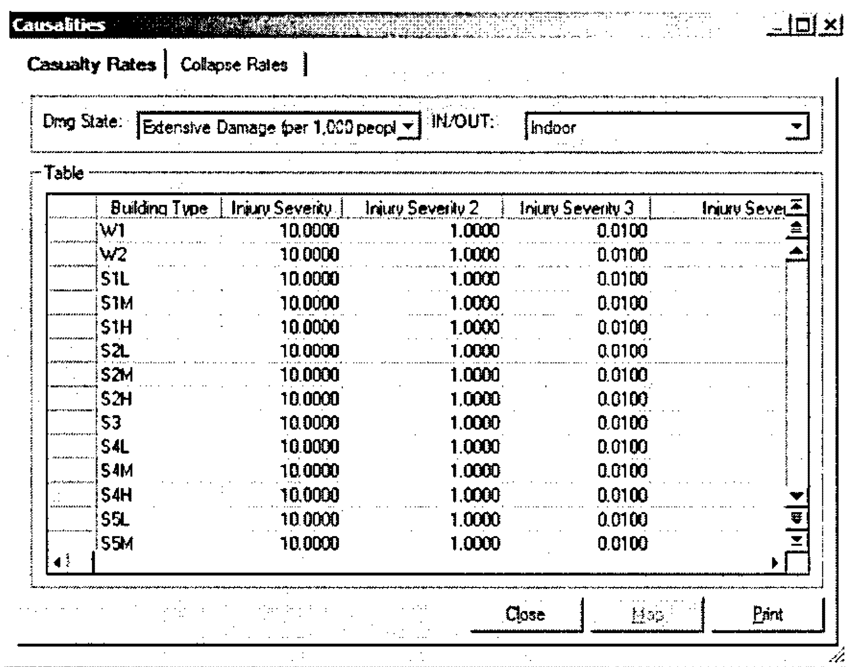


Figure 9.35 Casualty rates in number of casualties per 1,000 occupants by model building type for the slight structural damage state (indoors).

9.5.1.3 Collapse Rates

When collapses or partial collapses occur, individuals may become trapped under fallen debris or trapped in air pockets amongst the rubble. Casualties tend to be more severe in these cases, and as was discussed in Section 9.5 a separate set of casualty rates was developed for entrapped victims. It should be noted that building collapse rates (in percent of occupants) are developed only for the complete damage state. This is because it is assumed that no collapses or partial collapses occur in the slight, moderate or extensive damage states and collapse in these cases is unlikely. Collapse rates by model building type can be found in the *Technical Manual*. They can also be viewed within **HAZUS®MH** as is shown in Figure 9.36. This window is accessed from the **Analysis|Parameters|Casualties** menu. To modify values, type in the new numbers and click on the **Close** button. You will be asked to confirm your changes.

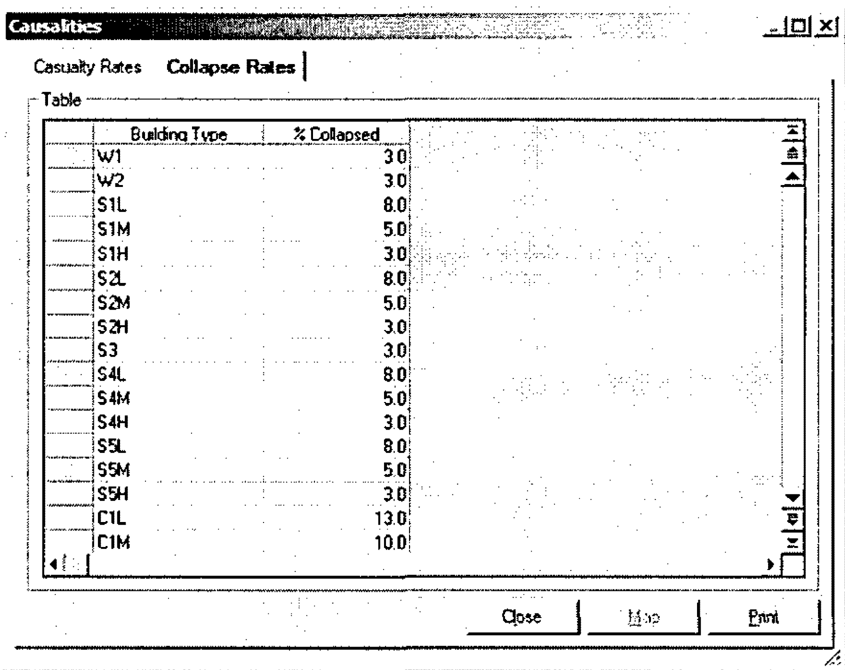


Figure 9.36 Collapse rates for buildings as displayed in HAZUS®MH.

9.5.2 Estimates of Displaced Households Due to Loss of Housing Habitability and Short-Term Shelter Needs

Earthquakes can cause loss of function or habitability of buildings that contain housing units resulting in predictable numbers of displaced households. These households will need alternative short-term shelter from family, friends, or public shelters provided by relief organizations such as the Red Cross and Salvation Army. For units where repair takes longer than a few weeks, long-term alternative housing can be achieved through importation of mobile homes, a reduction in vacant units, net emigration from the impacted area, and eventually by the repair or reconstruction of new public and private housing. While the number of people seeking short-term public shelter is of great concern to emergency response organizations, the longer-term impacts on the housing stock are of great concern to local governments. The shelter module provides two estimates:

- The total number of displaced households (due to loss of habitability)
- The number of people requiring short-term shelter

Loss of habitability is calculated directly from damage to the residential occupancy inventory and from loss of water and power. The methodology for calculating short-term shelter requirements recognizes that only a portion of those displaced from their homes will seek public shelter, and some will seek shelter even though their residence may have little, if any, damage.

Households also may be displaced as a result of fire following earthquake, inundation (or the threat of inundation) due to dam failure, and by significant hazardous waste releases. This module does not specifically deal with these issues, but an approximate estimate of displacement due to fire or inundation can be obtained by multiplying the residential inventory in affected census tracts by the areas of fire damage or inundation derived from those modules. No methodology for calculations of damage or loss due to hazardous materials is provided, and the user is confined to identifying locations of sites where hazardous materials are stored. If the particular characteristics of the study region give cause for concern about the possibility of loss of housing from fire, dam failure, or hazardous materials release, it would be advisable to initiate specific in-depth studies directed towards the problem.

All households living in uninhabitable dwellings will seek alternative shelter. Many will stay with friends and relatives or in the family car. Others will stay in hotels. Some will stay in public shelters provided by the Red Cross or others. **HAZUS**®*MH* estimates the number of displaced persons seeking public shelter. In addition, observations from past disasters show that approximately 80% of the pre-disaster homeless will seek public shelter. Finally, data from Northridge indicate that approximately one-third of those in public shelters came from residences with no or insignificant structural damage. Depending on the degree to which infrastructure damage is incorporated into the number of displaced households, that number could be increased by up to 50% to account for "perceived" structural damage as well as lack of water and power.

9.5.2.1 Development of Input for Displaced Households

The following inputs are required to compute the number of uninhabitable dwelling units and the number of displaced households.

- Fraction of dwelling units likely to be vacated if damaged
- Probability that the residential units are without power and/or water immediately after the earthquake.
- Percentage of households affected by utility outages likely to seek alternative shelter.

9.5.2.1.1 Fraction of Dwelling Units Likely to be vacated if damaged:

The number of uninhabitable dwelling units is not only a function of the amount of structural damage but it is also a function of the number of damaged units that are perceived to be uninhabitable by their occupants. All dwelling units located in buildings that are in the complete damage state are considered to be uninhabitable. In addition, dwelling units that are in moderately or extensively damaged multi-family structures can also be uninhabitable due to the fact that renters perceive some moderately damaged and most extensively damaged rental property as uninhabitable. On the other hand, those living in single-family homes are much more likely to tolerate damage and continue to live in their homes. Therefore weighting factors have been developed that describe the fraction of dwellings likely be vacated if they are damaged. These default weighting factors can be viewed and modified as shown in Figure 9.37. To access this window use the **Analysis|Parameters| Shelter** menu.

In this table, the subscript "SF" corresponds to single family dwellings and the subscript MF corresponds to multi-family dwellings. The subscripts M, E, and C correspond to moderate, extensive and complete damage states, respectively. For example, based on these defaults, it is assumed that 90% of multi-family dwellings will be vacated if they are in the extensive damage state (see w_{MFE}). Discussion of how the defaults were developed can be found in the *Technical Manual*.

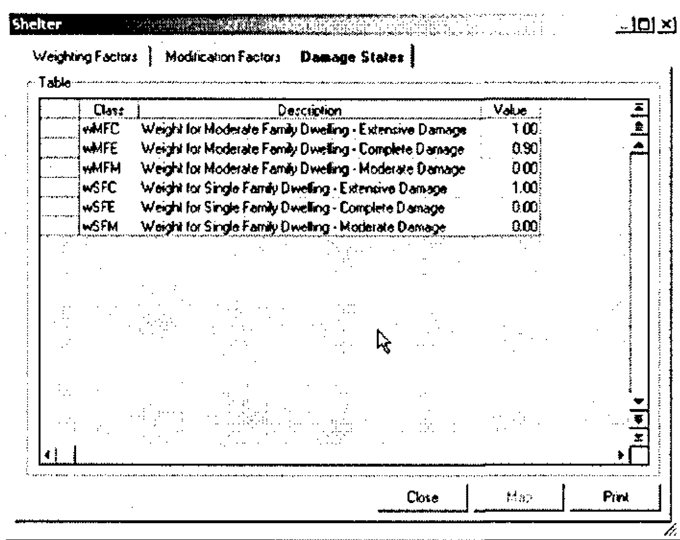


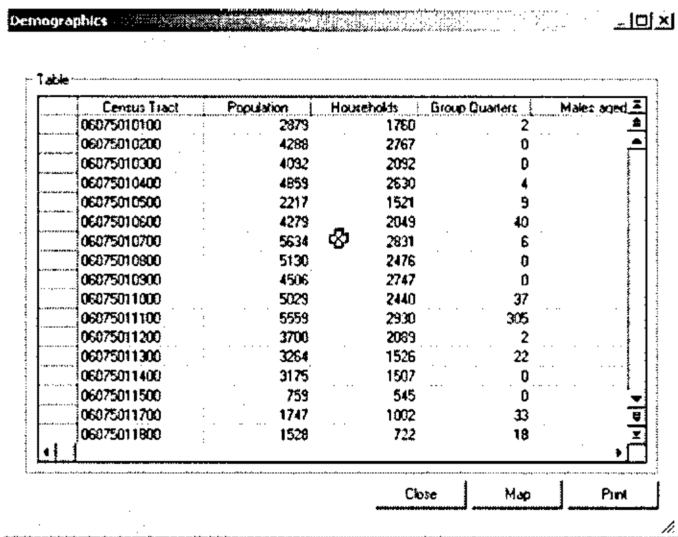
Figure 9.37 Default values for the fraction of dwelling units likely to be vacated if damaged.

9.5.2.2 Development of Input for Shelter Needs

The number of displaced households is combined with the following information to estimate shelter needs:

- Number of people in the census tract
- Number of households in census tract
- Income breakdown of households in census tract
- Ethnicity of households in census tract
- Percentage of homeowners and renters in the census tract
- Age breakdown of households in census tract

All of this information is provided in the default census database. The default census database can be viewed, modified and mapped in the inventory module as shown in Figure 9.38. Figure 9.39 is a map of households with incomes less than $10,000. Highlighting the Income column in the census database and clicking on the **Map** button accomplished this. Note that to see this column you would need to click on the right arrow at the bottom of Figure 9.38.



Census Tract	Population	Households	Group Quarters	Males aged
06075010100	2879	1760	2	
06075010200	4288	2767	0	
06075010300	4032	2092	0	
06075010400	4859	2630	4	
06075010500	2217	1521	9	
06075010600	4279	2049	40	
06075010700	5634	2831	6	
06075010800	5130	2476	0	
06075010900	4506	2747	0	
06075011000	5029	2440	37	
06075011100	5559	2930	305	
06075011200	3700	2089	2	
06075011300	3264	1526	22	
06075011400	3175	1507	0	
06075011500	759	545	0	
06075011700	1747	1002	33	
06075011800	1528	722	18	

Figure 9.38 Demographics data supplied in HAZUS$^{®MH}$.

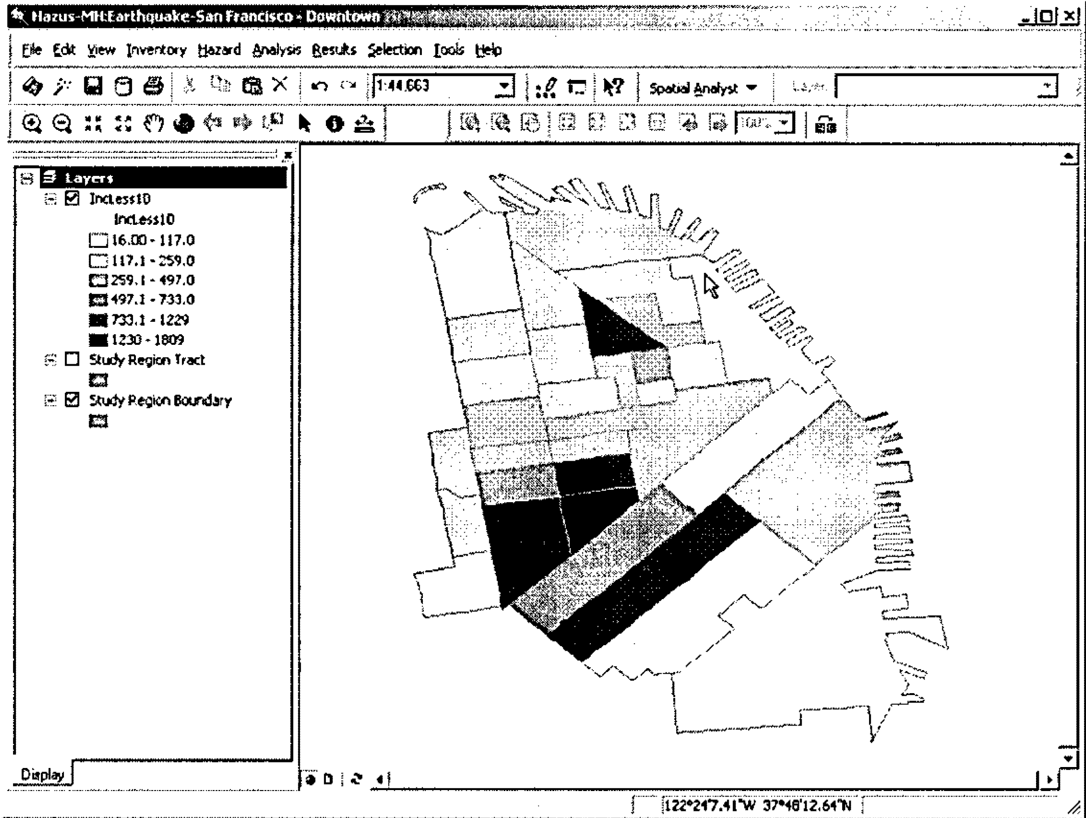


Figure 9.39 Map of households with incomes less than $10,000

Assumptions of the methodology are that the number of people who require short-term housing is a function of income, ethnicity, ownership and age. Based on experience in past disasters, including both hurricanes and earthquakes, those seeking shelter typically have very low incomes, and therefore have fewer options. In addition, they tend to have young children or are over 65. Finally, even given similar incomes, Hispanic populations from Central America and Mexico tend to be more concerned about reoccupying buildings than other groups. This tendency appears to be because of the fear of collapsed buildings instilled from past disastrous earthquakes.

To account for these trends, factors have been developed to represent the fraction of households in each category likely to seek public shelter if their dwellings become uninhabitable. The default values of these factors as shown in Table 9.9 are based upon data from the Northridge earthquake combined with expert opinion (see the *Technical Manual* for more information). From this table you can interpret that 62% of households with incomes less than $10,000 whose dwellings have become uninhabitable will seek public shelter.

Table 9.9 Fraction of Households Likely to Seek Public Shelter

Household Description	Default
Income	
Household Income < $10,000	0.62
$10,000 < Household Income < $15,000	0.42
$15,000 < Household Income < $25,000	0.29
$25,000 < Household Income < $35,000	0.22
$35,000 < Household Income	0.13
Ethnicity	
White	0.24
Black	0.48
Hispanic	0.47
Asian	0.26
Native American	0.26
Ownership	
Own Dwelling Unit	0.40
Rent Dwelling Unit	0.40
Age	
Population Under 16 Years Old	0.40
Population Between 16 and 65 Years Old	0.40
Population Over 65 Years Old	0.40

The factors in Table 9.9 can be viewed and modified in the **Shelter Parameters** window as shown in Figure 9.40. The **Income**, **Ethnicity**, **Ownership** and **Age** buttons can be used to view the various tables.

5.3 Description of Building Damage States

The results of damage estimation methods described in this chapter (i.e., damage predictions for model building types for a given level of ground shaking) are used in other modules of the methodology to estimate: (1) casualties due to structural damage, including fatalities, (2) monetary losses due to building damage (i.e. cost of repairing or replacing damaged buildings and their contents); (3) monetary losses resulting from building damage and closure (e.g., losses due to business interruption); (4) social impacts (e.g., loss of shelter); and, (5) other economic and social impacts.

The building damage predictions may also be used to study expected damage patterns in a given region for different scenario earthquakes (e.g., to identify the most vulnerable building types, or the areas expected to have the most damaged buildings).

In order to meet the needs of such broad purposes, damage predictions must allow the user to glean the nature and extent of the physical damage to a building type from the damage prediction output so that life-safety, societal functional and monetary losses which result from the damage can be estimated. Building damage can best be described in terms of its components (beams, columns, walls, ceilings, piping, HVAC equipment, etc.). For example, such component damage descriptions as "shear walls are cracked", "ceiling tiles fell", "diagonal bracing buckled", "wall panels fell out", etc. used together with such terms as "some" and "most" would be sufficient to describe the nature and extent of overall building damage.

Damage to nonstructural components of buildings (i.e., architectural components, such as partition walls and ceilings, and building mechanical/electrical systems) primarily affects monetary and societal functional losses and generates numerous casualties of mostly light-to-moderate severity. Damage to structural components (i.e., the gravity and lateral-load-resisting systems) of buildings, Hazard mitigation measures are different for these two categories of building components as well. Hence, it is desirable to separately estimate structural and nonstructural damage.

Building damage varies from "none" to "complete" as a continuous function of building deformations (building response). Wall cracks may vary from invisible or "hairline cracks" to cracks of several inches wide. Generalized "ranges" of damage are used by the Methodology to describe structural and nonstructural damage, since it is not practical to describe building damage as a continuous function.

The Methodology predicts a structural and nonstructural damage state in terms of one of four ranges of damage or "damage states": Slight, Moderate, Extensive, and Complete. For example, the Slight damage state extends from the threshold of Slight damage up to the threshold of Moderate damage. General descriptions of these damage states are provided for all model building types with reference to observable damage incurred by

C:\Program Files\HAZUS-DATA\Earthquake\Technical Draft structural (Section 5.3.1) and nonstructural building components (Section 5.3.2). Damage predictions resulting from this physical damage estimation method are then expressed in terms of the probability of a building being in any of these four damage states.

none + slight + moderate + extensive + complete = 1

5.3.1 Structural Damage

Descriptions for Slight, Moderate, Extensive, and Complete structural damage states for the 16 basic model building types are provided below. For estimating casualties, the descriptions of Complete damage include the fraction of the total floor area of each model building type that is likely to collapse. Collapse fractions are based on judgment and limited earthquake data considering the material and construction of different model building types.

It is noted that in some cases the structural damage is not directly observable because the structural elements are inaccessible or not visible due to architectural finishes or fireproofing. Hence, these structural damage states are described, when necessary, with reference to certain effects on nonstructural elements that may be indicative of the structural damage state of concern. Small cracks are assumed, throughout this section, to be visible cracks with a maximum width of less than 1/8". Cracks wider than 1/8" are referred to as "large" cracks.

Denver: W1, RM1L, URML
73% 20% 3%

Wood, Light Frame (W1):

Slight Structural Damage: Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate Structural Damage: Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive Structural Damage: Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of "room-over-garage" or other "soft-story" configurations; small foundations cracks.
Complete Structural Damage: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks. Approximately 3% of the total area of W1 buildings with Complete damage is expected to be collapsed.

Wood, Commercial and Industrial (W2):

Slight Structural Damage: Small cracks at corners of door and window openings and wall-ceiling intersections; small cracks on stucco and plaster walls. Some slippage may be observed at bolted connections.
Moderate Structural Damage: Larger cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by cracks in stucco and gypsum wall panels; minor slack (less than 1/8" extension) in diagonal rod bracing requiring re-tightening; minor lateral set at store fronts and other large openings; small cracks or wood splitting may be observed at bolted connections.
Extensive Structural Damage: Large diagonal cracks across shear wall panels; large slack in diagonal rod braces and/or broken braces; permanent lateral movement of floors and roof; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of "soft-story" configurations; bolt slippage and wood splitting at bolted connections.
Complete Structural Damage: Structure may have large permanent lateral displacement, may collapse or be in imminent danger of collapse due to failed shear walls, broken brace rods or failed framing connections; it may fall its foundations; large cracks in the foundations. Approximately 3% of the total area of W2 buildings with Complete damage is expected to be collapsed.

<u>Steel Moment Frame (S1):</u>

Slight Structural Damage: Minor deformations in connections or hairline cracks in few welds.
Moderate Structural Damage: Some steel members have yielded exhibiting observable permanent rotations at connections; few welded connections may exhibit major cracks through welds or few bolted connections may exhibit broken bolts or enlarged bolt holes.
Extensive Structural Damage: Most steel members have exceeded their yield capacity, resulting in significant permanent lateral deformation of the structure. Some of the structural members or connections may have exceeded their ultimate capacity exhibited by major permanent member rotations at connections, buckled flanges and failed connections. Partial collapse of portions of structure is possible due to failed critical elements and/or connections.
Complete Structural Damage: Significant portion of the structural elements have exceeded their ultimate capacities or some critical structural elements or connections have failed resulting in dangerous permanent lateral displacement, partial collapse or collapse of the building. Approximately 8%(low-rise), 5%(mid-rise) or 3%(high-rise) of the total area of S1 buildings with Complete damage is expected to be collapsed.

<u>Steel Braced Frame (S2):</u>

Slight Structural Damage: Few steel braces have yielded which may be indicated by minor stretching and/or buckling of slender brace members; minor cracks in welded connections; minor deformations in bolted brace connections.

Moderate Structural Damage: Some steel braces have yielded exhibiting observable stretching and/or buckling of braces; few braces, other members or connections have indications of reaching their ultimate capacity exhibited by buckled braces, cracked welds, or failed bolted connections.
Extensive Structural Damage: Most steel brace and other members have exceeded their yield capacity, resulting in significant permanent lateral deformation of the structure. Some structural members or connections have exceeded their ultimate capacity exhibited by buckled or broken braces, flange buckling, broken welds, or failed bolted connections. Anchor bolts at columns may be stretched. Partial collapse of portions of structure is possible due to failure of critical elements or connections.
Complete Structural Damage: Most the structural elements have reached their ultimate capacities or some critical members or connections have failed resulting in dangerous permanent lateral deflection, partial collapse or collapse of the building. Approximately 8%(low-rise), 5%(mid-rise) or 3%(high-rise) of the total area of S2 buildings with Complete damage is expected to be collapsed.

Steel Light Frame (S3):

These structures are mostly single story structures combining rod-braced frames in one direction and moment frames in the other. Due to repetitive nature of the structural systems, the type of damage to structural members is expected to be rather uniform throughout the structure.
Slight Structural Damage: Few steel rod braces have yielded which may be indicated by minor sagging of rod braces. Minor cracking at welded connections or minor deformations at bolted connections of moment frames may be observed.
Moderate Structural Damage: Most steel braces have yielded exhibiting observable significantly sagging rod braces; few brace connections may be broken. Some weld cracking may be observed in the moment frame connections.
Extensive Structural Damage: Significant permanent lateral deformation of the structure due to broken brace rods, stretched anchor bolts and permanent deformations at moment frame members. Some screw or welded attachments of roof and wall siding to steel framing may be broken. Some purlin and girt connections may be broken.
Complete Structural Damage: Structure is collapsed or in imminent danger of collapse due to broken rod bracing, failed anchor bolts or failed structural members or connections. Approximately 3% of the total area of S3 buildings with Complete damage is expected to be collapsed.

Steel Frame with Cast-In-Place Concrete Shear Walls (S4):

This is a "composite" structural system where primary lateral-force-resisting system is the concrete shear walls. Hence, slight, Moderate and Extensive damage states are likely to be determined by the shear walls while the collapse damage state would be determined by the failure of the structural frame.
Slight Structural Damage: Diagonal hairline cracks on most concrete shear wall surfaces; minor concrete spalling at few locations.

Moderate Structural Damage: Most shear wall surfaces exhibit diagonal cracks; some of the shear walls have exceeded their yield capacities exhibited by larger diagonal cracks and concrete spalling at wall ends.
Extensive Structural Damage: Most concrete shear walls have exceeded their yield capacities; few walls have reached or exceeded their ultimate capacity exhibited by large through-the wall diagonal cracks, extensive spalling around the cracks and visibly buckled wall reinforcement. Partial collapse may occur due to failed connections of steel framing to concrete walls. Some damage may be observed in steel frame connections.
Complete Structural Damage: Structure may be in danger of collapse or collapse due to total failure of shear walls and loss of stability of the steel frames. Approximately 8%(low-rise), 5%(mid-rise) or 3%(high-rise) of the total area of S4 buildings with Complete damage is expected to be collapsed.

<u>Steel Frame with Unreinforced Masonry Infill Walls (S5):</u>

This is a "composite" structural system where the initial lateral resistance is provided by the infill walls. Upon cracking of the infills, further lateral resistance is provided by the steel frames "braced" by the infill walls acting as diagonal compression struts. Collapse of the structure results when the infill walls disintegrate (due to compression failure of the masonry "struts") and the steel frame loses its stability.

Slight Structural Damage: Diagonal (sometimes horizontal) hairline cracks on most infill walls; cracks at frame-infill interfaces.
Moderate Structural Damage: Most infill wall surfaces exhibit larger diagonal or horizontal cracks; some walls exhibit crushing of brick around beam-column connections.
Extensive Structural Damage: Most infill walls exhibit large cracks; some bricks may be dislodged and fall; some infill walls may bulge out-of-plane; few walls may fall off partially or fully; some steel frame connections may have failed. Structure may exhibit permanent lateral deformation or partial collapse due to failure of some critical members.
Complete Structural Damage: Structure is collapsed or in danger of imminent collapse due to total failure of many infill walls and loss of stability of the steel frames. . Approximately 8%(low-rise), 5%(mid-rise) or 3%(high-rise) of the total area of S5 buildings with Complete damage is expected to be collapsed.

<u>Reinforced Concrete Moment Resisting Frames (C1):</u>

Slight Structural Damage: Flexural or shear type hairline cracks in some beams and columns near joints or within joints.
Moderate Structural Damage: Most beams and columns exhibit hairline cracks. In ductile frames some of the frame elements have reached yield capacity indicated by larger flexural cracks and some concrete spalling. Nonductile frames may exhibit larger shear cracks and spalling.
Extensive Structural Damage: Some of the frame elements have reached their ultimate capacity indicated in ductile frames by large flexural cracks, spalled concrete and buckled main reinforcement; nonductile frame elements may have suffered shear failures or bond

failures at reinforcement splices, or broken ties or buckled main reinforcement in columns which may result in partial collapse.
Complete Structural Damage: Structure is collapsed or in imminent danger of collapse due to brittle failure of nonductile frame elements or loss of frame stability. Approximately 13%(low-rise), 10%(mid-rise) or 5%(high-rise) of the total area of C1 buildings with Complete damage is expected to be collapsed.

Concrete Shear Walls (C2):

Slight Structural Damage: Diagonal hairline cracks on most concrete shear wall surfaces; minor concrete spalling at few locations.
Moderate Structural Damage: Most shear wall surfaces exhibit diagonal cracks; some shear walls have exceeded yield capacity indicated by larger diagonal cracks and concrete spalling at wall ends.
Extensive Structural Damage: Most concrete shear walls have exceeded their yield capacities; some walls have exceeded their ultimate capacities indicated by large, through-the-wall diagonal cracks, extensive spalling around the cracks and visibly buckled wall reinforcement or rotation of narrow walls with inadequate foundations. Partial collapse may occur due to failure of nonductile columns not designed to resist lateral loads.
Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to failure of most of the shear walls and failure of some critical beams or columns. Approximately 13%(low-rise), 10%(mid-rise) or 5%(high-rise) of the total area of C2 buildings with Complete damage is expected to be collapsed.

Concrete Frame Buildings with Unreinforced Masonry Infill Walls (C3):

This is a "composite" structural system where the initial lateral resistance is provided by the infill walls. Upon cracking of the infills, further lateral resistance is provided by the concrete frame "braced" by the infill acting as diagonal compression struts. Collapse of the structure results when the infill walls disintegrate (due to compression failure of the masonry "struts") and the frame loses stability, or when the concrete columns suffer shear failures due to reduced effective height and the high shear forces imposed on them by the masonry compression struts.

Slight Structural Damage: Diagonal (sometimes horizontal) hairline cracks on most infill walls; cracks at frame-infill interfaces.
Moderate Structural Damage: Most infill wall surfaces exhibit larger diagonal or horizontal cracks; some walls exhibit crushing of brick around beam-column connections. Diagonal shear cracks may be observed in concrete beams or columns.
Extensive Structural Damage: Most infill walls exhibit large cracks; some bricks may dislodge and fall; some infill walls may bulge out-of-plane; few walls may fall partially or fully; few concrete columns or beams may fail in shear resulting in partial collapse. Structure may exhibit permanent lateral deformation.

Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to a combination of total failure of the infill walls and nonductile failure of the concrete beams and columns. Approximately 15%(low-rise), 13%(mid-rise) or 5%(high-rise) of the total area of C3 buildings with Complete damage is expected to be collapsed.

Precast Concrete Tilt-Up Walls (PC1):

Slight Structural Damage: Diagonal hairline cracks on concrete shear wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; minor concrete spalling at few locations; minor separation of walls from the floor and roof diaphragms; hairline cracks around metal connectors between wall panels and at connections of beams to walls.
Moderate Structural Damage: Most wall surfaces exhibit diagonal cracks; larger cracks in walls with door or window openings; few shear walls have exceeded their yield capacities indicated by larger diagonal cracks and concrete spalling. Cracks may appear at top of walls near panel intersections indicating "chord" yielding. Some walls may have visibly pulled away from the roof. Some welded panel connections may have been broken, indicated by spalled concrete around connections. Some spalling may be observed at the connections of beams to walls.
Extensive Structural Damage: In buildings with relatively large area of wall openings most concrete shear walls have exceeded their yield capacities and some have exceeded their ultimate capacities indicated by large, through-the-wall diagonal cracks, extensive spalling around the cracks and visibly buckled wall reinforcement. The plywood diaphragms may exhibit cracking and separation along plywood joints. Partial collapse of the roof may result from the failure of the wall-to-diaphragm anchorages sometimes with falling of wall panels.
Complete Structural Damage: Structure is collapsed or is in imminent danger of collapse due to failure of the wall-to-roof anchorages, splitting of ledgers, or failure of plywood-to-ledger nailing; failure of beams connections at walls; failure of roof or floor diaphragms; or, failure of the wall panels. Approximately 15% of the total area of PC1 buildings with Complete damage is expected to be collapsed.

Precast Concrete Frames with Concrete Shear Walls (PC2):

Slight Structural Damage: Diagonal hairline cracks on most shear wall surfaces; minor concrete spalling at few connections of precast members.
Moderate Structural Damage: Most shear wall surfaces exhibit diagonal cracks; some shear walls have exceeded their yield capacities indicated by larger cracks and concrete spalling at wall ends; observable distress or movement at connections of precast frame connections, some failures at metal inserts and welded connections.
Extensive Structural Damage: Most concrete shear walls have exceeded their yield capacities; some walls may have reached their ultimate capacities indicated by large, through-the wall diagonal cracks, extensive spalling around the cracks and visibly buckled wall reinforcement. Some critical precast frame connections may have failed resulting partial collapse.

Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to failure of the shear walls and/or failures at precast frame connections. Approximately 15%(low-rise), 13%(mid-rise) or 10%(high-rise) of the total area of PC2 buildings with Complete damage is expected to be collapsed.

Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms (RM1):

Slight Structural Damage: Diagonal hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; minor separation of walls from the floor and roof diaphragms.
Moderate Structural Damage: Most wall surfaces exhibit diagonal cracks; some of the shear walls have exceeded their yield capacities indicated by larger diagonal cracks. Some walls may have visibly pulled away from the roof.
Extensive Structural Damage: In buildings with relatively large area of wall openings most shear walls have exceeded their yield capacities and some of the walls have exceeded their ultimate capacities indicated by large, through-the-wall diagonal cracks and visibly buckled wall reinforcement. The plywood diaphragms may exhibit cracking and separation along plywood joints. Partial collapse of the roof may result from failure of the wall-to-diaphragm anchorages or the connections of beams to walls.
Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to failure of the wall anchorages or due to failure of the wall panels. Approximately 13%(low-rise) or 10%(mid-rise) of the total area of RM1 buildings with Complete damage is expected to be collapsed.

Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms (RM2):

Slight Structural Damage: Diagonal hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings.
Moderate Structural Damage: Most wall surfaces exhibit diagonal cracks; some of the shear walls have exceeded their yield capacities indicated by larger cracks.
Extensive Structural Damage: In buildings with relatively large area of wall openings most shear walls have exceeded their yield capacities and some of the walls have exceeded their ultimate capacities exhibited by large, through-the wall diagonal cracks and visibly buckled wall reinforcement. The diaphragms may also exhibit cracking
Complete Structural Damage: Structure is collapsed or is in imminent danger of collapse due to failure of the walls. Approximately 13%(low-rise), 10%(mid-rise) or 5%(high-rise) of the total area of RM2 buildings with Complete damage is expected to be collapsed.

Unreinforced Masonry Bearing Walls (URM):

Slight Structural Damage: Diagonal, stair-step hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; movements of lintels; cracks at the base of parapets.

Moderate Structural Damage: Most wall surfaces exhibit diagonal cracks; some of the walls exhibit larger diagonal cracks; masonry walls may have visible separation from diaphragms; significant cracking of parapets; some masonry may fall from walls or parapets.
Extensive Structural Damage: In buildings with relatively large area of wall openings most walls have suffered extensive cracking. Some parapets and gable end walls have fallen. Beams or trusses may have moved relative to their supports.
Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to in-plane or out-of-plane failure of the walls. Approximately 15% of the total area of URM buildings with Complete damage is expected to be collapsed.

Mobile Homes (MH):

Slight Structural Damage: Damage to some porches, stairs or other attached components.
Moderate Structural Damage: Major movement of the mobile home over its supports resulting in some damage to metal siding and stairs and requiring resetting of the mobile home on its supports.
Extensive Structural Damage: Mobile home has fallen partially off its supports, often severing utility lines.
Complete Structural Damage: Mobile home has totally fallen off its supports; usually severing utility lines, with steep jack stands penetrating through the floor. Approximately 3% of the total area of MH buildings with Complete damage is expected to be collapsed.

5.3.2 Nonstructural Damage

Four damage states are used to describe nonstructural damage: Slight, Moderate, Extensive and Complete nonstructural damage. Nonstructural damage is considered to be independent of the structural model building type (i.e. partitions, ceilings, cladding, etc. are assumed to incur the same damage when subjected to the same interstory drift or floor acceleration whether they are in a steel frame building or in a concrete shear wall building), consequently, building-specific damage state descriptions are not meaningful. Instead, general descriptions of nonstructural damage states are provided for common nonstructural systems.

Damage to drift-sensitive nonstructural components is primarily a function of interstory drift (e.g. full-height drywall partitions) while for acceleration-sensitive components (e.g. mechanical equipment) damage is a function of the floor acceleration. Developing fragility curves for each possible nonstructural component is not practicable for the purposes of regional loss estimation and there is insufficient data to develop such fragility curves. Hence, in this methodology nonstructural building components are grouped into drift-sensitive and acceleration-sensitive component groups, and the damage functions estimated for each group are assumed to be "typical" of it sub-components. Note, however, that damage depends on the anchorage/bracing provided to the nonstructural

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non-structural components are affected by both acceleration and drift, but for simplification, components are identified with one or the other as summarized in Table 9.3.

Table 9.3 Building Component Non-structural Damage

Type of Non-structural Damage	
Drift Sensitive	Acceleration Sensitive
• wall partitions • exterior wall panels and cladding • glass • ornamentation	• suspended ceilings • mechanical and electrical equipment • piping and ducts • elevators

9.3.2 Definitions of Damage States - Buildings

Damage estimates are used in **HAZUS**®MH to estimate life-safety consequences of building damage, expected monetary losses due to building damage, expected monetary losses which may result as a consequence of business interruption, expected social impacts, and other economic and social impacts. The building damage predictions may also be used to study expected damage patterns in a given region for different scenario earthquakes, for example, to identify the most vulnerable building types, or the areas with the worst expected damage to buildings.

To serve these purposes, damage predictions must be descriptive. The user must be able to glean the nature and extent of the physical damage to a building type from the damage prediction output so that life-safety, societal and monetary losses that result from the damage can be estimated. Building damage can best be described in terms of the nature and extent of damage exhibited by its components (beams, columns, walls, ceilings, piping, HVAC equipment, etc.). For example, such component damage descriptions as "shear walls are cracked", "ceiling tiles fell", "diagonal bracing buckled", or "wall panels fell out", used together with such terms as "some" and "most" would be sufficient to describe the nature and extent of overall building damage.

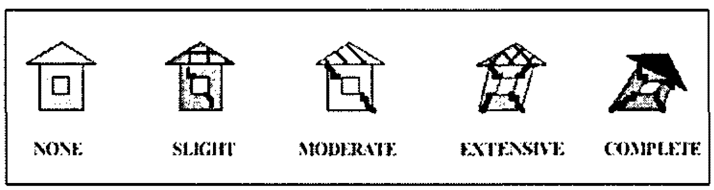


Figure 9.18 The five damage states.

Using the criteria described above, damage is described by five **damage states**: none, slight, moderate, extensive or complete (see Figure 9.18). General descriptions for the structural damage states of 16 common building types are found in the *Technical Manual.* Table 9.4 provides an example of the definitions of damage states for light wood frame buildings. It should be understood that a single damage state could refer to a wide range of damage. For example the **slight** damage state for light wood frame structures may vary from a few very small cracks at one or two windows, to small cracks at all the window and door openings.

Table 9.4 Examples of Structural Damage State Definitions

Wood, Light Frame
Slight : Small plaster or gypsum board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate: Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive: Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations; small foundations cracks.
Complete: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Damage to non-structural components is considered to be independent of building type. This is because partitions, ceilings, cladding, etc., are assumed to incur the same damage when subjected to the same inter-story drift or floor acceleration whether they are in a steel frame building or in a concrete shear wall building. Therefore as shown in the example in Table 9.5, descriptions of non-structural damage states are developed for common non-structural systems, rather than as a function of building type.

Table 9.5 Examples of Non-structural Damage State Definitions

Suspended Ceilings
Slight : A few Ceiling tiles may have moved or fallen down.
Moderate: Falling of tiles is more extensive; in addition the ceiling support framing (t-bars) may disconnect and/or buckle at a few locations; lenses may fall off a few light fixtures.
Extensive: The ceiling system may exhibit extensive buckling, disconnected t-bars and falling ceiling tiles; ceiling may have partial collapse at a few locations and a few light fixtures may fall.
Complete: The ceiling system is buckled throughout and/or has fallen down and requires complete replacement.

9.3.3 Definitions of Damage States - Lifelines

As with buildings, five damage states are defined: none, slight, moderate, extensive and complete. For each component of each lifeline a description of the damage is provided for each damage state. These descriptions are found in Sections 7.1 through 8.6 of the *Technical Manual*. An example of the damage state descriptions for electrical power system distribution circuits is found in Table 9.6

Table 9.6 Damage State Descriptions for Electrical Power System

Damage State	Damage Description
Slight	Failure of 4% of all circuits
Moderate	Failure of 12% of all circuits
Extensive	Failure of 50% of all circuits
Complete	Failure of 80% of all circuits

Damage states can be defined in numerical terms as is the case for distribution circuits or they can be more descriptive as shown in Table 9.7.

Table 9.7 Damage State Descriptions for Electrical Power System

Damage State	**Damage Description**
Slight	Turbine tripping, or light damage to diesel generator, or the building is in the slight damage state.
Moderate	Chattering of instrument panels and racks, or considerable damage to boilers and pressure vessels, or the building is in the moderate damage state.
Extensive	Considerable damage to motor driven pumps, or considerable damage to large vertical pumps, or the building is in the extensive damage state.
Complete	Extensive damage to large horizontal vessels beyond repair, or extensive damage to large motor operated valves, or the building is in the complete damage state.

9.3.4 Fragility Curves - Buildings

Based on the damage state descriptions described in the previous section and using a series of engineering calculations that can be found in the *Technical Manual*, **fragility curves** were developed for each building type. A fragility curve describes the probability of being in a specific damage state as a function of the size of earthquake input. For structural damage the fragility curves express damage as a function of building displacement (see Figure 9.19). The fragility curves express non-structural damage as a function of building displacement or acceleration, depending upon whether they refer to drift-sensitive or acceleration-sensitive damage.

Default fragility curves are supplied with the methodology. It is highly recommended that default curves be used in the loss studies. Modification of these fragility curves requires the input of a structural engineer experienced in the area of seismic design.

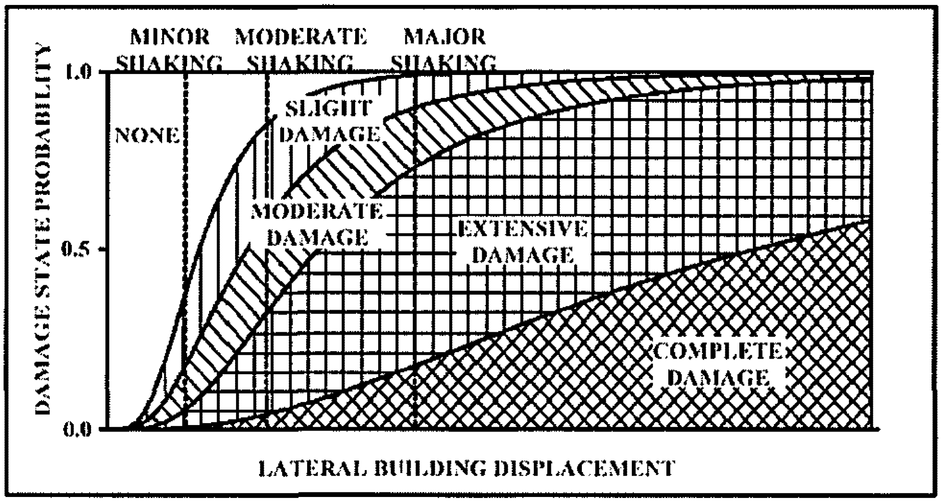


Figure 9.19 Sample building fragility curve.

9.3.5 Fragility Curves - Lifelines

As with buildings, default damage functions (fragility curves) have been developed for all components of all lifeline systems. Typical damage functions are shown in Figure 9.20 and Figure 9.21. The damage functions are provided in terms of PGA (Figure 9.20) and PGD (Figure 9.21). The top curve in Figure 9.20 gives the probability that the damage state is at least slight given that the bridge has been subjected to a specified PGA. For example, if the bridge experiences a PGA of 0.4g, there is a 0.7 probability that the damage will be slight or worse. Figure 9.21 is similar, except it is in terms of PGD. Thus if a bridge experiences a permanent ground deformation of 12 inches, there is a 100 percent chance that it will have at least slight damage and a 70% chance it will have moderate damage or worse.

Table 5.3 Approximate Basis for Seismic Design Levels

Seismic Design Level	Seismic Zone (*Uniform Building Code*)	Map Area (*NEHRP Provisions*)
High-Code	4	7
Moderate-Code	2B	5
Low-Code	1	3 ?
Pre-Code	0	1

The capacity and fragility curves represent buildings designed and constructed to modern seismic code provisions. Study areas (e.g., census tracts) of recent construction are appropriately modeled using building damage functions with a seismic design level that corresponds to the seismic zone or map area of the governing provisions. Older areas of construction, not conforming to modern standards, should be modeled using a lower level of seismic design. For example, in areas of high seismicity (e.g., coastal California), buildings of newer construction (e.g., post-1973) are best represented by High-Code damage functions, while buildings of older construction would be best represented by Moderate-Code damage functions, if built after about 1940, or by Pre-Code damage functions, if built before about 1940 (i.e., before seismic codes existed). Pre-Code damage functions are appropriate for modeling older buildings that were not designed for earthquake load, regardless of where they are located in the United States. Guidance is provided to expert users in Section 5.7 for selection of appropriate building damage functions

5.4.2 Capacity Curves

Most buildings are presently designed or evaluated using linear-elastic analysis methods, primarily due to the relative simplicity of these methods in comparison to more complex, nonlinear methods. Typically, building response is based on linear-elastic properties of the structure and forces corresponding to the design-basis earthquake. For design of building elements, linear-elastic (5%-damped) response is reduced by a factor (e.g. the "R-Factor" in 1994 *NEHRP Provisions*) that varies for different types of lateral force resisting systems. The reduction factor is based on empirical data and judgment that account for the inelastic deformation capability (ductility) of the structural system, redundancy, overstrength, increased damping (above 5% of critical) at large deformations, and other factors that influence building capacity. Although this "force-based" approach is difficult to justify by rational engineering analysis, buildings designed using these methods have performed reasonably well in past earthquakes. Aspects of these methods found not to work well in earthquakes have been studied and improved. In most cases, building capacity has been increased by improvements to detailing practices (e.g., better confinement of steel reinforcement in concrete elements).

Except for a few brittle systems and acceleration-sensitive elements, building damage is primarily a function of building displacement, rather than force. In the inelastic range of building response, increasingly larger damage would result from increased building displacement although lateral force would remain constant or decrease. Hence, successful prediction of earthquake damage to buildings requires reasonably accurate estimation of building displacement response in the inelastic range. This, however, can not be accomplished using linear-elastic methods, since the buildings respond inelastically to earthquake ground shaking of magnitudes of interest for damage prediction. Building capacity (push-over) curves, used with capacity spectrum method (CSM) techniques [Mahaney, et. al., 1993, Kircher, 1996], provide simple and reasonably accurate means of predicting inelastic building displacement response for damage estimation purposes.

A building capacity curve (also known as a push-over curve) is a plot of a building's lateral load resistance as a function of a characteristic lateral displacement (i.e., a force-deflection plot). It is derived from a plot of static-equivalent base shear versus building (e.g., roof) displacement. In order to facilitate direct comparison with earthquake demand (i.e. overlaying the capacity curve with a response spectrum), the force (base shear) axis is converted to spectral acceleration and the displacement axis is converted to spectral displacement. Such a plot provides an estimate of the building's "true" deflection (displacement response) for any given earthquake response spectrum.

The building capacity curves developed for the Methodology are based on engineering design parameters and judgment. Three control points that define model building capacity describe each curve:

- Design Capacity
- Yield Capacity
- Ultimate Capacity

Design capacity represents the nominal building strength required by current model seismic code provisions (e.g., 1994 *NEHRP Provisions*) or an estimate of the nominal strength for buildings not designed for earthquake loads. Wind design is not considered in the estimation of design capacity, and certain buildings (e.g., tall buildings located in zones of low or moderate seismicity) may have a lateral design strength considerably greater than that based on seismic code provisions.

Yield capacity represents the true lateral strength of the building considering redundancies in design, conservatism in code requirements and true (rather than nominal) strength of materials. Ultimate capacity represents the maximum strength of the building when the global structural system has reached a fully plastic state. Ultimate capacity implicitly accounts for loss of strength due to shear failure of brittle elements. Typically, buildings are assumed capable of deforming beyond their ultimate point without loss of stability, but their structural system provides no additional resistance to lateral earthquake force.

Up to the yield point, the building capacity curve is assumed to be linear with stiffness based on an estimate of the true period of the building. The true period is typically longer than the code-specified period of the building due to flexing of diaphragms of short, stiff buildings, flexural cracking of elements of concrete and masonry structures, flexibility of foundations and other factors observed to affect building stiffness. From the yield point to the ultimate point, the capacity curve transitions in slope from an essentially elastic state to a fully plastic state. The capacity curve is assumed to remain plastic past the ultimate point. An example building capacity curve is shown in Figure 5.3.

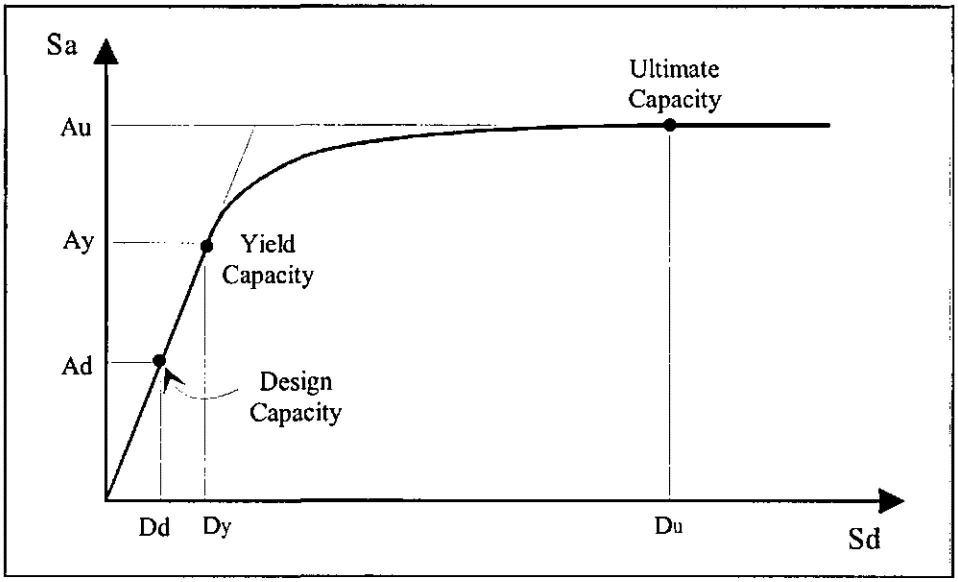


Figure 5.3 Example Building Capacity Curve.

The building capacity curves are constructed based on estimates of engineering properties that affect the design, yield and ultimate capacities of each model building type. These properties are defined by the following parameters:

- C_s design strength coefficient (fraction of building's weight),
- T_e true "elastic" fundamental-mode period of building (seconds),
- α_1 fraction of building weight effective in push-over mode,
- α_2 fraction of building height at location of push-over mode displacement,
- γ "overstrength" factor relating "true" yield strength to design strength,
- λ "overstrength" factor relating ultimate strength to yield strength, and

μ "ductility" factor relating ultimate displacement to λ times the yield displacement (i.e., assumed point of significant yielding of the structure)

The design strength, C_s, is approximately based, on the lateral-force design requirements of current seismic codes (e.g., *1994 NEHRP Provisions*). These requirements are a function of the building's seismic zone location and other factors including: site soil condition, type of lateral-force-resisting system and building period. For each of the four design levels (High-Code, Moderate-Code, Low-Code and Pre-Code), design capacity is based on the best estimate of typical design properties. Table 5.4 summarizes design capacity for each building type and design level. Building period, T_e, push-over mode parameters α_1 and α_2, the ratio of yield to design strength, γ, and the ratio of ultimate to yield strength, λ, are assumed to be independent of design level. Values of these parameters are summarized in Table 5.5 for each building type. Values of the "ductility" factor, μ, are given in Table 5.6 for each building type and design level. Note that for the following tables, shaded boxes indicate types that are not permitted by current seismic codes.

Chapter 4
Potential Earth Science Hazards (PESH)

Potential earth science hazards (PESH) include ground motion, ground failure (i.e., liquefaction, landslide and surface fault rupture) and tsunami/seiche. Methods for developing estimates of ground motion and ground failure are discussed in the following sections. Tsunami/seiche can be included in the Methodology in the form of user-supplied inundation maps as discussed in Chapter 9. The Methodology, highlighting the PESH component, is shown in Flowchart 4.1.

4.1 Ground Motion

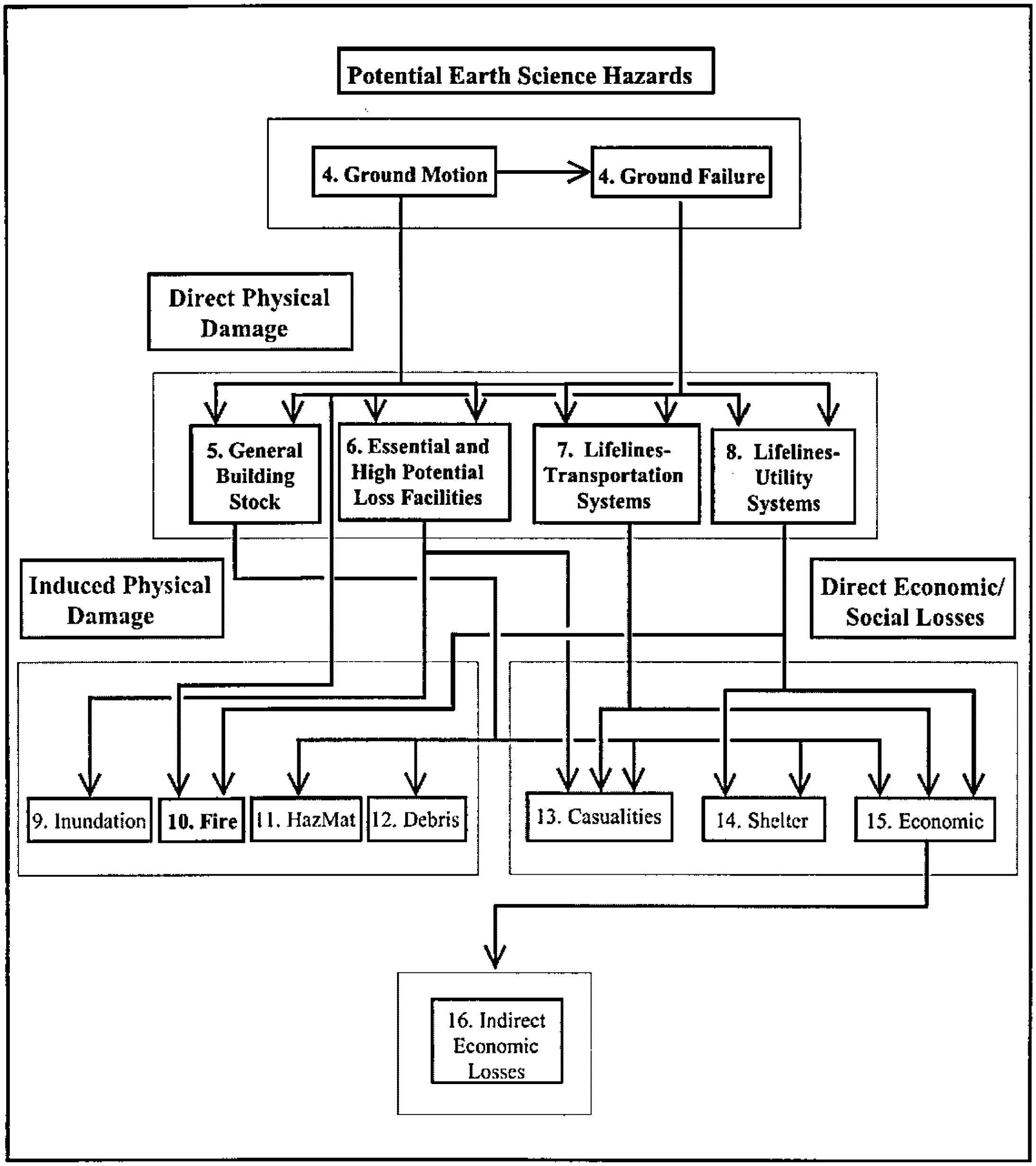
4.1.1 Introduction

Ground motion estimates are generated in the form of GIS-based contour maps and location-specific seismic demands stored in relational databases. Ground motion is characterized by: (1) spectral response, based on a standard spectrum shape, (2) peak ground acceleration and (3) peak ground velocity. The spatial distribution of ground motion can be determined using one of the following methods or sources:

- Deterministic ground motion analysis (Methodology calculation)
- USGS probabilistic ground motion maps (maps supplied with **HAZUS**)
- Other probabilistic or deterministic ground motion maps (user-supplied maps)

Deterministic seismic ground motion demands are calculated for user-specified scenario earthquakes (Section 4.1.2.1). For a given event magnitude, attenuation relationships (Section 4.1.2.3) are used to calculate ground shaking demand for rock sites (Site Class B), which is then amplified by factors (Section 4.1.2.4) based on local soil conditions when a soil map is supplied by the user. The attenuation relationships provided with the Methodology for Western United States (WUS) sites are based on Boore, Joyner & Fumal (1993, 1994a, 1994b), Campbell and Bozorgnia (1994), Munson and Thurber (1997), Sadigh, Chang, Abrahamson, Chiou and Power (1993) and Youngs, Chiou, Silva and Humphrey (1997). For sites in the Central and Eastern United States (CEUS), the attenuation relationships are based on Frankel et al. (1996), Savy (1998) and Toro, Abrahamson and Schneider (1997).

In the Methodology's probabilistic analysis procedure, the ground shaking demand is characterized by spectral contour maps developed by the United States Geological Survey (USGS) as part of Project 97 project (Frankel et. al, 1996). The Methodology includes maps for eight probabilistic hazard levels: ranging from ground shaking with a 39% probability of being exceeded in 50 years (100 year return period) to the ground shaking with a 2% probability of being exceeded in 50 years (2500 year return period). The USGS maps describe ground shaking demand for rock (Site Class B) sites, which the Methodology amplifies based on local soil conditions.



Flowchart 4.1: Ground Motion and Ground Failure Relationship to other Modules of the Earthquake Loss Estimation Methodology

User-supplied peak ground acceleration (PGA) and spectral acceleration contour maps may also be used with **HAZUS** (Section 4.1.2.1). In this case, the user must provide all contour maps in a pre-defined digital format (as specified in the *User's Manual*). As stated in Section 4.1.2.1, the Methodology assumes that user-supplied maps include soil amplification.

4.1.1.1 Form of Ground Motion Estimates / Site Effects

Ground motion estimates are represented by: (1) contour maps and (2) location-specific values of ground shaking demand. For computational efficiency and improved accuracy, earthquake losses are generally computed using location-specific estimates of ground shaking demand. For general building stock the analysis has been simplified so that ground motion demand is computed at the centroid of a census tract. However, contour maps are also developed to provide pictorial representations of the variation in ground motion demand within the study region. When ground motion is based on either USGS or user-supplied maps, location-specific values of ground shaking demand are interpolated between PGA, PGV or spectral acceleration contours, respectively.

Elastic response spectra (5% damping) are used by the Methodology to characterize ground shaking demand. These spectra all have the same "standard" format defined by a PGA value (at zero period) and spectral response at a period of 0.3 second (acceleration domain) and spectral response at a period of 1.0 second (velocity domain). Ground shaking demand is also defined by peak ground velocity (PGV).

4.1.1.2 Input Requirements and Output Information

For computation of ground shaking demand, the following inputs are required:

- **Scenario Basis** - The user must select the basis for determining ground shaking demand from one of three options: (1) a deterministic calculation, (2) probabilistic maps, supplied with the Methodology, or (3) user-supplied maps. For deterministic calculation of ground shaking, the user specifies a scenario earthquake magnitude and location. In some cases, the user may also need to specify certain source attributes required by the attenuation relationships supplied with the Methodology.

- **Attenuation Relationship** - For deterministic calculation of ground shaking, the user selects an appropriate attenuation relationship from those supplied with the Methodology. Attenuation relationships are based on the geographic location of the study region (Western United States vs. Central Eastern United States) and on the type of fault for WUS sources. WUS regions include locations in, or west of, the Rocky Mountains, Hawaii and Alaska. Figure 4-1 shows the regional separation of WUS and CEUS locations as defined in Project 97 (Frankel et al., 1996). The designation of states as WUS or CEUS as specified in the Methodology is found in Table 3C.1. For WUS sources, the attenuation functions predict ground shaking based on source type, including: (1) strike-slip faults, (2) reverse-slip faults, (3) normal faults (4) deep faults (> 50 km) and (5) Cascadia subduction zone sources. The Methodology provides "default" combinations of attenuation functions for the WUS and CEUS, respectively, following the theory developed by the USGS for the 48 contiguous states in Project 97 (Frankel et al., 1996), for Alaska (Frankel, 1997), and Hawaii (Klein et al., 1998).

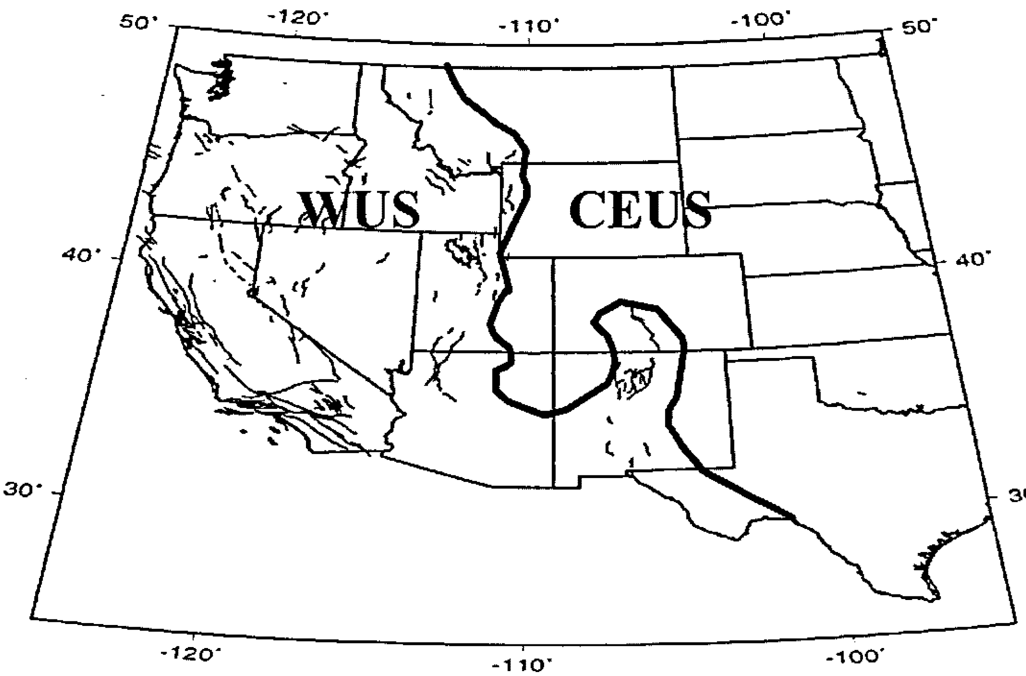


Figure 4.1 Boundaries Between WUS and CEUS Locations as Defined in Project 97.

- **Soil Map** - The user may supply a detailed soil map to account for local site conditions. This map must identify soil type using a scheme that is based on, or can be related to, the site class definitions of the 1997 *NEHRP Provisions* (Section 4.1.2.4), and must be in pre-defined digital format (as specified in the *User's Manual*). In the absence of a soil map, **HAZUS** will amplify the ground motion demand assuming Site Class D soil at all sites. However; a user may specify a soil map on a census tract basis using **HAZUS** (see Section 6.8 of the *User's Manual*).

4.1.2 Description of Methods

The description of the methods for calculating ground shaking is divided into four separate areas:

- Basis for ground shaking (Section 4.1.2.1)
- Standard shape of response spectra (Section 4.1.2.2)
- Attenuation of ground shaking (Section 4.1.2.3)
- Amplification of ground shaking - local site conditions (Section 4.1.2.4)

4.1.2.1 Basis for Ground Shaking

The methodology supports three options as the basis for ground shaking:

- Deterministic calculation of scenario earthquake ground shaking
- Probabilistic seismic hazard maps (USGS)
- User-supplied seismic hazard maps

Deterministic Calculation of Scenario Earthquake Ground Shaking

For deterministic calculation of the scenario event, the user specifies the location (e.g., epicenter) and magnitude of the scenario earthquake. The Methodology provides three options for selection of an appropriate scenario earthquake location. The user can either: (1) specify an event based on a database of WUS seismic sources (faults), (2) specify an event based on a database of historical earthquake epicenters, or (3) specify an event based on an arbitrary choice of the epicenter. These options are described below.

Seismic Source Database (WUS Fault Map)

For the WUS, the Methodology provides a database of seismic sources (fault segments) developed by the USGS, the California Department of Mines and Geology (CDMG) and the Nevada Bureau of Mines and Geology (NBMG). The user accesses the database map (using **HAZUS**) and selects a magnitude and epicenter on one of the identified fault segments. The database includes information on fault segment type, location, orientation and geometry (e.g., depth, width and dip angle), as well as on each fault segment's seismic potential (e.g., maximum moment).

The Methodology computes the expected values of surface and subsurface fault rupture length. Fault rupture length is based on the relationship of Wells and Coppersmith (1994) given below:

$$\log_{10}(L) = a + b \cdot M \qquad (4\text{-}1)$$

where:

	L	is the rupture length (km)
	M	is the moment magnitude of the earthquake

Table 4.1 Regression Coefficients of Fault Rupture Relationship of Wells and Coppersmith (1994)

Rupture Type	Fault Type	a	b
Surface	Strike Slip	-3.55	0.74
	Reverse	-2.86	0.63
	All	-3.22	0.69
Subsurface	Strike Slip	-2.57	0.62
	Reverse	-2.42	0.58
	All	-2.44	0.59

Fault rupture is assumed to be of equal length on each side of the epicenter, provided the calculated rupture length is available in both directions along the specified fault segment. If the epicenter location is less than one-half of the rupture length from an end point of the fault segment (e.g., the epicenter is located at or near an end of the fault segment), then fault rupture length is truncated so that rupture does not extend past the end of the fault segment. If the calculated rupture length exceeds the length of the fault segment, then the entire fault segment is assumed to rupture between its end points, unless the fault is connected to other fault segments. In the case where multiple faults segments share common endpoints (i.e. the segments are connected), the methodology provides the user with the ability to create an earthquake rupture across multiple segments.

Historical Earthquake Database (Epicenter Map)

The Methodology software provides a database of historical earthquakes developed from the Global Hypocenter Database available from the National Earthquake Information Center (NEIC, 1992), which contains reported earthquakes from 300 BC to 1990. The database has been sorted to remove historical earthquakes with magnitudes less than 5.0. The user accesses the database via **HAZUS** and selects a historical earthquake epicenter which includes location, depth and magnitude information.

For the WUS, the attenuation relationships require the user to specify the type and orientation of the fault associated with the selected epicenter. The Methodology computes the expected values of surface and subsurface fault rupture length using Equation (4-1). Fault rupture is assumed to be of equal length on each side of the epicenter. For the CEUS, the attenuation relationships depend on the hypocentral distance (Frankel et al., 1996 & Savy, 1998) or closest horizontal distance to the epicenter (Toro et al., 1997).

Arbitrary Event

Under this option, the user specifies a scenario event magnitude and arbitrary epicenter (using **HAZUS**). For the WUS, the user must also supply the type and orientation of the fault associated with the arbitrary epicenter. The Methodology computes the fault rupture length based on Equation (4-1) and assumes fault rupture to be of equal length on each side of the epicenter. For the CEUS the user must supply the depth of the hypocenter.

Probabilistic Seismic Hazard Maps (USGS)

The Methodology includes probabilistic seismic hazard contour maps developed by the USGS for Project 97. The USGS maps provide estimates of PGA and spectral acceleration at periods of 0.3 second and 1.0 second, respectively. Ground shaking estimates are available for eight hazard levels: ranging from the ground shaking with a 39% probability of being exceeded in 50 years to ground shakeing with a 2% probability of being exceeded in 50 years. In terms of mean return periods, the hazard levels range from 100 years to 2500 years.

User-Supplied Seismic Hazard Maps

The Methodology allows the user to supply PGA and spectral acceleration contour maps of ground shaking in a pre-defined digital format (as specified in the User's Manual). This option permits the user to develop a scenario event that could not be described adequately by the available attenuation relationships, or to replicate historical earthquakes (e.g., 1994 Northridge Earthquake). The maps of PGA and spectral acceleration (periods of 0.3 and 1.0 second) must be provided. The Methodology software assumes these ground motion maps include soil amplification, thus no soil map is required.

Should only PGA contour maps be available, the user can develop the other required maps based on the spectral acceleration response factors given in Table 4.2 (WUS) and Table 4.3 (CEUS).

4.1.2.2 Standard Shape of the Response Spectra

The Methodology characterizes ground shaking using a standardized response spectrum shape, as shown in Figure 4.2. The standardized shape consists of four parts: peak ground acceleration (PGA), a region of constant spectral acceleration at periods from zero seconds to T_{AV} (seconds), a region of constant spectral velocity at periods from T_{AV} to T_{VD} (seconds) and a region of constant spectral displacement for periods of T_{VD} and beyond.

In Figure 4.2, spectral acceleration is plotted as a function of spectral displacement (rather than as a function of period). This is the format of response spectra used for evaluation of damage to buildings (Chapter 5) and essential facilities (Chapter 6). Equation (4-2) may be used to convert spectral displacement (inches), to period (seconds) for a given value of spectral acceleration (units of g), and Equation (4-3) may be used to convert spectral acceleration (units of g) to spectral displacement (inches) for a given value of period.

$$T = 0.32\sqrt{\frac{S_D}{S_A}} \tag{4-2}$$

$$S_D = 9.8 \cdot S_A \cdot T^2 \tag{4-3}$$

The region of constant spectral acceleration is defined by spectral acceleration at a period of 0.3 second. The constant spectral velocity region has spectral acceleration proportional to 1/T and is anchored to the spectral acceleration at a period of 1 second. The period, T_{AV}, is based on the intersection of the region of constant spectral acceleration and constant spectral velocity (spectral acceleration proportional to 1/T). The value of T_{AV} varies depending on the values of spectral acceleration that define these two intersecting regions. The constant spectral displacement region has spectral acceleration proportional to $1/T^2$ and is anchored to spectral acceleration at the period, T_{VD}, where constant spectral velocity transitions to constant spectral displacement.

The period, T_{VD}, is based on the reciprocal of the corner frequency, f_c, which is proportional to stress drop and seismic moment. The corner frequency is estimated in Joyner and Boore (1988) as a function of moment magnitude (M). Using Joyner and Boore's formulation, the period T_{VD}, in seconds, is expressed in terms of the earthquake's moment magnitude as shown by the following Equation (4-4):

$$T_{VD} = 1/f_c = 10^{\frac{(M-5)}{2}} \tag{4-4}$$

When the moment magnitude of the scenario earthquake is not known (e.g., when using USGS maps or user-supplied maps), the period T_{VD} is assumed to be 10 seconds (i.e., moment magnitude is assumed to be **M** = 7.0).

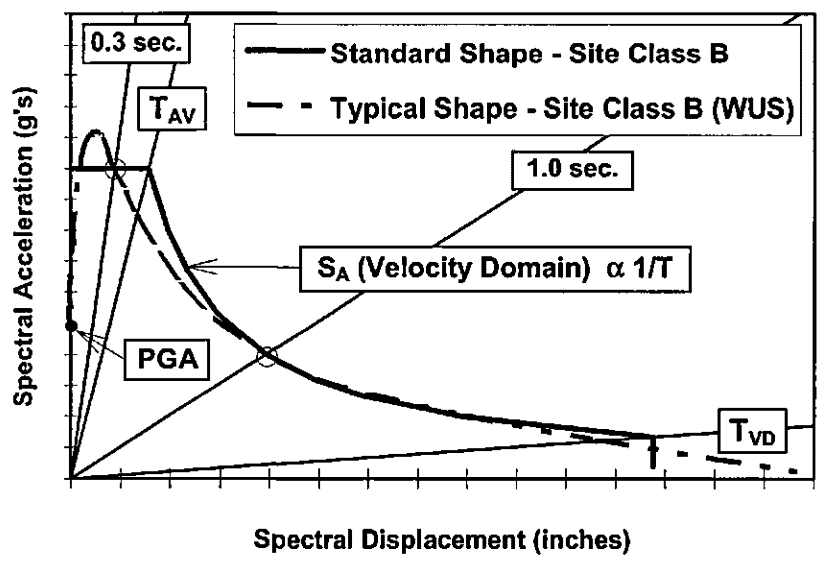


Figure 4.2 Standardized Response Spectrum Shape

Using a standard response spectrum shape simplifies calculation of response needed in estimating damage and loss. In reality, the shape of the spectrum will vary depending on whether the earthquake occurs in the WUS or CEUS, whether it is a large or moderate size event and whether the site is near or far from the earthquake source. However, the differences between the shape of an actual spectrum and the standard spectrum tend to be significant only at periods less than 0.3 second and at periods greater than T_{VD}, which do not significantly affect the Methodology's estimation of damage and loss.

The standard response spectrum shape (with adjustment for site amplification) represents all site/source conditions, except for site/source conditions that have strong amplification at periods beyond 1 second. Although relatively rare, strong amplification at periods beyond 1 second can occur. For example, strong amplification at a period of about 2 seconds caused extensive damage and loss to taller buildings in parts of Mexico City during the 1985 Michoacan earthquake. In this case, the standard response spectrum shape would tend to overestimate short-period spectral acceleration and to underestimate long-period (i.e., greater than 1-second) spectral acceleration.

Inferred Ground Shaking Hazard Information

Certain ground shaking hazard information is inferred from other ground shaking hazard information when complete hazard data is not available. Inferred data includes the following:

- Peak ground velocity (PGV) is inferred from 1-second spectral acceleration response
- Spectral acceleration response is inferred from the peak ground acceleration (PGA)
- 0.3-second spectral acceleration response is inferred from 0.2-second response

PGV Inferred from 1-Second Spectral Response

Unless supplied by the user (i.e., as user-supplied PGV maps), peak ground velocity (inches per second) is inferred from 1-second spectral acceleration, S_{A1} (units of g), using Equation (4-5).

$$PGV = \left(\frac{386.4}{2\pi} \cdot S_{A1} \right) / 1.65 \tag{4-5}$$

The factor of 1.65 in the denominator of Equation (4-5) represents the amplification assumed to exist between peak spectral response and PGV. This factor is based on the median spectrum amplification, as given in Table 2 of Newmark and Hall (1982) for a 5%-damped system whose period is within the velocity-domain region of the response spectrum.

Spectral Acceleration Response Inferred from Peak Ground Acceleration (PGA)

When a user has maps of PGA only, short-period spectral acceleration, S_{AS}, maps are developed from PGA, and 1.0-second spectral acceleration, S_{A1}, is inferred from short-period spectral acceleration, S_{AS}, based on the factors given in Table 4.2 for WUS rock (Site Class B) locations and in Table 4.3 for CEUS rock (Site Class B) locations.

Table 4.2 Spectral Acceleration Response Factors - WUS Rock (Site Class B)

Closest Distance to Fault Rupture	S_{AS}/PGA given Magnitude, M:				S_{AS}/S_{A1} given Magnitude, M:			
	≤ 5	6	7	≥ 8	≤ 5	6	7	≥ 8
≤ 10 km	1.4	1.8	2.1	2.1	5.3	3.7	3.1	1.8
20 km	1.5	2.0	2.1	2.0	5.0	3.5	2.5	1.7
40 km	1.6	2.1	2.2	2.0	4.6	3.3	2.3	1.6
≥ 80 km	1.3	1.8	2.1	2.0	4.1	3.1	2.1	1.5

Table 4.3 Spectral Acceleration Response Factors - CEUS Rock (Site Class B)

Hypocentral Distance	S_{AS}/PGA given Magnitude, M:				S_{AS}/S_{A1} given Magnitude, M:			
	≤ 5	6	7	≥ 8	≤ 5	6	7	≥ 8
≤ 10 km	0.9	1.2	1.5	2.1	8.7	4.2	3.1	2.3
20 km	1.0	1.3	1.4	1.6	8.1	4.0	3.0	2.7
40 km	1.2	1.4	1.6	1.6	7.3	3.7	2.8	2.6
≥ 80 km	1.5	1.7	1.8	1.9	6.5	3.3	2.5	2.4

The factors given in Tables 4.2 and 4.3 are based on the default combinations of attenuation WUS and CEUS functions, described in the next section. These factors distinguish between small-magnitude and large-magnitude events and between sites that are located at different distances from the source (i.e., closest distance to fault rupture for the WUS and distance to the hypocenter for the CEUS). The ratios of S_{AS}/S_{A1} and S_{AS}/PGA define the standard shape of the response spectrum for each of the magnitude/distance combinations of Tables 4.2 and 4.3.

Tables 4.2 and 4.3 require magnitude and distance information to determine spectrum amplification factors. This information would likely be available for maps of observed earthquake PGA, or scenario earthquake PGA, but is not available for probabilistic maps of PGA, since these maps are aggregated estimates of seismic hazard due to different event magnitudes and sources.

0.3-Second Spectral Acceleration Response Inferred from 0.2-Second Response

Some of the probabilistic maps developed by the USGS for Project 97, estimate short-period spectral response for a period of 0.2 second. Spectral response at a period of 0.3 second is calculated by dividing 0.2-second response by a factor of 1.1 for WUS locations and by dividing 0.2-second response by a factor of 1.4 for CEUS locations.

The factors describing the ratio of 0.2-second and 0.3-second response are based on the default combinations of WUS and CEUS attenuation functions, described in the next section, and the assumption that large-magnitude events tend to dominate seismic hazard at most WUS locations and that small-magnitude events tend to dominate seismic hazard at most CEUS locations.

4.1.2.3 Attenuation of Ground Shaking

Ground shaking is attenuated with distance from the source using relationships provided with the Methodology. These relationships define ground shaking for rock (Site Class B) conditions based on earthquake magnitude and other parameters. These relationships are used to estimate PGA and spectral demand at 0.3 and 1.0 seconds, and with the standard response spectrum shape (described in Section 4.1.2.2) fully define 5%-damped demand spectra at a given location.

The Methodology provides five WUS and three CEUS attenuation functions. The WUS relationships should be used for study regions located in, or west of, the Rocky Mountains, Hawaii and Alaska. The CEUS attenuation relationships should be used for the balance of the continental United States and Puerto Rico. Table 3C.1 defines the distribution of states for the WUS and CEUS.

Western United States Attenuation Relationships

The WUS attenuation relationships provided with the Methodology are based on:

- Boore, Joyner & Fumal (1993, 1994a, 1994b) - shallow crustal earthquakes
- Sadigh, Chang, Abrahamson, Chiou, and Power (1993) - shallow crustal earthquakes
- Campbell and Bozorgnia (1994) - shallow crustal earthquakes (PGA only)
- Munson and Thurber (1997) - Hawaiian earthquakes (PGA only)
- Youngs, Chiou, Silva and Humphrey (1997) - deep and subduction zone earthquakes

Boore, Joyner and Fumal (1993, 1994a, 1994b)

The Boore, Joyner and Fumal (1993, 1994a, 1994b) attenuation relationships predict PGA and spectral acceleration for different site conditions. In the Methodology, the Boore, Joyner and Fumal (BJF 1994) relationship, given in Equation (4-6), predicts the mean value of ground shaking for a site with a shear wave velocity of $V_S = 760$ m/sec. A shear wave velocity of 760 m/sec is the minimum value of shear wave velocity that defines Site Class B conditions (see Table 4.9), and is the same velocity used by the USGS (Project 97) to develop hazard maps for rock sites (Site Class B).

$$log_{10}(SD) = B_{SA} + a_{SS} \cdot G_{SS} + a_{RS} \cdot G_{RS} + b(\mathbf{M}-6) + c(\mathbf{M}-6)^2 + d\left(\sqrt{r^2+h^2}\right) + e[\,log_{10}\left(\sqrt{r^2+h^2}\right)] + f(2.881 - log_{10}V_B) \qquad (4\text{-}6)$$

where:	SD	is mean of the seismic demand (PGA or spectral acceleration (S_A) in units of g)
	M	is the moment magnitude of the earthquake
	r	is the horizontal distance, in km, from the site to the closest point on the surface projection of fault rupture (see Figure 4.3)
	B_{SA}	is a factor converting spectral velocity (cm/sec) to spectral acc. (g)

a_{SS}, a_{RS}	are coefficients for strike-slip/normal and reverse-slip faults, respectively, as given in Table 4.4*
G_{SS}, G_{RS}	are fault-type flags: G_{SS} =1 for strike-slip/normal faults, 0 otherwise; G_{RS} = 1 for reverse-slip/thrust faults, 0 otherwise*
b, c, d, e, f	are coefficients given in Table 4.4
h	is the value of a 'fictitious' depth that is determined by the regression methods and varies by period. It should not be confused with measures of depth of the top edge of the fault rupture (Y_D) that is used in other attenuation relationships
V_B	is the value of effective shear wave velocity for WUS rock sites (Site Class B) given in Table 4.4

* Oblique faults are categorized as strike slip if the rake angle is within 30° of horizontal; otherwise, they are defined as reverse slip. The Methodology uses the strike slip relationship for normal slip earthquakes.

Table 4.4 Boore, Joyner and Fumal (1994) Coefficients - WUS Attenuation

Period	B_{SA}	a_{SS}	a_{RS}	b	c	e	f	h	V_B
Spectral Coefficients (5%-Damped Response Spectra)									
0.3	-1.670	1.930	2.019	0.334	-0.070	-0.893	-0.401	5.94	2130
1.0	-2.193	1.701	1.755	0.450	-0.014	-0.798	-0.698	2.90	1410
Peak Ground Acceleration Coefficients									
0.0	0.0	-0.136	-0.051	0.229	0.000	-0.778	-0.371	5.57	1400

Values of coefficients: B_{SA}, a_{SS}, a_{RS}, b, c, d, e, f, h, and V_B for prediction of 5%-damped response of the random horizontal component of ground shaking are given in Table 4.4.

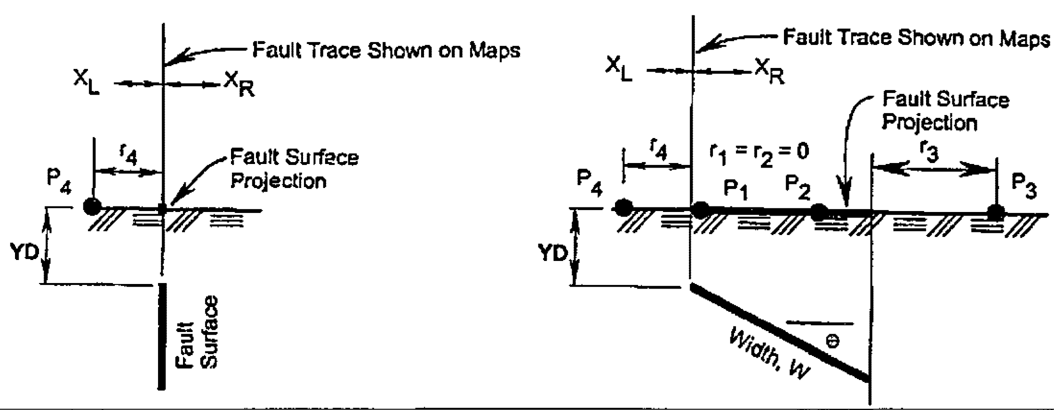


Figure 4.3 Measure of distance for vertical and dipping faults used in Boore Joyner & Fumal (1994) and Munson & Thurber (1997) attenuation relationships.