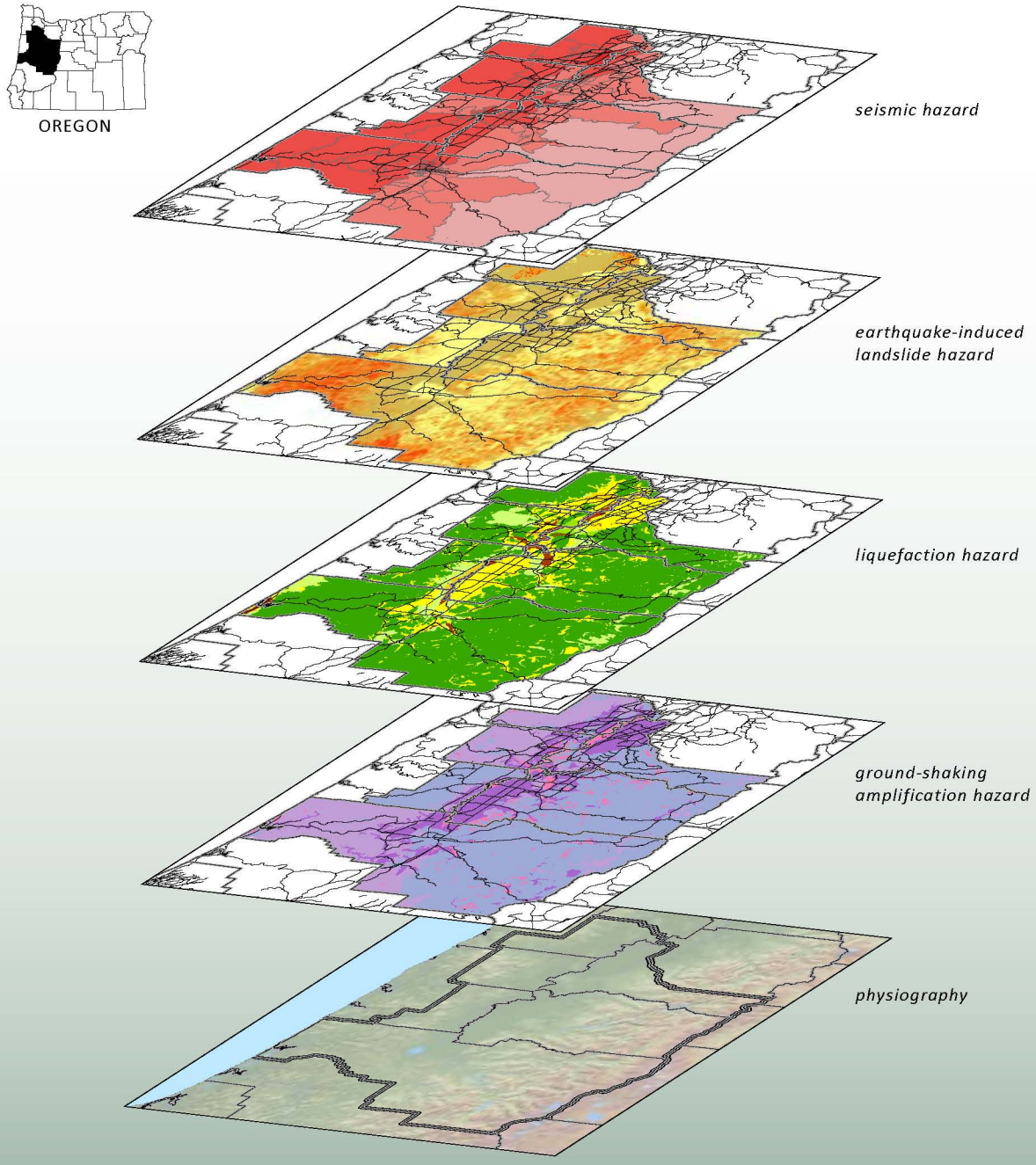
Geologic Hazards, Earthquake and Landslide Hazard Maps, and Future Earthquake Damage Estimates

for Six Counties in the Mid/Southern Willamette Valley Including Yamhill, Marion, Polk, Benton, Linn, and Lane Counties, and the City of Albany, Oregon

by William J. Burns, R. Jon Hofmeister, and Yumei Wang



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State of Oregon
Department of Geology and Mineral Industries
Vicki S. McConnell, State Geologist

Interpretive Map Series
IMS-24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES, AND THE CITY OF ALBANY, OREGON

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DISCLAIMER

Maps in this publication depict relative earthquake and landslide hazard zones on the basis of limited data as described further in the text. The maps cannot serve as a substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from those shown on the maps. The maps can be used as a general guide for emergency response planning.

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1.0 EXECUTIVE SUMMARY

To become resilient from geologic hazards, communities in Oregon have begun a large-scale endeavor to perform pre-disaster mitigation. A first step in this process is the development of natural hazards mitigation plans. For this project, six counties and one city in the Mid/Southern Willamette Valley (Oregon Partnership for Disaster Resilience Region 3) merged together resources to begin:

- Identifying potential natural hazards
- Identifying vulnerability to these hazards
- Assessing the level of risk, and thus
- Increasing the level of resilience through pre-disaster mitigation

To assist planners in the developing their natural hazards mitigation plans, the Department of Geology and Mineral Industries (DOGAMI) performed the following tasks related to geologic hazards:

- Identified the primary geologic hazards of Yamhill, Marion, Polk, Benton, Linn, and Lane Counties and the City of Albany (herein known as the study area or individual communities)
- Developed countywide earthquake and landslide hazard maps for each county
- Developed future earthquake damage estimates for each community

The purpose of this study is to help communities prepare pre-disaster mitigation plans, to identify potential geologic hazards, to help communities perform earthquake damage and loss estimation, and to recommend future action items. Several products have been generated as part of this project. They include digital geographic information system (GIS) layers for each community, depicting:

- Relative earthquake ground-shaking amplification hazards
- Relative earthquake liquefaction hazards
- Relative earthquake-induced landslide hazards
- Identified landslide areas

Damage and loss estimates for each community were analyzed for two earthquake scenarios:

- A magnitude ~6.5 crustal fault earthquake
- A magnitude 9.0 Cascadia Subduction Zone earthquake

To improve existing hazard maps and data, action items are provided. These action items range from site-specific items such as identification of individual school buildings that have a high risk of collapse in an earthquake to identification of landslide hazard areas over large regions of the state.

Identified earthquake-induced hazards include ground-shaking amplification, liquefaction, earthquake-induced landslides, and tsunamis. To evaluate non-earthquake related landslide hazards, we used identified landslide areas, potential "rapidly moving landslide" (debris flow) hazards maps, and an inventory of slope failures in Oregon from three storm events (1996-1997). Dam failures are frequently caused by geologic hazard events, and we evaluate these. Finally, we discuss volcanic hazards from Mount Jefferson and the Three Sisters region.

The relative earthquake hazard maps developed in this study identify areas of higher or lower potential hazard and can help guide planners who must determine which areas should require future site-specific seismic evaluations. The identified landslide areas map is a digitized compilation of previously identified landslides. All of these maps should only serve as a guide for future site-specific evaluations.

Ground-shaking amplification and liquefaction hazards are usually highest in the young, soft alluvial sediments of the Willamette Valley and along other major stream channels. Landslide hazards are highest in steep, mountainous terrain and at the base of steep canyons. Landslide areas identified in the accompanying GIS files also pose significant hazards for development.

We used regional earthquake hazard information developed in this study to assess potential damage and loss for various earthquake scenarios. We consolidated information into the Hazards U.S. Multi-Hazard methodology and computer application (HAZUS-MH), which is a federally developed program used to model various earthquake scenarios and estimate associated damage and loss. With the improved HAZUS-MH study regions (included with this report), we modeled damage and loss estimates for two earthquake scenarios — resulting in expected total building damage on the order of $11.7 billion for a Cascadia Subduction Zone event.

The products from this study can be used to help mid/southern Willamette Valley communities become more resilient from the impacts of geologic hazards through pre-disaster mitigation.

2.0 INTRODUCTION

The three main objectives of this study were 1) to assist communities in development of county and city pre-disaster mitigation plans, 2) to identify and map potential geologic hazards and to improve the abilities of the communities to perform earthquake damage and loss estimation, and 3) to recommend future action items. The body of this report describes the results for these three objectives.

This study was initiated by the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) Pre-Disaster Mitigation (PDM) grant program, which provides funds to states, territories, Indian tribes, communities, colleges, and universities for pre-disaster mitigation planning efforts to better address natural hazards.

Geologic hazards pose a significant threat in many parts of Oregon. For example, earthquakes as large as magnitude 9.0 have occurred along the offshore Cascadia Subduction Zone repeatedly in the geologic past (Atwater, 1987; Yamaguchi and others, 1997), and the scientific consensus is that they will happen again (Clague and others, 2000). Smaller crustal earthquakes, which can be more damaging in local areas than subduction zone earthquakes, also pose significant risks where faults are close to urban areas. Important reminders of the dangers and effects of local earthquakes include the magnitude 5.6 earthquake that occurred near Scotts Mills, Oregon, in 1993 and the Klamath Falls, Oregon, earthquakes (magnitudes 5.9 and 6.0) that occurred later that year. Combined, these earthquakes caused more than $40 million in direct damage, and there were two fatalities in the Klamath Falls earthquakes (Wiley and others, 1993).

Many parts of Oregon are also highly susceptible to landslides. Landslides pose significant threats to people and infrastructure, particularly in the portions of the state with moderate to steep slopes. As population growth continues and as development into steeper terrain occurs, greater losses are likely to result. Most of Oregon's landslide damage has been associated with severe winter storms where landslide losses exceed $100 million in direct damage (such as the February 1996 event; see FEMA [1996]). Annual average maintenance and repair costs for landslides in Oregon are over $10 million (Wang and others, 2002). Landslides induced by earthquake shaking are likely in many parts of Oregon, and losses associated with sliding in moderate-to-large earthquakes are likely to be significant. Volcanic hazards and dam failure due to geologic hazards are also potential threats to many parts of Oregon.

3.0 PREVIOUS WORK

A number of previous regional and site-specific geologic and geologic hazard studies have been conducted throughout the study area to identify natural hazards, to assess risks, and to mitigate hazards. In our current efforts, we consolidate this large body of work into a GIS database to help assess hazards affecting the study area and we highlight some possible ways individual communities can address these hazards.

For the earthquake hazard mapping components of this study, we used a number of previously developed geologic maps and other related data. Specific sources of geologic information include Allison (1953), Allison and Felts (1956), Baldwin (1956, 1964, 1974), Beaulieu and others (1974), Bela (1981), Black and others (1987), Brown (1980), Brown and others (1980), Brownfield (1982a, 1982b, 1982c), Brownfield and Schlicker (1981a, 1981b), Hladky and McCaslin (2005), Madin and Murray (2003, 2005), Madin and others (2006), Miller and Orr (1984a, 1984b), Murray (2005), Niem and others (1989), O'Connor and others (2001), Orr and Miller (1984, 1986), Priest and others (1987, 1988), Ramp (1972), Schlicker (1967), Schlicker and others (1974), Sherrod (1988), Snavely and others (1976), Thayer (1939), Tolan and others (1999), Vokes and others (1951), Walker and Duncan (1989), Walker and others (2002), Wells and others (1983), and White (1980).

In addition to traditional geologic maps, natural hazard maps have been developed for portions of the counties. These include publications by Bela (1979), Black and others (2000), Burns and others (1997), Harvey and Peterson (1998, 2000), Hofmeister and others (2000), Hofmeister and Wang (2000), Madin and Wang (2000a, 2000b), Madin and Wang (1999), Madin and Wang (2000c), Schlicker and Deacon (1967), Wang and Leonard (1996), and Wang and others (2001). Appendix H includes list of these publications (Table H1) with reference numbers that are identified spatially in Figure H4.

For the earthquake damage and loss estimation portion of this study, we used information from several data sources and publications. A report specific to Benton County geologic hazards loss estimation was developed in 2001 (Wang and others, 2001). The report includes building inventory information, background discussion of natural hazards in the county, and initial loss estimations for earthquakes. Rogers and others (1998) provide overall reviews of earthquake hazards in the Pacific Northwest; Turner and Schuster (1996) summarize landslide types and characteristics; and Spangle Associates (1998) summarizes potential uses of natural hazard maps in Oregon.

4.0 STUDY AREA

The study covers an area of 26,520 km^2 (10,240 mi^2) and is geographically bounded by Chehalem Mountain to the north, the peaks of the Coast Range to the west (with the exception of Lane County, which extends all the way to the Pacific Coast), and the peaks of the Cascade Range to the east (Figure 1 and Figure 2). The study area makes up most of what is called the "Mid/Southern Willamette" valley. Elevations range from 0 m (0 ft) at the coast to 3,157 m (10,358 ft) at the peak of South Sister Mountain. The physiographic provinces in the study area include the Willamette River Valley, the Coast Range, and the Cascade Range. The Willamette Valley is characterized by predominately flat and gentle topography, while the Cascade Range and Coast Range are characterized by densely forested mountains. The convergence of the Cascade Range and the Coast Range mark the southern boundary of the study area.

The geology, topography, and climate of the study area are conducive to a number of natural hazards including floods, landslides, windstorms, volcanic eruptions, and earthquakes. The risks associated with earthquakes and landslides, in particular, are increasing as population continues to expand and to cause increased development.

The geology of the study area roughly matches the physiographic provinces (Figure 2 and Figure 3). The western portions within the Coast Range are composed of Tertiary volcanic and sedimentary rocks. The central portion contains the Willamette Valley, which is blanketed with unconsolidated Quaternary sediments. In the eastern portion of the study area the Cascade Mountains are formed mostly from Quaternary and Tertiary volcanic rocks and unconsolidated Quaternary alluvium. So, in even more general terms, there is loose material in the river valley and harder material in the Coast Range and Cascades.

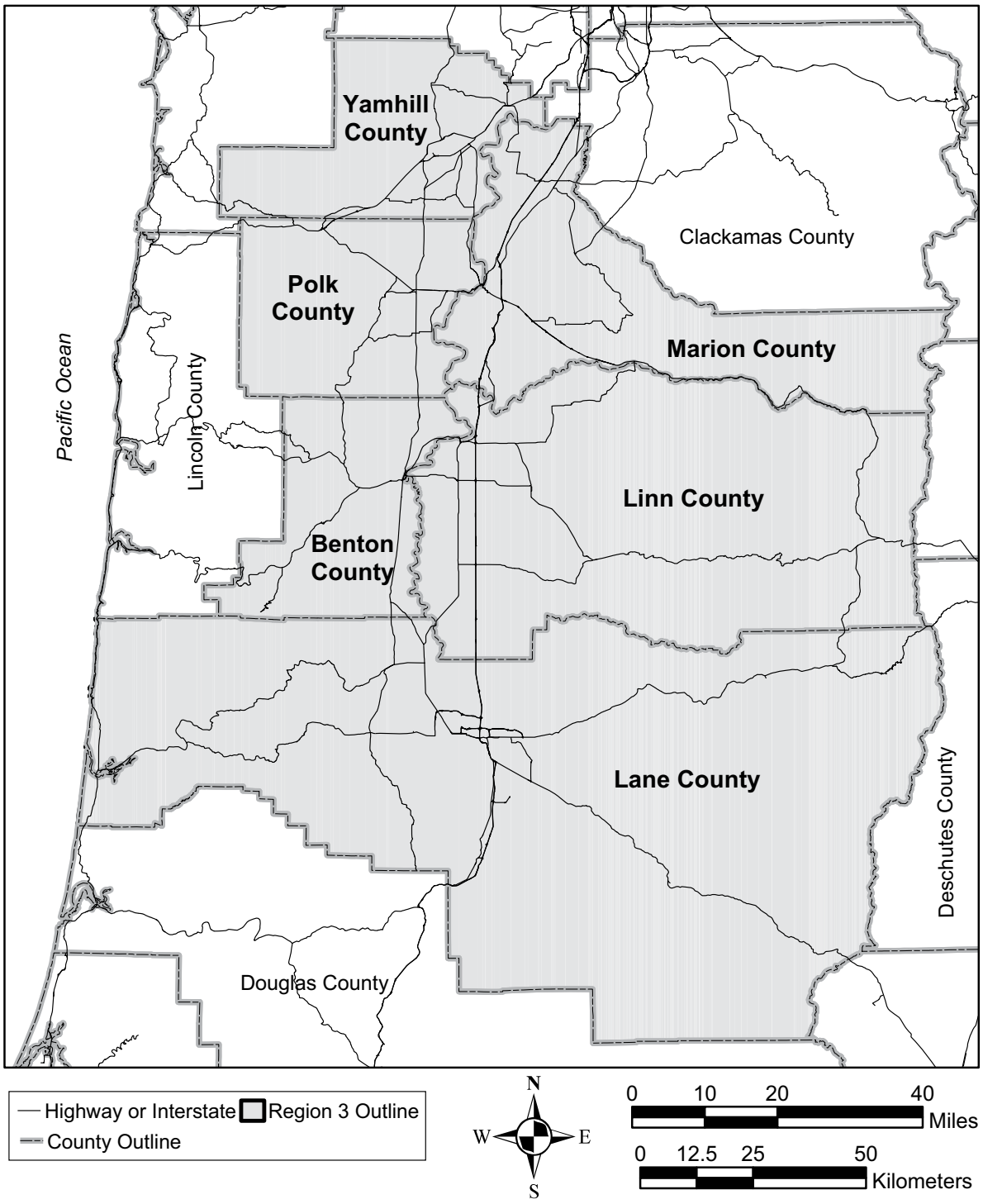


Figure 1. The study area (Oregon Partnership for Disaster Resilience Region 3) includes Yamhill, Polk, Marion, Benton, Linn, and Lane Counties, Oregon.

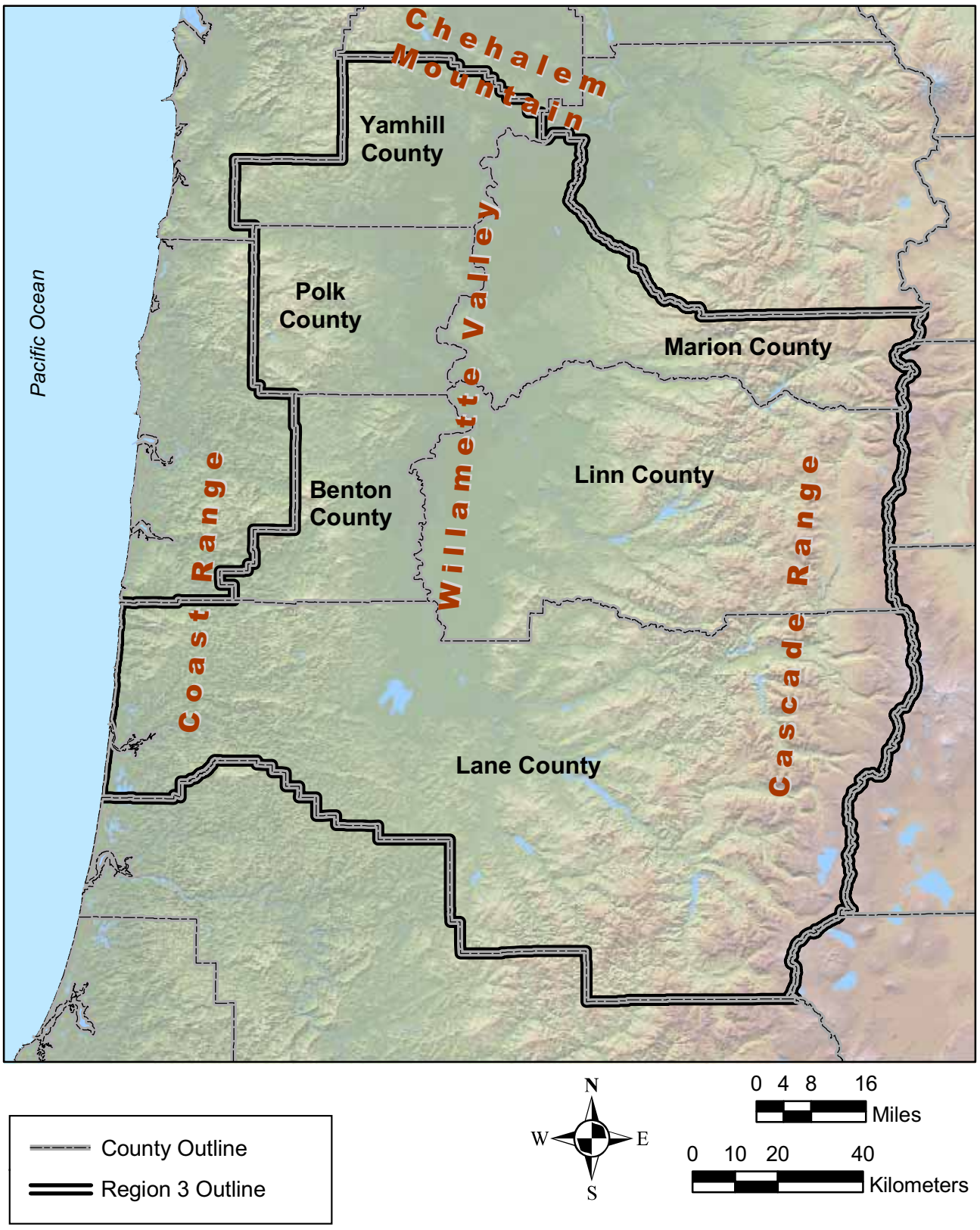


Figure 2. Shaded relief map of the study area with physiographic provinces including the Willamette Valley, the Coast Range, and the Cascade Range.

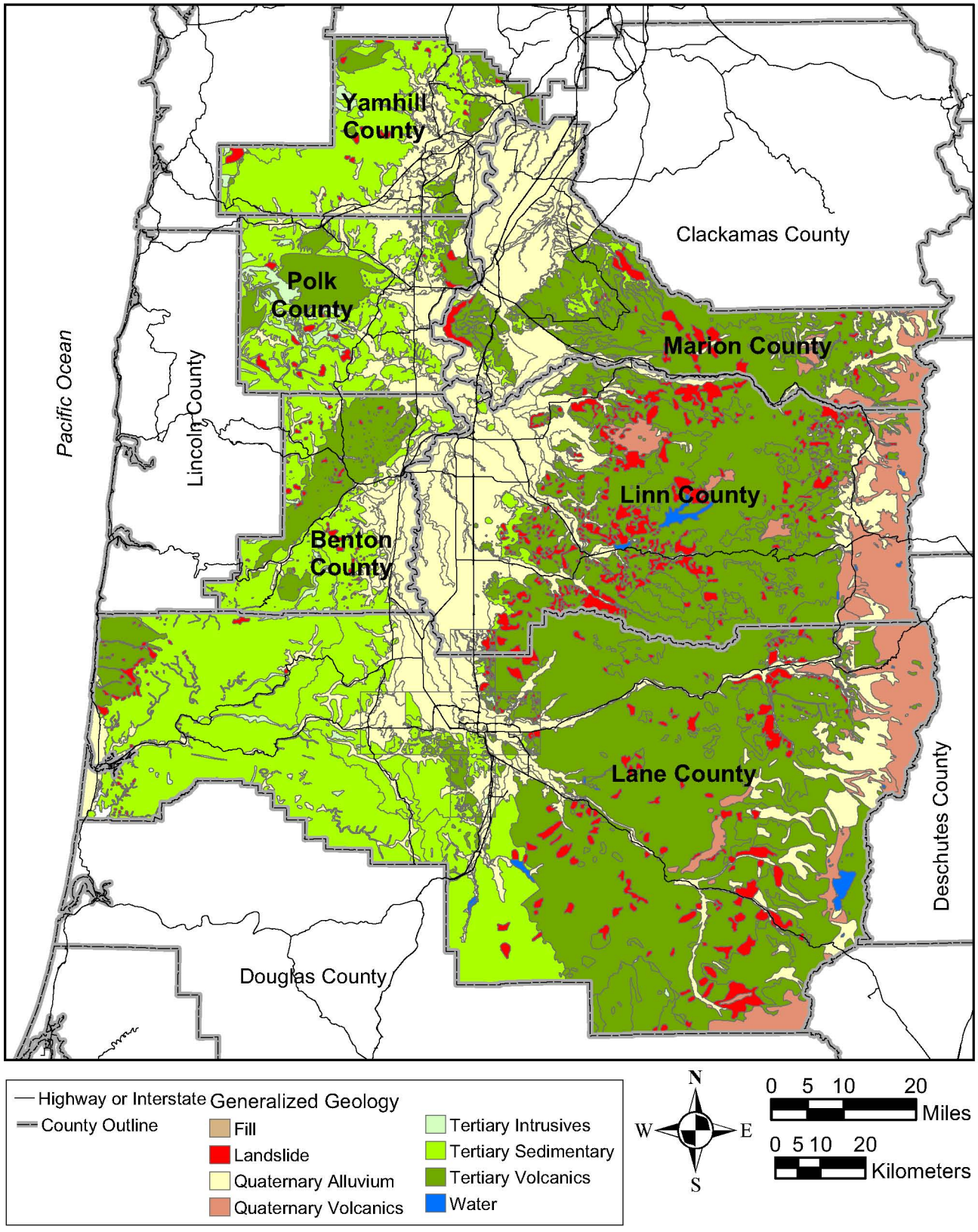


Figure 3. Generalized geologic map of the study area showing recent alluvium in the Willamette Valley (central portion of the map) and mostly Tertiary volcanics in the Cascade Range and Tertiary sedimentary rocks in the Coast Range.

5.0 GEOLOGIC HAZARDS

Several kinds of geologic hazards have the potential for major impact to communities within the study area. Earthquake-induced hazards include ground shaking, liquefaction, earthquake-induced landslides, and tsunamis. Deep-seated and rapidly moving landslides can occur on or adjacent to steep slopes. Earthquakes, landslides, and volcanic eruptions can trigger dam failures. Mount Jefferson and the Three Sisters region volcanic hazards pose specific threats in eastern Marion, Linn, and Lane Counties.

5.1 Potential Earthquake Sources and Earthquake-Induced Hazards

Earthquake effects are a significant threat in the study area and can come from subduction zone, intraplate, and crustal sources (Figure 4 and Figure 5).

5.1.1 Subduction Zone Earthquakes

Subduction zone earthquakes occur around the world where two tectonic plates meet and move toward each other, with one plate sliding (subducting) beneath the other. The subducted plate material melts and is reabsorbed in the mantle (Figure 4). The huge faults that separate the plates in these zones produce some of the most powerful earthquakes ever recorded, often having moment magnitudes of 8.0 to 9.0+. The 1960 Chilean (magnitude 9.5) and the 1964 Great Alaska (magnitude 9.2) earthquakes were subduction zone earthquakes. Both produced large tsunamis (Kanamori, 1977).

A magnitude 9.0 subduction zone earthquake located just off the west coast of Sumatra occurred December 26, 2004. This devastating earthquake occurred on the fault along which the India plate subducts beneath the overriding Burma plate and was the fourth largest earthquake in the world since 1900. It is estimated that

Figure 4. Schematic block diagram of the three earthquake sources: subduction, intraplate, and crustal.

250,000 people were killed and roughly 1,000,000 were displaced by the earthquake and subsequent tsunami in 10 countries in South Asia and East Africa (USGS Earthquake Program, 2004a). Three months later, on March 28, 2005, a second significant subduction zone earthquake with a magnitude of 8.7 shook the same region. Luckily, the epicenter of this earthquake was beneath shallow water and did not cause a significant tsunami (USGS Earthquake Program, 2005).

The Cascadia subduction zone, which lies off the Oregon and Washington coasts, is similar to the Sumatra area subduction zone. Though no earthquakes have been recorded on the Cascadia subduction zone during Oregon's short 200-year historical record, various studies have found widespread evidence that very large earthquakes have occurred, most recently about 300 years ago, in January 1700 (e.g., Atwater, 1987; Yamaguchi and others, 1997). The best available evidence and observations indicate that these earthquakes occur at intervals of about 200 to 1,000 years (Atwater and Hemphill-Haley, 1997).

5.1.2 Intraplate Earthquakes

Intraplate earthquakes occur in the Pacific Northwest within the Juan de Fuca plate as it subducts beneath the North American plate. Intraplate earthquakes have caused damage in the Puget Sound region in 1949, 1965, and 2001 (the 2001 event was the magnitude 6.8 Nisqually earthquake). These types of earthquakes typically occur at depths of 40–60 km (25–37 mi).

5.1.3 Crustal Earthquakes

Crustal earthquakes occur in the North American plate at relatively shallow depths of 10–20 km (6–12 mi) below the surface. The 1993 magnitude 5.6 earthquake at Scotts Mills, Oregon (Madin and others, 1993) and the 1993 magnitude 5.9 and 6.0 Klamath Falls, Oregon, main shocks (Wiley and others, 1993) are examples of crustal earthquakes.

The distance from a potentially active fault and a site is critical to the evaluation of the earthquake hazard. Figure 5 shows selected historical earthquake epicenters and known potentially active faults for the study area.

The U.S. Geological Survey (USGS) National Quaternary Fault and Fold Database (http://earthquake.usgs.gov/qfaults/) contains information on faults and folds in the United States that are believed to be sources of magnitude 6 and greater earthquakes during the Quaternary (the past 1,600,000 years). Maps of these geologic structures are linked to detailed descriptions and references as shown in Figure 6 (USGS Earthquake Program, 2004b).

Although the definition in Figure 5 of active faults is movement in the last 780,000 years, most scientists and engineers in the seismic field define active faults as having movement in the last 11,000 years or having multiple earthquakes during the Quaternary period.

The most severe damage inflicted by earthquakes is commonly associated with areas that experience one or more of the following phenomena:

- Amplification of ground shaking by soil columns
- Liquefaction of water-saturated sand, silt, or gravel, creating areas of "quicksand"
- Earthquake-induced landslides
- Tsunamis

Fortunately, each of these effects can be evaluated to a large extent before an earthquake occurs. The products of this study include maps of each of these earthquake hazards for each county and for the City of Albany.

5.1.4 Ground-Shaking Amplification

When an earthquake occurs, seismic waves radiate away from the epicenter and/or rupture zone. In general, the strength and duration of the shaking at a site is dependent on the size of the earthquake, distance away from the epicenter and/or rupture zone, and site-specific soil characteristics at the site. "In fact, ground shaking can be considered to be the most important of all seismic hazards because all the other hazards are caused by ground shaking" (Kramer, 1996, p. 2). This is true except for tsunami generation.

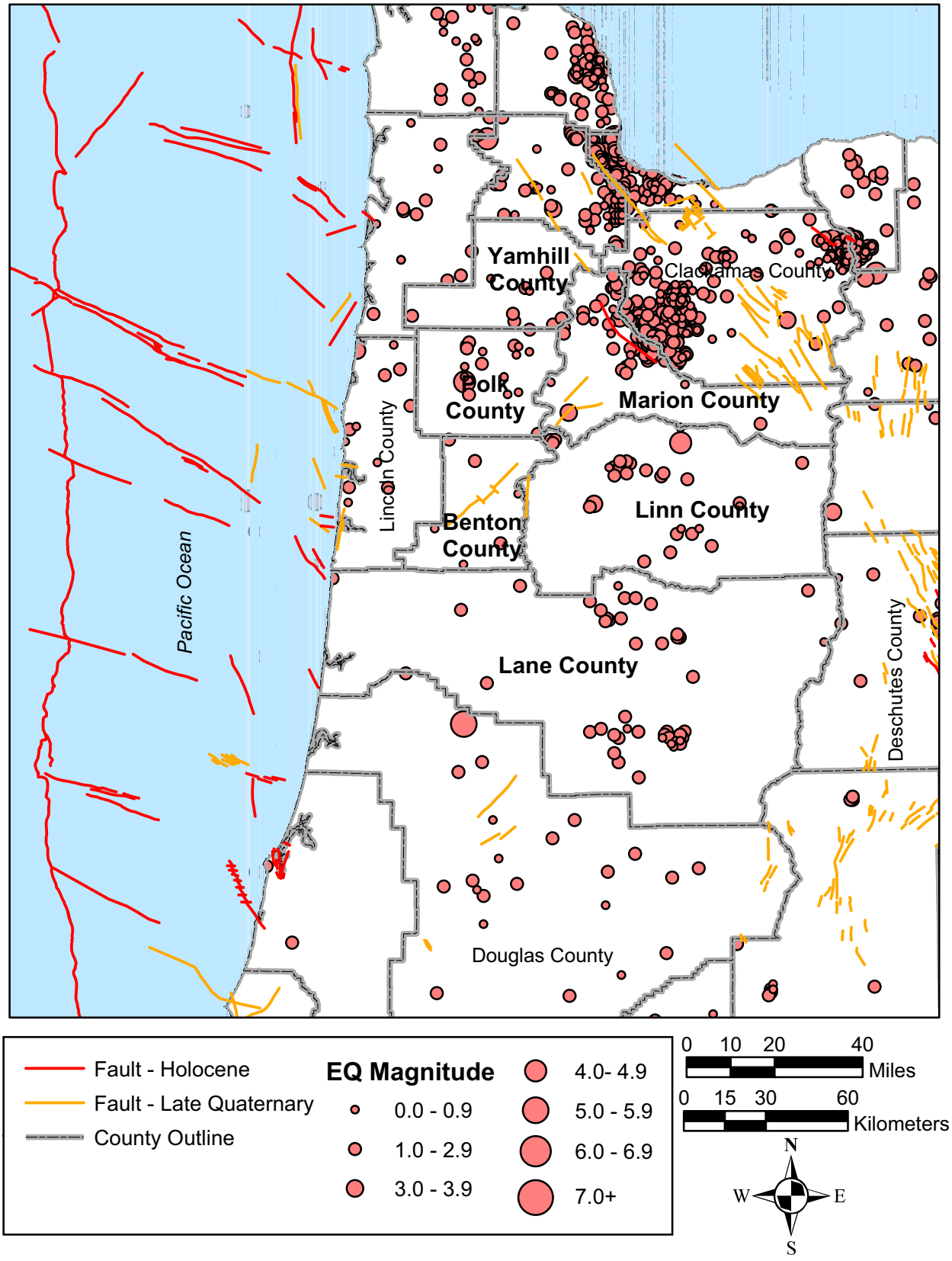


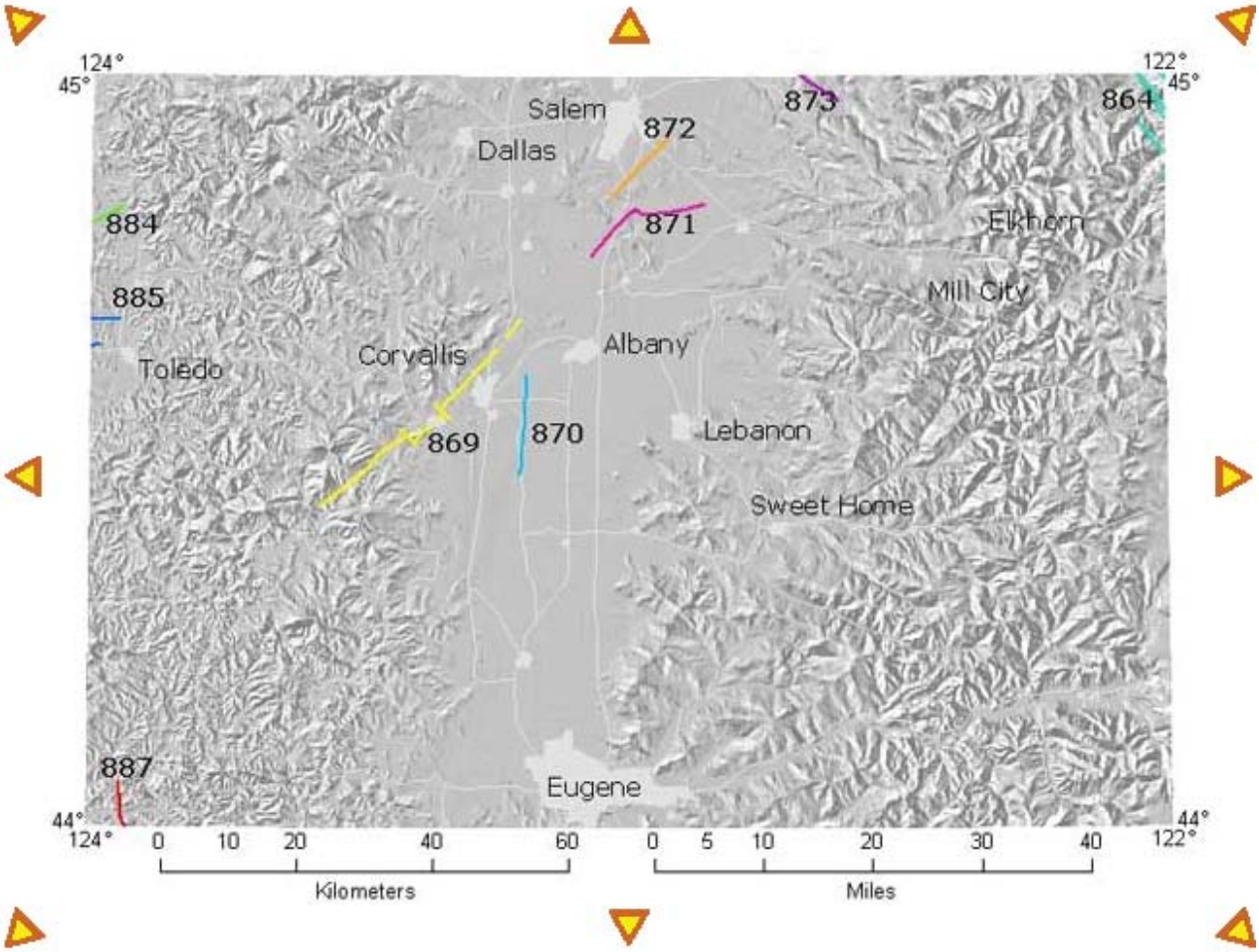
Figure 5. Map of selected historic earthquakes between 1841 and 2002 and Quaternary faults (from Niewendorp and Neuhaus [2003]). Active faults on this map are defined as those that have moved in the last 780,000 years (Geomatrix Consultants, Inc., 1995). Faults active in the last 20,000 years are colored red. Faults active between 20,000 and 780,000 years ago are colored gold.

USGS

Quaternary Fault and Fold Database for the United States

Salem 1° x 2° Sheet

Home > US Map > Oregon



Number	Name
864	Clackamas River fault zone
869	Corvallis fault zone
870	Owl Creek fault
871	Mill Creek fault
872	Waldo Hills fault
873	Mount Angel fault
884	Cape Foulweather fault
885	Yaquina faults
887	Unnamed Siuslaw River anticline

Figure 6. Example of U.S. Geological Survey Quaternary fault and fold database output of the Salem 1° × 2° quadrangle (USGS Earthquake Program, 2004b).

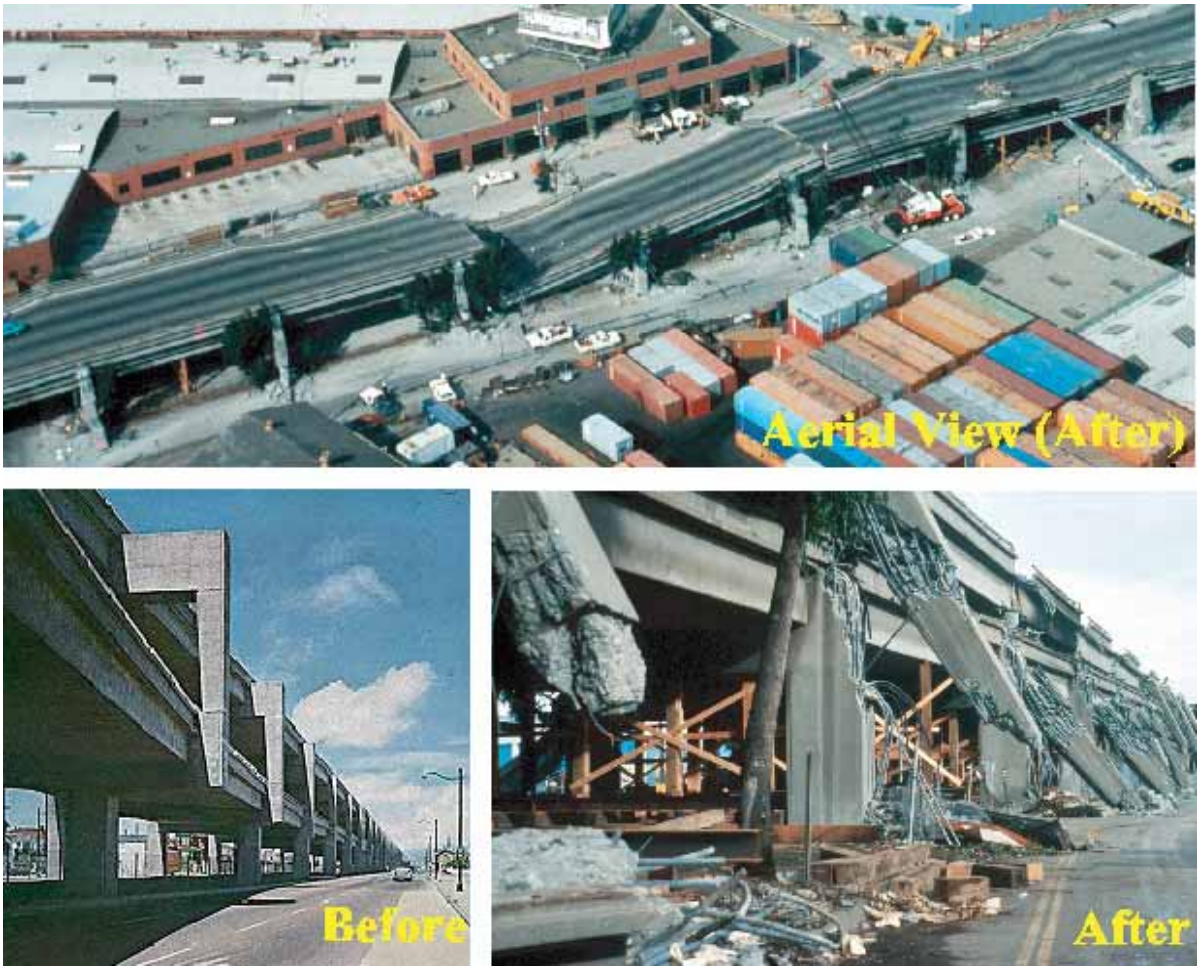


Figure 7. Example of damage to the Cypress viaduct of Interstate 880 caused by ground-shaking amplification during the October 17, 1989, Loma Prieta, California, earthquake (top: Nakata and Peterson, 1990) (bottom: Windmiller, 2000).

As seismic waves travel through bedrock, some energy propagates through surface soils to the ground surface. During propagation, soil deposits can either de-amplify (weaken) or amplify (strengthen) the shaking depending on the characteristics of the deposit. This phenomenon is generally referred to as ground-shaking amplification (GSA). Because soil deposits can change significantly over short distances, levels of ground-shaking amplification can also change markedly over a short distance, even if sites are at an equal distance from the earthquake source (Kramer, 1996).

Although earthquake site response is complicated and depends on factors such as frequency and duration of the shaking, subsurface stratigraphy and material properties, and surface topography, useful generalizations can be made about the performance of various soils. For example, thick deposits of soft soil tend to amplify the shaking of long-period ground motions, such as those associated with subduction zone earthquakes. In contrast, sites with thin soil profiles are not likely to amplify ground motions. The degree of amplification greatly affects the performance of structures during earthquakes; thus, substantially higher concentrations of damage are found in areas with high amplification factors (Holzer, 1994; Seed and others, 1988).

An example of ground-shaking amplification damage can be seen in the aftermath of the Loma Prieta, California, earthquake of October 17, 1989. Both the Cypress and the Embarcadero freeways were built on fill; in addition, the Cypress freeway was on an ancient streambed, not solid bedrock (Windmiller, 2000). During the earthquake, ancient streambed deposits

amplified the shaking, which partially caused the Cypress viaduct to collapse. Braces securing the upper level of the viaduct to the lower level broke and then split outward, sending the upper level down (Figure 7). The collapse started in the northern sections of the freeway, and each section collapsed until most of the viaduct was destroyed (Windmiller, 2000).

5.1.5 Liquefaction

During seismic shaking, deposits of loose, saturated sands can contract, resulting in an increase in pore water pressure. If the increase in pore water pressure is high enough (i.e., the effective stress equals zero), the deposit becomes "liquefied," losing its strength and thus its ability to hold support loads (Day, 2002; Kramer, 1996) (Figure 8).

If an earthquake induces liquefaction, several things can happen: 1) the liquefied layer and everything on top of it may move down slope, even on very gentle slopes, 2) the liquefied layer may oscillate with displacements large enough to rupture pipelines, move bridge abutments, or rupture building foundations, and 3) buoyant buried objects such as underground storage tanks can float toward the surface, and heavy objects such as buildings can sink. Typical displacements can range from centimeters to meters. Liquefaction can therefore significantly increase the damage resulting from an earthquake.

An example this kind of damage be seen in the aftermath of the Kawagishicho, Niigata, Japan, earthquake of 1964 (Figure 8). Settlement and tilt of apartment buildings due to liquefaction was very dramatic, although in many cases there was little structural damage.

Figure 8. (top) Example of liquefaction induced settlement of apartment buildings, Kawagishicho, Niigata earthquake, Japan, 1964 (Hausler and Sitar, 2001). (bottom) Example of a liquefaction sill at Hunting Island along the Columbia River. The sill most likely is a result of the last Cascadia Subduction Zone earthquake (in 1700 AD).

5.1.6 Earthquake-Induced Landslides

Strong ground shaking can also cause landslides and reactivate dormant landslides. Commonly, slopes that are marginally stable prior to an earthquake become unstable and fail. Some landslides result from liquefaction that causes lateral movement of soil, or lateral spread (Figure 9) (Kramer, 1996; Day, 2002). Section 5.2 contains describes non earthquake-induced landslides.

Figure 9. (top) Road prism rotational type landslide and (bottom) lateral spread landslide along the shoreline of Capitol Lake Olympia, Washington, caused by the 2001 magnitude 6.8 Nisqually earthquake (Nisqually Earthquake Information Clearinghouse, 2001).

5.1.7 Tsunamis

Tsunamis are caused by large-scale disturbance of the sea floor. During a subduction zone earthquake the sea floor is uplifted. This in turn uplifts the overlying column of water, forming the initial tsunami wave. Tsunamis can arrive at nearby coastlines in minutes, causing extensive damage and loss of life, as recently occurred in Indonesia in December 2004 (Figure 10). Subduction zone earthquakes also typically cause landslides that can greatly amplify tsunami runup, should the landslides occur under the sea or slide from land into water (Priest, 1995).

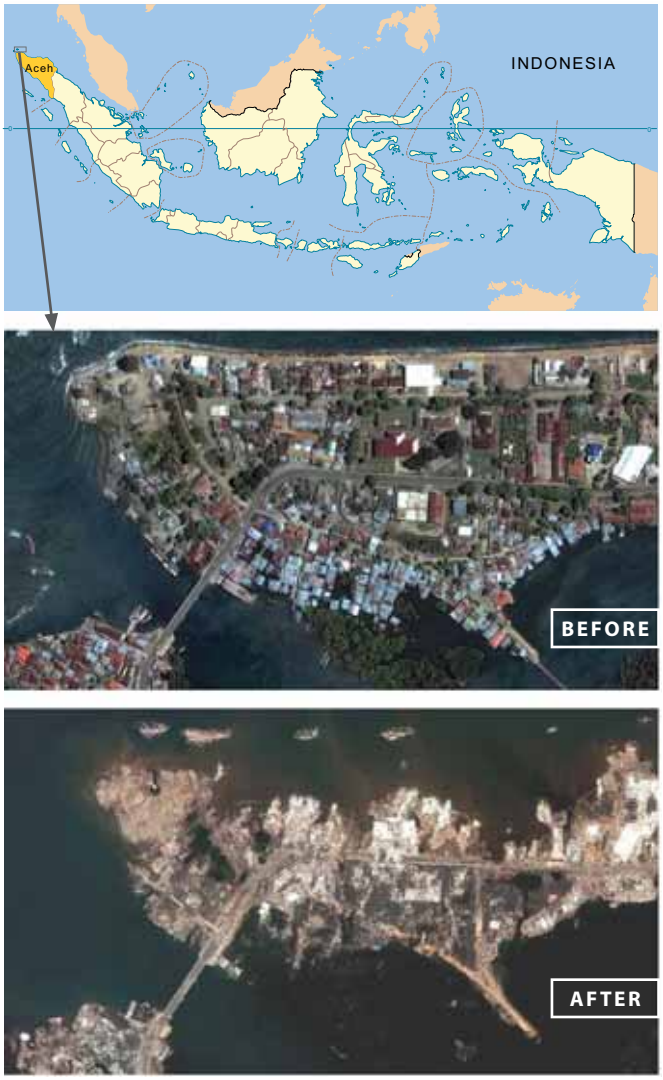


Figure 10. Devastation caused by tsunami waves is shown in "before" and "after" aerial photographs of an island off the northern tip of the Aceh province of Indonesia (photographs copyright DigitalGlobe, 2004).

5.2 Landslide Types and Characteristics

Landslides pose a significant hazard in the study area and can take many different shapes and forms. Landslides in the United States cause an average of 25 to 50 deaths and $1 to $2 billion in economic losses annually (Schuster and Fleming, 1986). In Oregon, a minimum estimated $10 million in damage occurs annually (Wang and others, 2002). During 1996 and 1997, heavier than normal rains caused over 700 landslides in the Portland metropolitan area, which cost more than $40 million to mitigate (Burns, 1999).

5.2.1 Landslide Types and Trigger Mechanisms

The general term landslide refers to a range of geologic failures including rock falls, debris flows, earth slides, and other mass movements (Figure 11). Most slope failures in the study area are complex combinations of these distinct types, but generalized groupings provide a useful means for framing discussion of slide characteristics, identification methods, and potential mitigation alternatives. Landslides can be initiated in marginally stable slopes by a number of natural and human disturbances. Processes and conditions that can trigger slope failure include earthquake shaking, volcanic eruptions, deforestation and deforestation-related activities such as road building, and rapid snow melt (Turner and Schuster, 1996). Two of the most common triggering events in the Pacific Northwest are intense rainfall and man-made changes to land.

In the Pacific Northwest region, large and devastating landslides in and around Kelso, Washington, have captured national attention. A massive landslide began to move in 1998 and destroyed almost half of the 137 houses in the Aldercrest subdivision (Figure 12).

Of the 700 landslides recorded during 1996 in Portland, Oregon, metropolitan region by Burns and others (1998), 76% were caused or exacerbated by human activity. In a similar study in and around Seattle, Washington, man-made alterations were associated with over 75% of the recorded landslides (W. D. Nashem and W. T. Laprade, update on the Seattle landslide inventor, electronic mail distribution, 1999).

The mechanics of slope stability can be divided into two forces: driving forces and resisting forces. These forces are a function of the material properties and the geometry of the slope. These two forces oppose each other, and slope stability can be thought of as their ratio (Burns and others, 1998).

$$\text{factor of safety} = \frac{\text{resisting forces}}{\text{driving forces}}$$

A ratio greater than 1 indicates a stable slope because the resisting forces are greater than the driving forces. A ratio less than 1 indicates an unstable slope because the driving forces are greater than the resisting forces. A critically stable slope would have a ratio equal to roughly 1. However, because not all conditions present within a slope can be accounted for, Senneset (1996) recommends that slopes with a factor of safety of less than 1.3–1.5 be considered potentially unstable (Burns, 1999).

Prior to developing remedial measures for slope instability on a site-specific basis, it is helpful to have a solid grasp of the regional tendency for landslide activity based on a synthesis of geologic, topographic, climatological, and historical data. The maps developed in this study allow for systematic, objective evaluations of slope hazards at a regional scale. These evaluations can lead to identification of specific sites that warrant attention, a fundamental goal of this project.

One potentially devastating type of landslide is a channelized debris flow or "rapidly moving landslide." This type of flow initiates upslope, moves into or transports down a steep channel (or drainage), then deposits its material, usually at the mouth of the channel. Debris flows can be initiated by other types of landslides that occur on slopes near a channel. They can also initiate within the channel in areas of accelerated erosion during heavy rainfall or snowmelt.

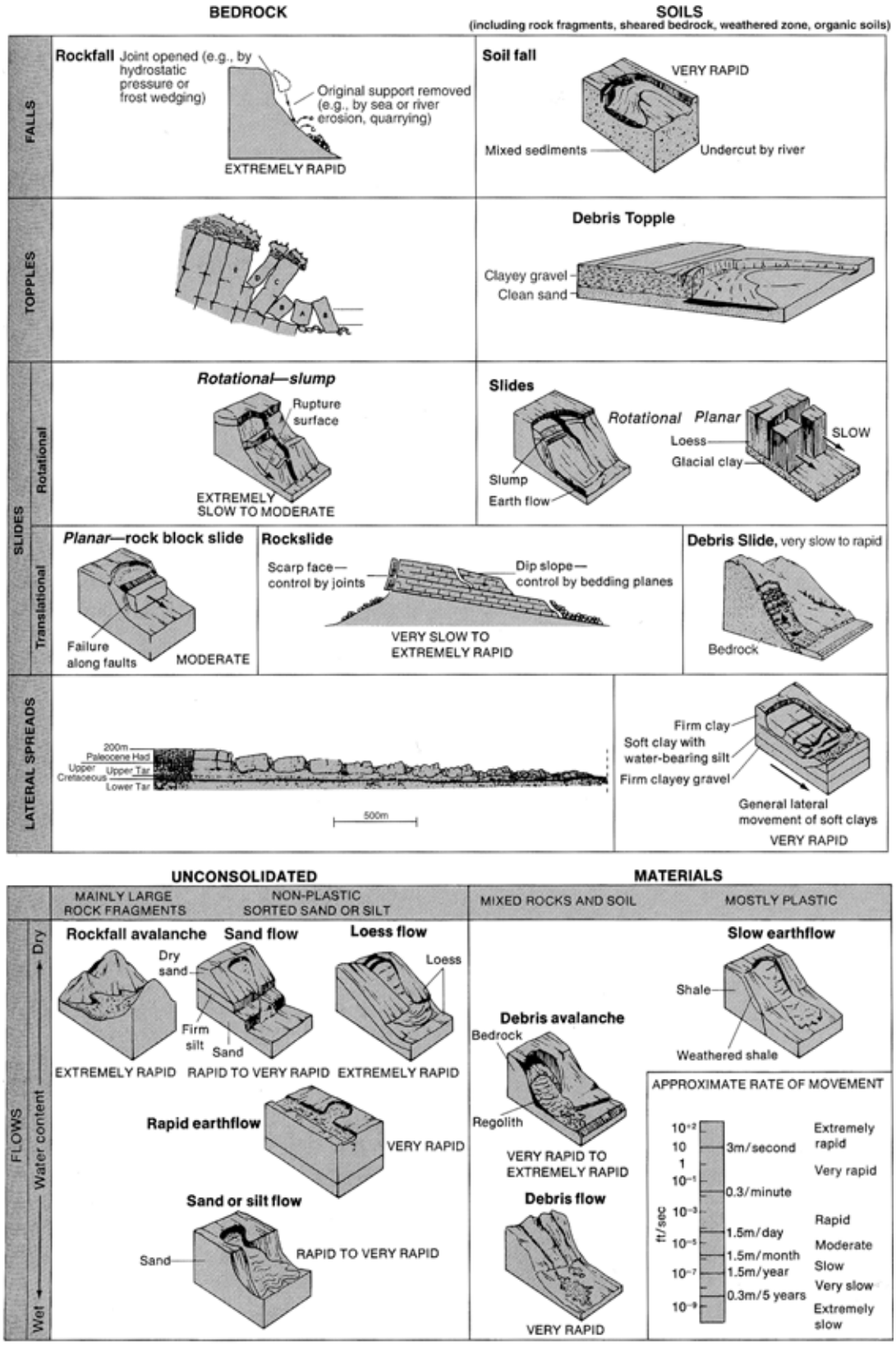


Figure 11. Landslides can be categorized by material type, type of movement, relative water content, and rate of movement (from Ritter and others, 1995).

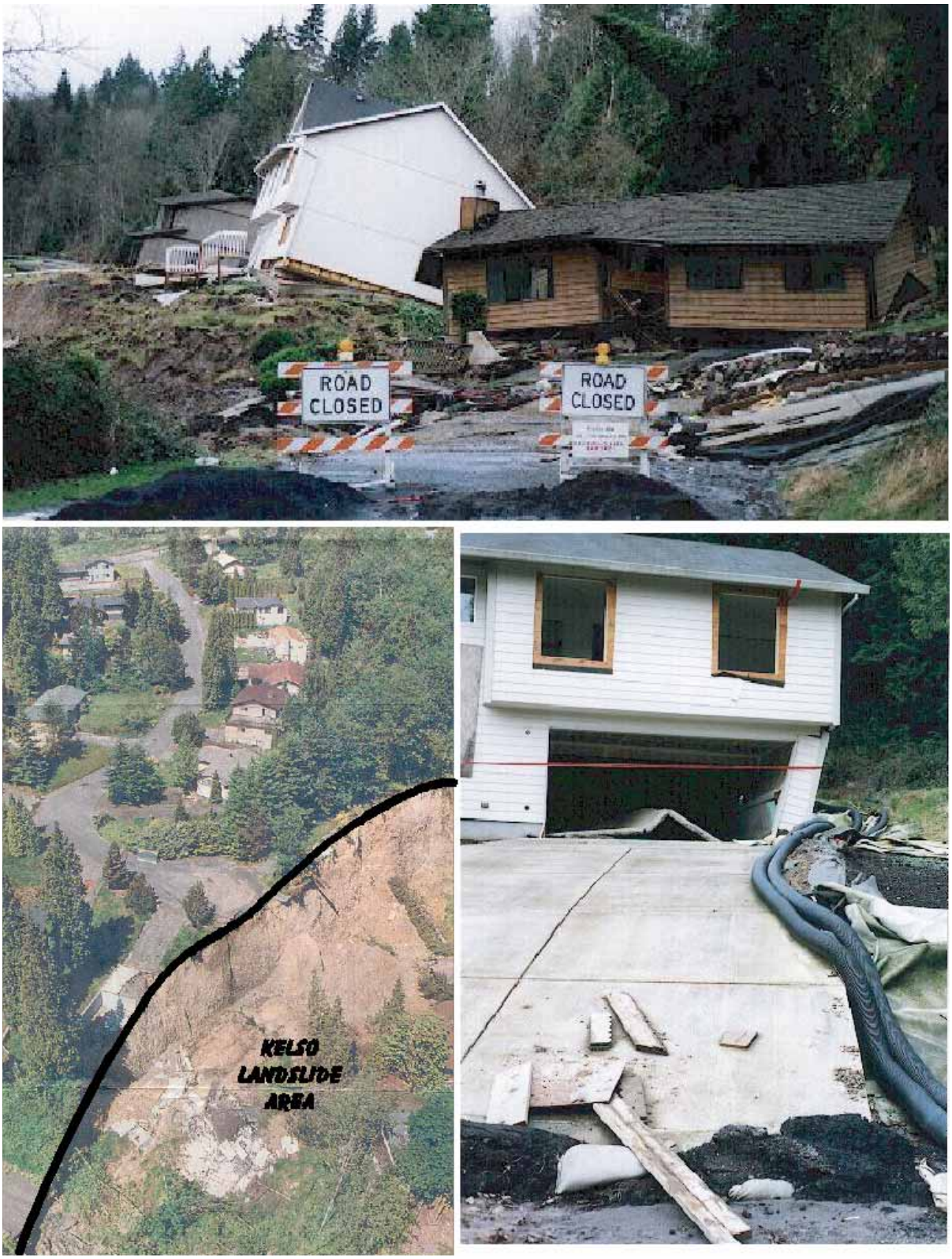


Figure 12. Destruction from the Kelso, Washington, landslide that initiated in 1998. (top) Houses have been tilted and pulled apart. (left) Aerial view of the head scarp area. (right) Concrete driveway has "bulldozed" the asphalt and the garage slab has been uplifted. Photographs were taken between January 1999 and June 2000 (NW Geoscience.com, 2002).

5.3 Other Geologic Hazards

5.3.1 Volcanic Hazards

Paralleling the coast of northern California, Oregon, Washington, and southern British Columbia is a chain of volcanoes, which are part of the Cascade Range. These volcanoes exist because the Juan De Fuca oceanic plate subducts below the North American plate (continental crust), where the rock becomes molten at depth and rises to the surface to erupt as volcanoes (Figure 4 and Figure 13). Mount Saint Helens, a volcano in this chain, erupted violently in 1980. The volcano erupted steam and ash again during fall 2004 and spring 2005, with activity continuing intermittently.

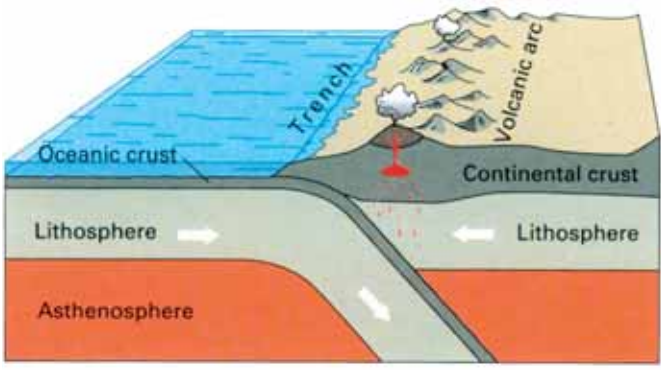


Figure 13. Converging plate margin schematic displaying the relationship between the subducting plate and the resulting volcanic arc.

Volcanic activity can produce many types of hazardous events including landslides, fallout of tephra (volcanic ash), lahars, pyroclastic flows, and lava flows (Figure 14) (Scott and others, 1999). Pyroclastic flows are fluid mixtures of hot rock fragments, ash, and gases that can move down the flanks of volcanoes at speeds of 50 to more than 150 kilometers per hour (30 to 90 miles per hour) (Scott and others, 1999). Lahars or volcanic debris flows are water-saturated mixtures of soil and rock fragments and can travel very long distances (over 100 km) and travel as fast as 80 kilometers per hour (50 miles per hour) in steep channels close to a volcano (Scott and others, 1999). These hazards can affect very small local zones (only meters across) to areas hundreds of kilometers downwind (Walder and others, 1999).

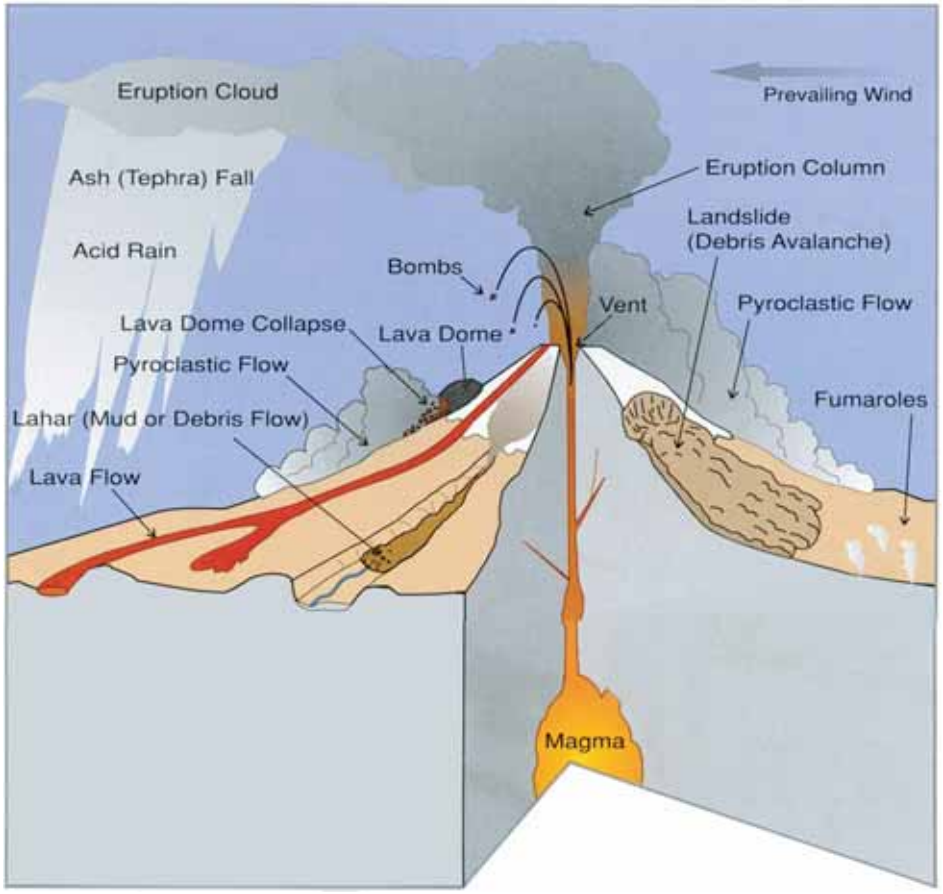


Figure 14. Volcanic hazard from a composite type volcano (Scott and others, 1999).

5.3.2 Dam Failure

The U.S. Army Corps of Engineers maintains a database (National Inventory of Dams; NID) of all dams in the United States that have a high or significant hazard potential or low hazard with certain other criteria such as dam height or storage volume (Goettel and others, 2004). The NID hazard classification is related only to impact if a dam fails, not dam safety level or likelihood of failure. In other words, a "high hazard dam" simply means that people downstream from the dam in the inundation area are at risk. Since 1874, there have been six large-impact dam failures in the United States, and each caused greater than 100 deaths. The worst dam failure, in terms of casualties, was the 1889 Johnstown, Pennsylvania, dam failure, which killed over 2,200 people.

Two geologic hazards are mainly associated with potential dam failure: landslides and earthquakes. If a landslide moves debris into a reservoir, a local tsunami wave could be generated and could cause the dam to fail. After dam failure and the related fast drawdown of water in the reservoir, it is very common to have many landslides into the now empty reservoir. Landslides can also directly impact the dam itself. The Seminary Hill Reservoir dam, located within the City of Centralia, Washington, failed October 5, 1991; the failure was caused by a massive landslide in the siltstone rock formation that underlies the reservoir (Figure 15) (Washington State Department of Ecology, Water Resources, 1991).

A major earthquake, either a Cascadia Subduction Zone earthquake or a smaller, crustal or intraplate earthquake, could also cause sufficient damage to a dam and pose a risk of failure. Most dams in Oregon were designed and built in the 1940s to 1960s, when seismic design considerations were significantly lower than they are now (Goettel and others, 2004).

Figure 15. Seminary Hill Reservoir dam failure caused by a landslide. Portions of the City of Centralia, Washington, were inundated. (Washington State Department of Ecology, Water Resources, 1991).

6.0 GEOLOGIC HAZARD MAPS

Although the specific location and the exact timing of natural hazard events are difficult to forecast, we do have tools for planning and forecasting. Historical observations of natural hazards coupled with significant advances in computer modeling and GIS capabilities allow us to map potential hazards over large areas.

The following sections briefly describe the GIS map layers that communities can use to identify regional natural hazard areas. Maps in the list below denoted with asterisks were produced in this study; county maps are provided in appendices A–G. The other listed maps come from previous studies.

- Ground-shaking amplification *
- Liquefaction *
- Tsunami inundation zone map
- Earthquake-induced landslides *
- Identified landslide areas *
- Inventory of slope failures in Oregon from three storm events (1996-1997)
- Map of potential "rapidly moving landslide" or debris flow hazards
- Volcanic hazard maps
- Dam failure inundation and hazard maps

For Benton County we used existing countywide hazard layers provided by DOGAMI Open-File Report O-01-05 (Wang and others, 2001) except the identified landslide map, which we improved from the 2001 version and which is included.

6.1 Ground-Shaking Amplification Map

A commonly used method of categorizing regional ground-shaking amplification hazards was developed by the National Earthquake Hazard Reduction Program (NEHRP) (FEMA, 2003b). The NEHRP 2003 method classifies local geology into one of six categories generally labeled hard rock (type A), rock (type B), very dense soil and soft rock (type C), stiff soils (type D), soft soils (type E), and soils requiring site-specific evaluations (type F).

Table 1 summarizes some of the defining characteristics of these categories. Because site-specific information is needed to classify soils as type F, this class was lumped with the type E soils in this study; furthermore, type F soils may also be located within other classes.

Table 1. National Earthquake Hazards Reduction Program ground-shaking amplification site classes (FEMA, 2003b) and corresponding DOGAMI ground-shaking amplification hazard classes used in this study.

Site Class	Site Class Description	Shear Wave Velocity, $\bar{v}_s$ (m/s) Min.	Shear Wave Velocity, $\bar{v}_s$ (m/s) Max.	DOGAMI Hazard Class
A	**Hard Rock**	1500	—	very low
B	**Rock**	760	1500	low
C	**Very Dense Soil and Soft Rock.** $s_u \geq$ 2,000 psf (100 kPa) or $N > 50$	360	760	moderate
D	**Stiff Soils** (stiff soil with undrained shear strength). 1,000 psf ≤ s_u ≤ 2,000 psf (50 kPa ≤ s_u ≤ 100 kPa) or 15 ≤ N ≤ 50	180	360	high
E	**Soft Soils**. Profile with more than 3 m of soft clay defined as soil with $PI > 20$, moisture content $w > 40\%$, and undrained shear strength $s_u <$ 2,000 psf (50 kPa) ($N <$ 15 blows/ft)	—	180	very high*
F	**Soils Requiring Site-Specific Evaluations** 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peat and/or highly organic clays ($H > 3$ m of peat and/or highly organic clay) 3. Very high plasticity clays ($H > 8$ m with PI > 75) 4. Very thick, soft/medium stiff clays ($H > 36$ m) with $s_u <$ 1,000 psf (50 kPa)	—	—	

Min. is minimum, Max. is maximum, s_u is undrained shear strength; N is ; PI is plasticity index; H is soil thickness.
*Note that because site-specific information is needed to classify soils as type F, this class was lumped with the type E soils in this study; furthermore, type F soils may also be located within other hazard classes.

We developed the ground-shaking amplification maps based generally on the NEHRP 1997 method of categorizing site geology. As explained in more detail in Appendix H, we started by geographically combining available GIS data from previous hazard studies with surface geology layers. We then assigned NEHRP 1997 susceptibility classes based on the dominant lithologies for each geologic unit in the study area.

The resulting maps are not intended to be used in place of site-specific studies. The simple five-class scale of Very Low, Low, Moderate, High, and Very High on the maps corresponds to the NEHRP site classes as shown in Table 1. These classes are the relative amount of expected ground-shaking amplification at the site. No type A areas were mapped within the study area (type A profiles are not common on the west coast of the United States). In addition to the regional hazard maps developed for this study, some existing local hazard maps were used to override the generalized regional maps. Most of these existing maps were produced for the major cities in the study area and include DOGAMI publications IMS-7, -8, -9, -10, -14, -17, -18, and Open-File Report O-01-05. For Benton County (Open-File Report O-01-05) the existing amplification GIS layers developed by DOGAMI (Wang and others, 2001) were subjected to the same GIS topology cleanup process as the files developed in this study.

A version of the resulting GIS map layer is shown as Figure 16. In general, areas characterized by loose, Quaternary sedimentary deposits are mapped as Moderate and High hazard for ground-shaking amplification (mostly D, E, and F type soil profiles). Most areas adjacent to major rivers in the more populated central portion of the study area are mapped as High and Very High hazard. Upland areas in the eastern part of the study area are mapped as Low ground motion amplification hazard, reflecting bedrock exposures and thin mantles of soil overlying rock. The western portion of the study area is varied, with competent bedrock areas mapped as Low hazard, dense soil areas mapped as Moderate hazard, and younger landslide and alluvial deposit areas mapped as High hazard for ground-shaking amplification.

6.2 Liquefaction Hazard Map

Liquefaction hazards can be evaluated several ways, but for regional mapping it is common to assess hazards using a classification system developed by Youd and Perkins (1978). Table 2 summarizes the liquefaction susceptibility rating system developed by Youd and Perkins (1978). The method takes into account the geologic environment of soil deposition and the general age of deposits. Again, as with ground-shaking hazards, several existing hazard maps produced at local levels were used to override the regional maps developed in this study. Because most of these geologic maps did not make a distinction between cohesionless (i.e., sand) and cohesive (i.e., silt and clay) materials (in fact, most map unit descriptions included both), the deposit types listed in Table 2 were used in a very general way to classify all of these deposits. The steps used to develop the liquefaction hazard map and original data sources are provided in Appendix H.

We assigned liquefaction susceptibility classes based on the dominant lithologies for each geologic unit in the study area and simplified the GIS output into six relative hazard classes: Rare (includes bedrock units older than Pleistocene; not included in Table 1), Very Low, Low, Moderate, High, and Very High.

A version of the GIS map layer for liquefaction hazards is shown as Figure 17. Areas with Moderate to High liquefaction susceptibilities are concentrated along the rivers and flood plains in the Willamette Valley, Cascade Range tributaries, and major stream valleys within the Cascade Range. We assigned older river terrace deposits in the Willamette Valley a lower liquefaction hazard, but we still consider these deposits to be susceptible to liquefaction during larger earthquakes. It is important to note that the quality and scale of the available geologic base maps precluded identification of all liquefaction hazard areas.

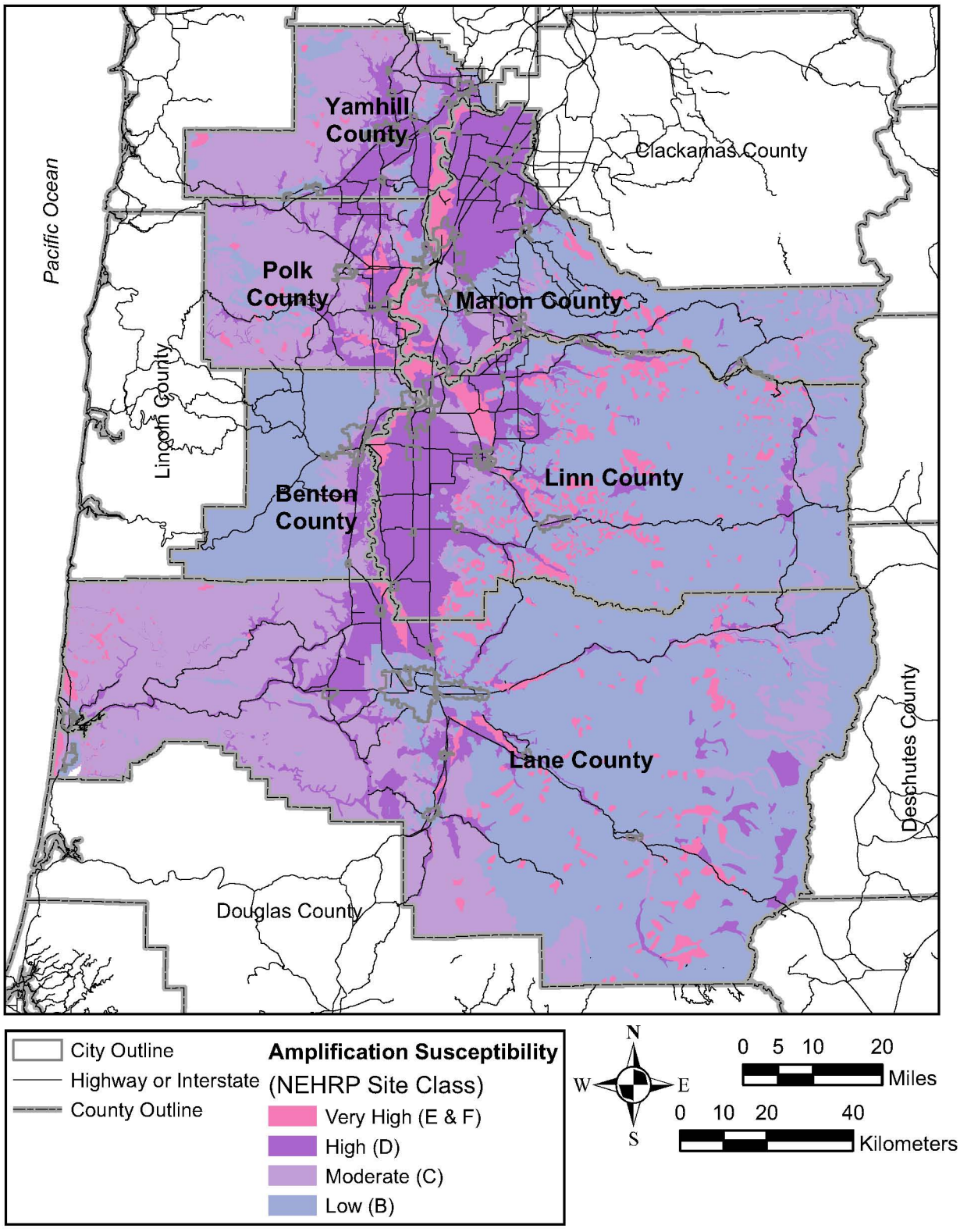


Figure 16. Ground-shaking amplification hazard map for the study area. The simple five-class scale of hazard classes generally corresponds to NEHRP classes. No type A areas were mapped within the study area (type A profiles are not common on the west coast of the United States). Benton County data were modified from Wang and others (2001).

Table 2. Liquefaction susceptibility rating system (from Youd and Perkins [1978]).

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood That Cohesionless Sediments When Saturated Would Be Susceptible to Liquefaction (by Age of Deposit)			
		Modern < 500 yr	Holocene < 11 ka	Pleistocene 11 ka - 2 Ma	Pre-Pleistocene > 2 Ma
(a) Continental Deposits					
River channel	locally variable	very high	high	low	very low
Flood plain	locally variable	high	moderate	low	very low
Alluvian fan and plain	widespread	moderate	low	low	very low
Marine terraces and plains	widespread	—	low	very low	very low
Delta and fan-delta	widespread	high	moderate	low	very low
Lacustrine and playa	variable	high	moderate	low	very low
Colluvium	variable	high	moderate	low	very low
Talus	widespread	low	low	very low	very low
Dunes	widespread	high	moderate	low	very low
Loess	variable	high	high	high	unknown
Glacial till	variable	low	low	very low	very low
Tuff	rare	low	low	very low	very low
Tephra	widespread	high	high	?	?
Residual soils	rare	low	low	very low	very low
Sebka	locally variable	high	moderate	low	very low
(b) Coastal Zone					
Delta	widespread	very high	high	low	very low
Esturine	locally variable	high	moderate	low	very low
Beach					
High wave energy	widespread	moderate	low	very low	very low
Low wave energy	widespread	high	moderate	low	very low
Lagoonal	locally variable	high	moderate	low	very low
Fore shore	locally variable	high	moderate	low	very low
(c) Artificial					
Uncompacted fill	variable	very high	—	—	—
Compacted fill	variable	low	—	—	—

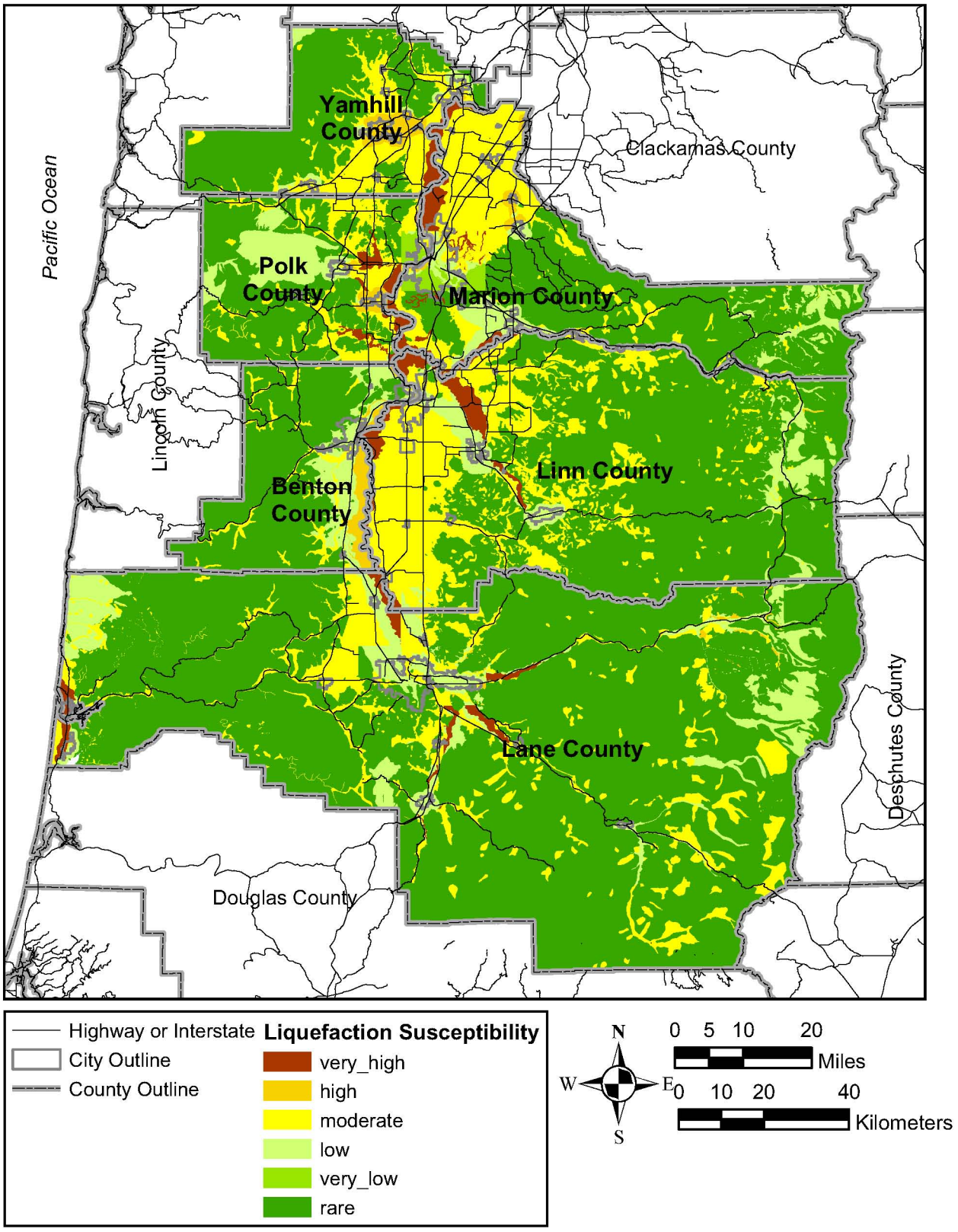


Figure 17. Liquefaction hazard map for the study area displays the six liquefaction potential classes used in this study. Benton County data were modified from Wang and others (2001).

6.3 Tsunami Hazard

Tsunamis are caused by large-scale disturbance of the sea floor. The most common cause is the concurrent uplift and subsidence of sea floor caused by great subduction zone earthquakes. The shape of the deformed sea floor is transmitted to the overlying sea surface, forming the initial tsunami wave that can arrive at nearby coastlines in minutes, causing extensive damage and loss of life. Subduction zone earthquakes also typically cause submarine landslides that can greatly amplify tsunami runup. This latter hazard is not directly addressed here but could be an important consideration when adding factors of safety for evacuation planning (Priest, 1995). Priest (1995) produced tsunami inundation maps by modeling the deformation from an earthquake, numerically simulating the resulting waves, and mapping the maximum inland flooding limit (inundation zone) (Figure 18) on 1:24,000 scale topographic maps. The inundation limit takes into account the effects of expected coseismic subsidence estimated from the study of wetland soils buried during prehistoric earthquakes.

6.4 Landslide Hazard Maps

In this study, we used a combination of approaches to develop two new landslide hazard identification products. The first new product is a regional earthquake-induced landslide hazard map (see subsection 6.4.1) that distinguishes different areas on the basis of the simple combination of slope gradient derived from a 10-m digital elevation model (DEM)[1] and generalized material type (USGS, 2004). The second new product is a GIS compilation of identified landslide areas (see subsection 6.4.2) derived from published geologic reports and geohazards studies.

Two previously prepared landslide hazard maps are included in this report. The first is a GIS database of known landslide locations (point and polyline features) from previous DOGAMI compilation efforts following the 1996-1997 Oregon major storm events (Hofmeister, 2000) (see subsection 6.4.3). The second existing product is a regional debris flow or "rapidly moving landslide" hazard map (see subsection 6.4.4) (Hofmeister and others, 2002).

6.4.1 Earthquake-Induced Landslide Map

We prepared the regional earthquake-induced landslide hazard map using an approach similar to the Wilson and Keefer (1985) methodology employed within HAZUS-MH. The method combines two important factors relating to landslide susceptibility: slope gradient and geologic material strength (relative slope instability susceptibility). In regional applications such as this study, slope gradient is derived from digital elevation models (in this case, a 10-m DEM). We estimated material strength by grouping geologic units into three simple geologic groups — Low, Moderate, and High — based on the unit characteristics identified in the geologic reports and our comparisons with other landslide hazard information. We assigned the vast majority of units to the Medium material class (highly weathered rock and unconsolidated sediments); only units with substantially divergent characteristics were assigned to the Low (consolidated bedrock) and High (existing landslides) classes. The steps used to develop the earthquake-induced landslide hazard map and original data sources are provided in Appendix H.

We assigned hazard classes of Low, Moderate, High, and Very High from the combination of slope map and geologic group categories as shown in Table 3. We developed these categories specifically for this project, although the table reflects a structure similar to that of Wilson and Keefer (1985) within HAZUS-MH.

The resulting landslide hazard map with relative designations Low, Moderate, High, and Very High is shown in Figure 19. The relative hazard map depicts locations of higher and lower relative hazard based on general material type and slope at 10-m grid spacing. Steep slopes tend to dominate the higher hazard zones throughout the counties. Many mountainous areas are identified as having an elevated landslide hazard, but steeper portions of the lowland Willamette Valley also have elevated landslide hazards. For example, areas of historic landslide activity such as along the banks

1 A DEM is a digital representation of topography, usually consisting of a grid (a regularly spaced series of points) with elevation values assigned to geographic coordinates (such as latitude, longitude). The grid spacing (10 m in this case) refers to the map view distance between the grid points.

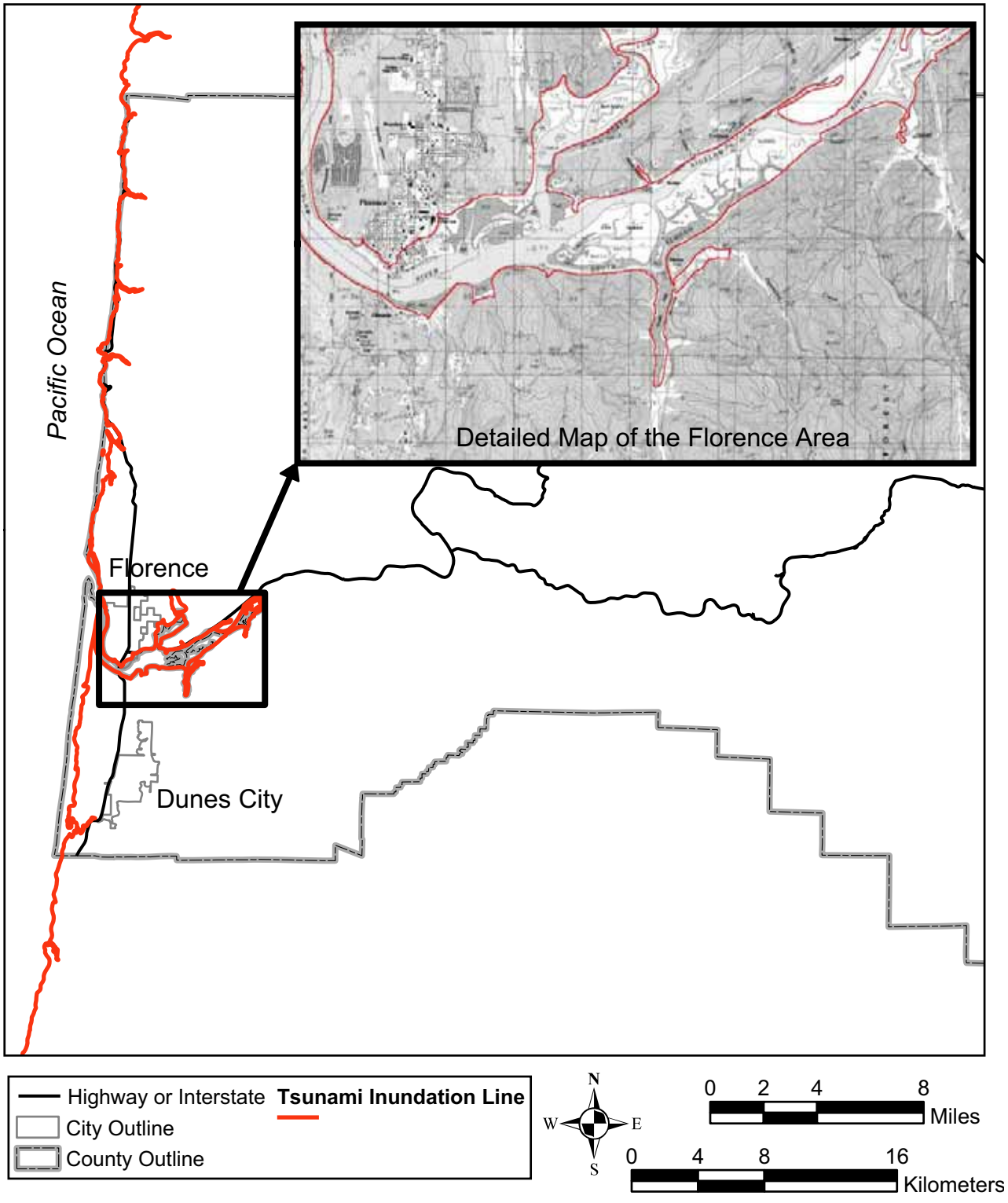


Figure 18. Tsunami inundation zone line for Lane County and the City of Florence, Oregon (modified after Priest, 1995).

Table 3. Landslide hazard class assignments based on combination of material type categories (Low, Moderate, High, and Very High) and slope gradient values.

Geologic Group (relative slope instability susceptibility)	Slope					
	0°–10°	10°–15°	15°–20°	20°–30°	30°–40°	40°+
Low (consolidated rock)	low	low	low	moderate	high	very high
Moderate (highly weathered rock and unconsolidated sediments)	moderate	moderate	moderate	high	very high	very high
High (existing landslides, landslide topography, and colluvium)	high	high	high	very high	very high	very high

of the Willamette River south of Salem are shown as higher susceptibility areas.

6.4.2 Identified Landslide Areas

Slopes that have failed in the past often remain in a weakened state, and many landslide areas tend to fail repeatedly over time. In some cases, areas that have previously failed assume rather subtle geometries, and these areas may or may not be obvious on relative hazard maps that emphasize slope (such as the earthquake-induced landslide map described in the previous subsection). Previously failed areas are nonetheless particularly important to identify, as they may pose a substantial hazard for future instability.

In this study, we extracted existing landslide polygons from the final geologic map to create the identified landslide hazard layer. This GIS compilation of landslide areas was derived from published geologic reports and existing geologic hazard studies.

We used GIS operations to select areas mapped as landslide deposits and colluvium and/or digitized the original maps to develop the database of identified landslide areas.

The current GIS layer includes more than 1,000 landslide areas (Figure 20). Some landslide areas overlap because of variations in interpretation by individual mappers. For sources in the Willamette Valley, we performed some manual editing to minimize duplication of landslide entries by selecting the most topographically accurate source. The existing information is not comprehensive, but future efforts can build on and refine the data.

6.4.3 Landslide Inventory

The regional inventory of landslides by Hofmeister (2000) incorporated information compiled by federal, state, and local data sources following the 1996-1997 storms in Oregon. The quality of the data varies considerably. This inventory is the foundation for the statewide database of landslide locations maintained by DOGAMI. The database format is easily expandable to include additional events as they are recorded. For example, the landslide data form in Appendix K can be used in conjunction with the existing inventory to efficiently gather data on future landslides. Landslide locations within the current study area from the Hofmeister (2000) study are shown in Figure 21.

Landslide inventories are valuable for tracking and monitoring historic effects, such as how many times a road cut has sloughed at one location, as well as for mitigating future effects, such as the cost effectiveness of fixing a location that sloughs every year and needs maintenance versus the cost of the yearly maintenance. Such inventories are also helpful for evaluating regional trends, calibrating existing hazards, and developing new hazard identification and mitigation tools (for examples, see Turner and Schuster [1996]). In general, the more extensive and complete the available base information, the more accurate follow-on studies can be.

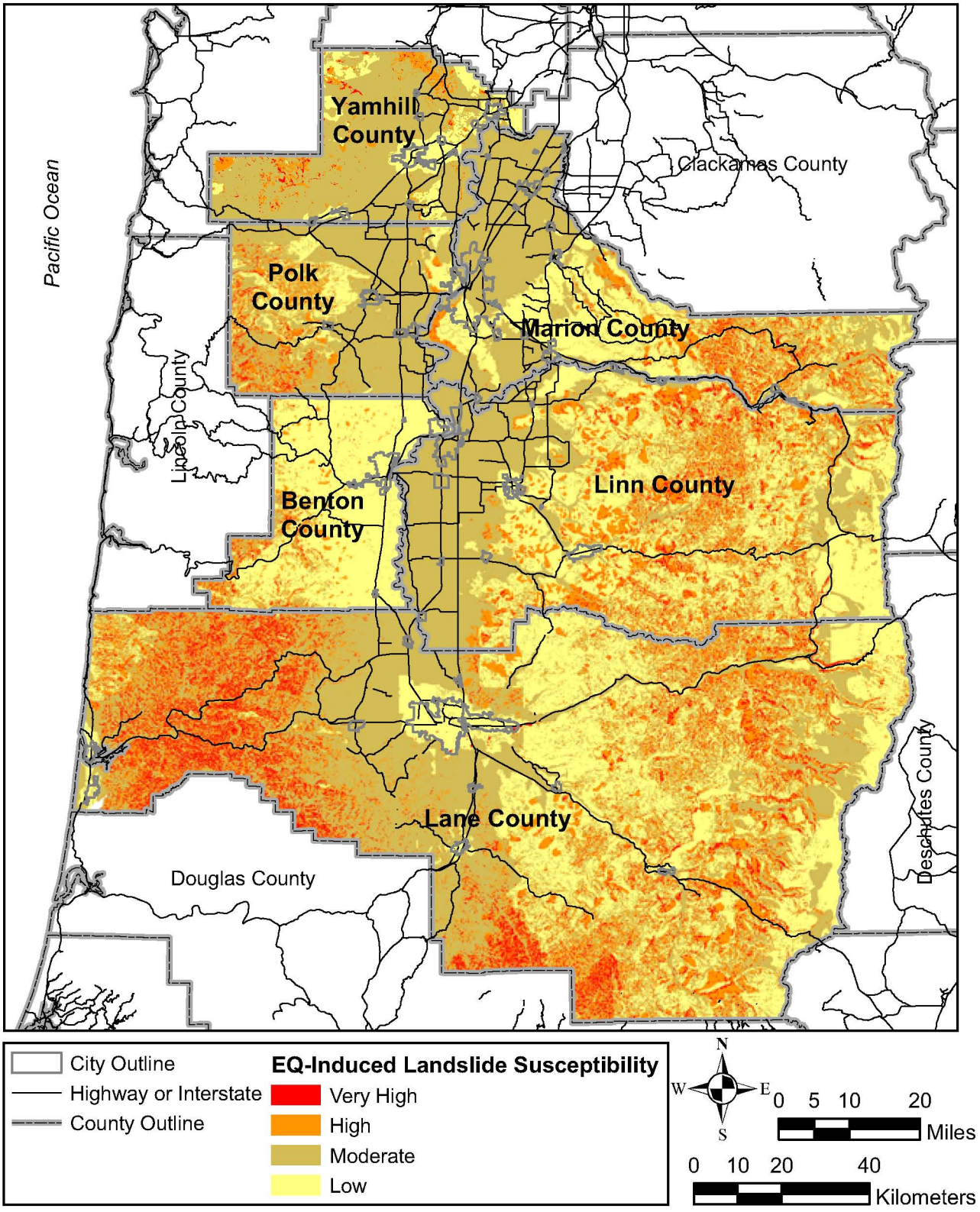


Figure 19. Earthquake-induced landslide hazard map for the study area displays the four relative hazard classes: Low, Moderate, High, and Very High. Benton County data were modified from Wang and others (2001).

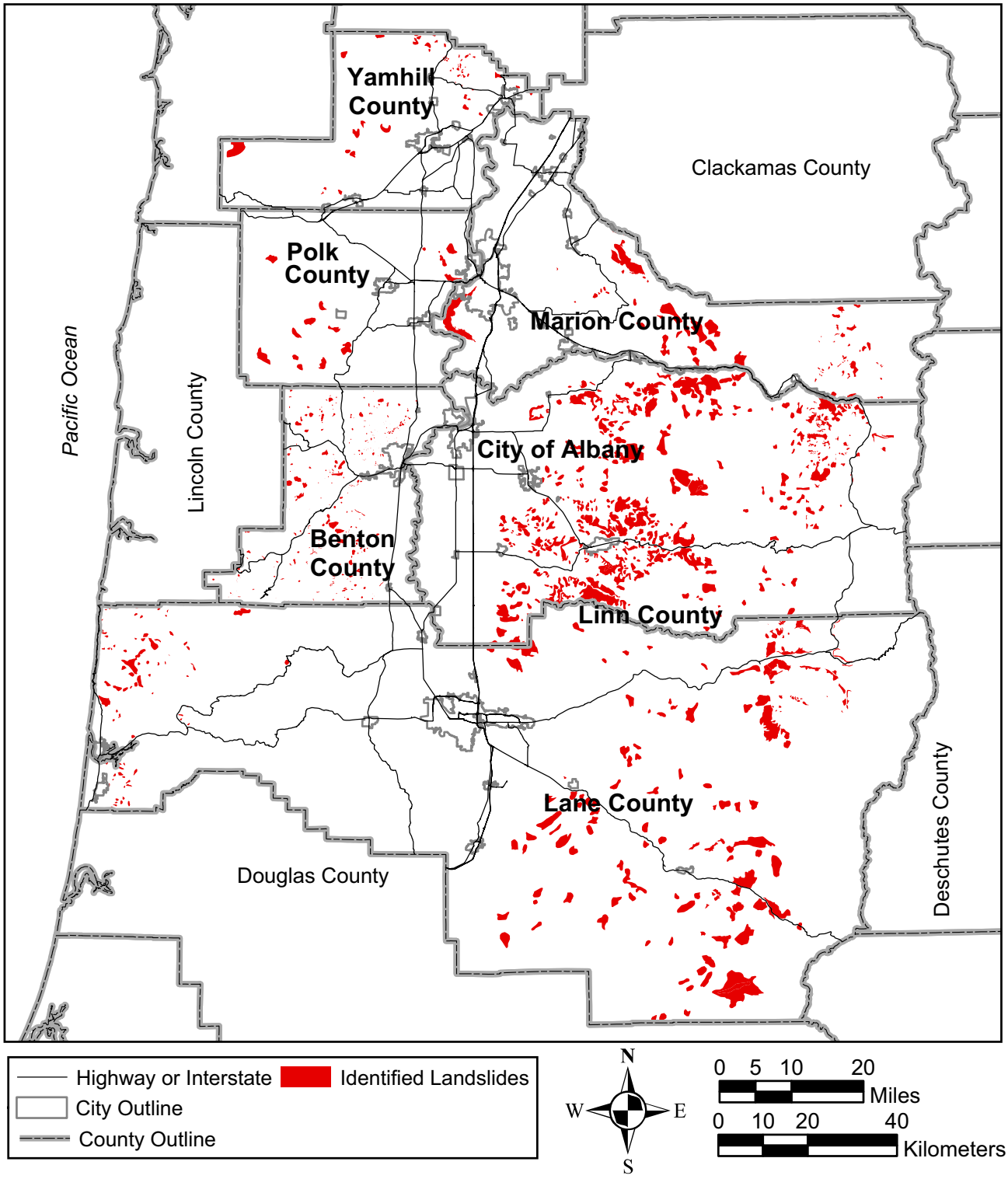


Figure 20. Identified landslides map of study area. Over 1,000 identified landslide areas are shown.

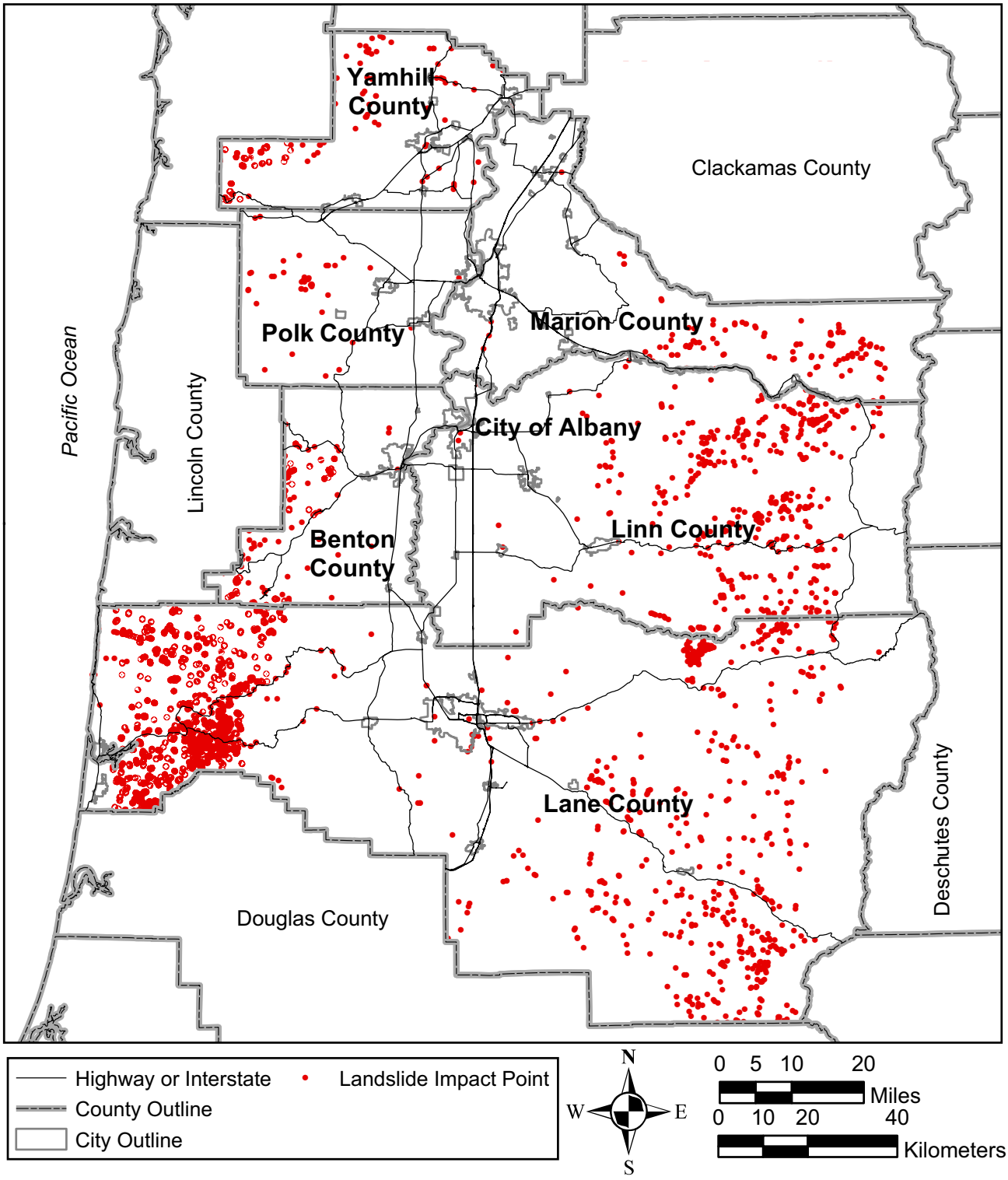


Figure 21. Landslide impact inventory from three storm events during 1996-1997. Landslide locations are mapped as points (Hofmeister, 2000).

6.4.4 Debris Flow/Rapid Moving Landslide Areas

Debris flows can originate as minor landslides and grow dramatically in size as they move down stream channels, causing tremendous destruction miles from their origins. Large debris flows can travel at velocities exceeding 50 mph and are easily capable of flattening homes, crushing cars, and taking the lives of people in their paths. In 1991 in an attempt to address the most dangerous landslide hazards more systematically, the Oregon legislature passed Senate Bill 12 (SB 12) with the overarching goal of saving lives and reducing future landslide losses.

Hofmeister and others (2002) produced a landslide hazard map showing areas where debris flows or rapidly moving landslides (RML) are possible in western Oregon. The debris flow maps were created by computer models that divide the debris flow process into three zones: 1) source area, 2) transport zone, and 3) deposition zone. An iterative process that included multiple phases of GIS screening, field data collection, inventory comparisons, and peer reviews was used to create the map (Hofmeister and others, 2002). In the final map, the three zones were combined into a single zone as shown in Figure 22.

6.5 Other Geologic Hazards

6.5.1 Volcanic Hazard Maps

In the study area the USGS defines two potentially active volcanic hazard regions, the Mount Jefferson region and the Three Sisters region (Figure 23). Numerous small volcanoes occupy areas between these regions but pose only local hazards (Walder and others, 1999). Appendix I includes the volcanic hazard maps developed by the USGS for these regions.

6.5.2 Dam Failure Maps

Throughout Oregon there are thousands of dams ranging in size and type from earthen constructions only several meters high to concrete constructions tens of meters high. Some of these dams were built before many geologic hazards such as a Cascadia Subduction Zone earthquake were identified. The National Inventory of Dams (NID) tracks 812 of these dams in Oregon, because they meet certain criteria including significant hazard potential and height (Goettel and others, 2004). Two hundred and seventy nine of these dams have a high or significant hazard (Figure 24) (Goettel and others, 2004). As previously mentioned, this hazard is related only to the impact if a dam fails, not to dam safety level or likelihood to fail. In order to assess the risk from dam failure, communities should acquire or produce inundation zone maps. An example of an inundation zone map from outside the study area is shown in Figure 25.

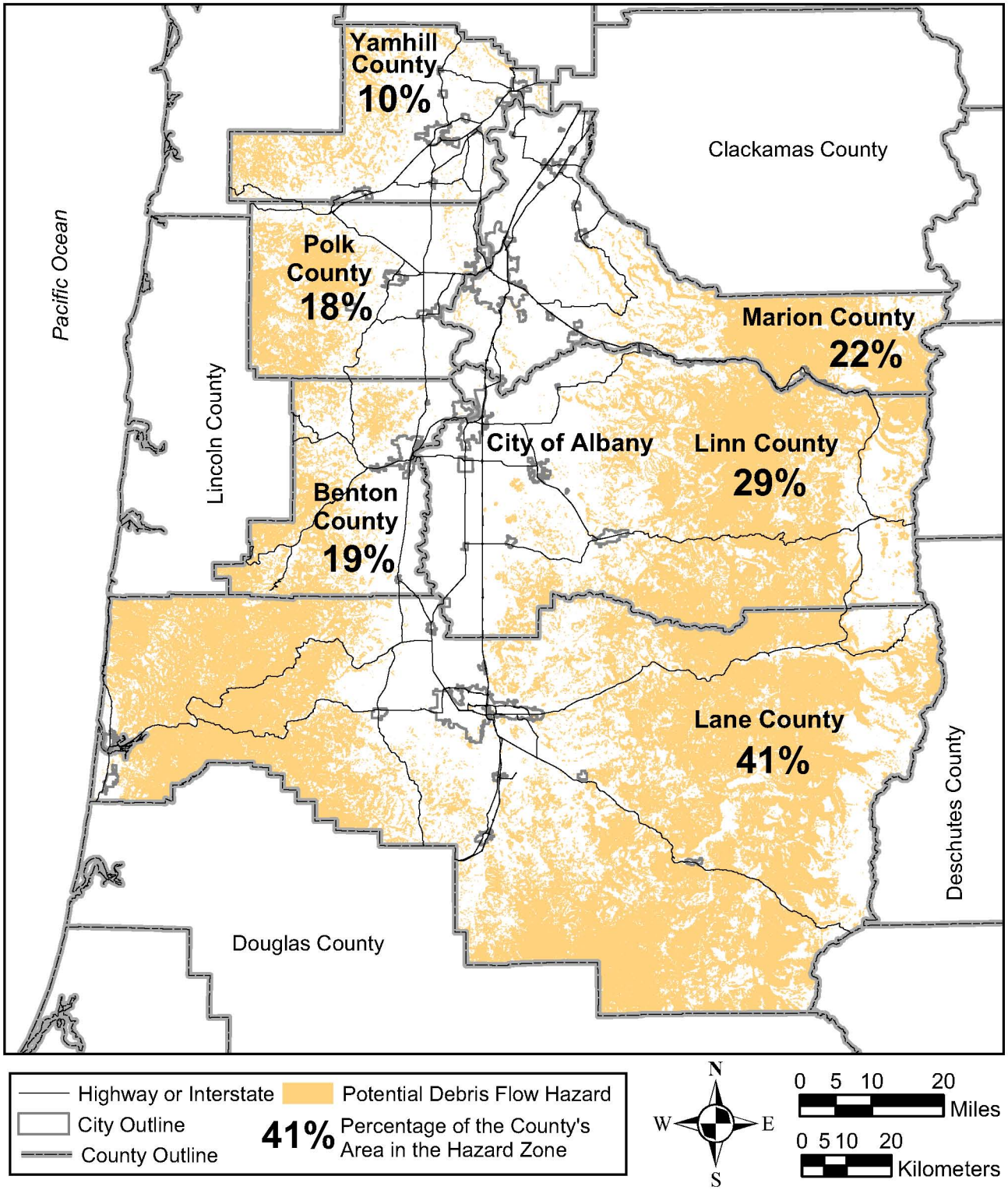


Figure 22. Debris flow ("rapidly moving landslide") hazard map displaying areas in the hazard zone and percentage of county area in the hazard zone (Hofmeister and others, 2002).

Figure 23. Aerial view looking north toward Three Sisters (left) and Broken Top (right) (Walder and others, 1999).

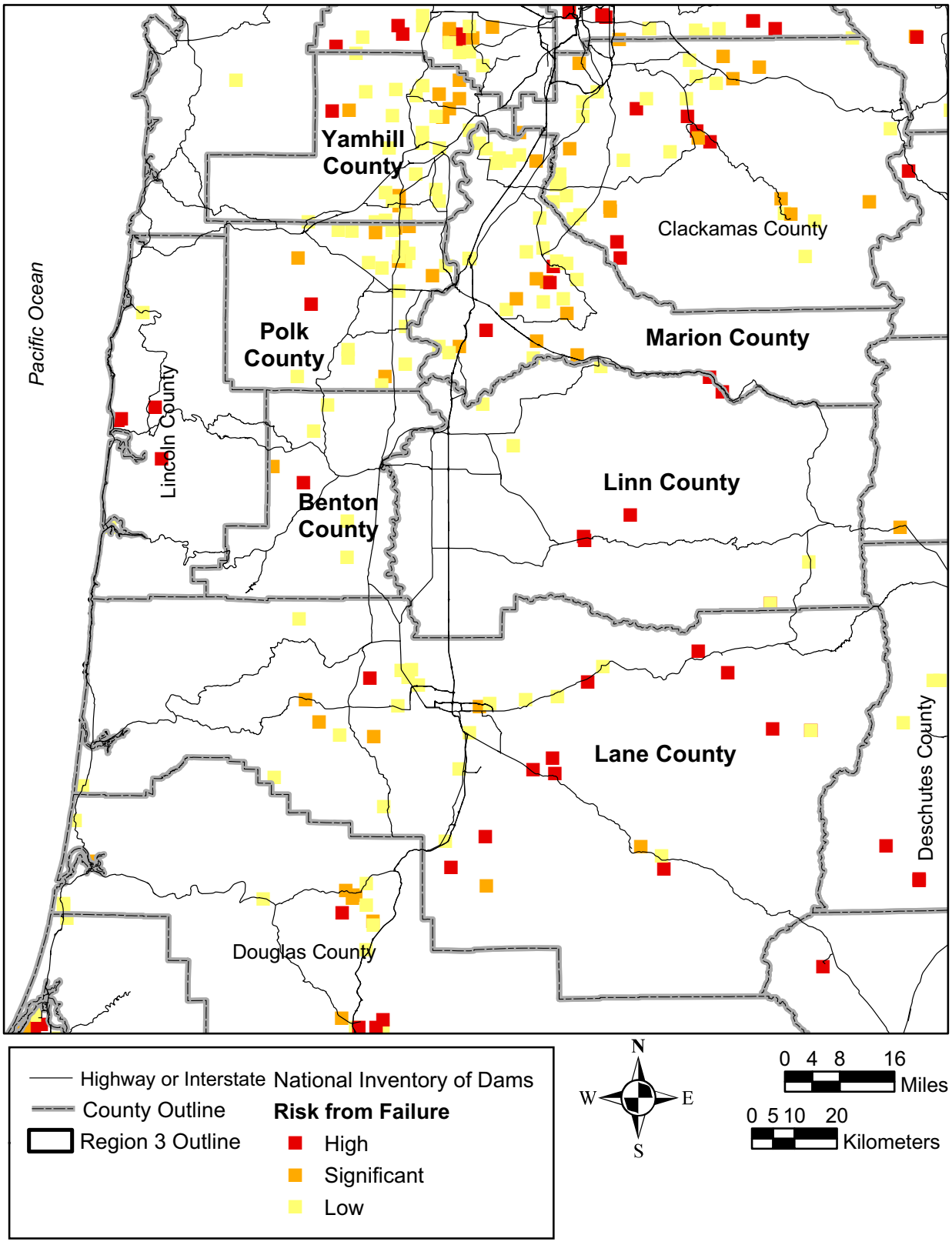


Figure 24. Map of National Inventory of Dams (NID) dams with relative levels of related risk from impact if dams were to fail (U.S. Army Corps of Engineers, 2005).

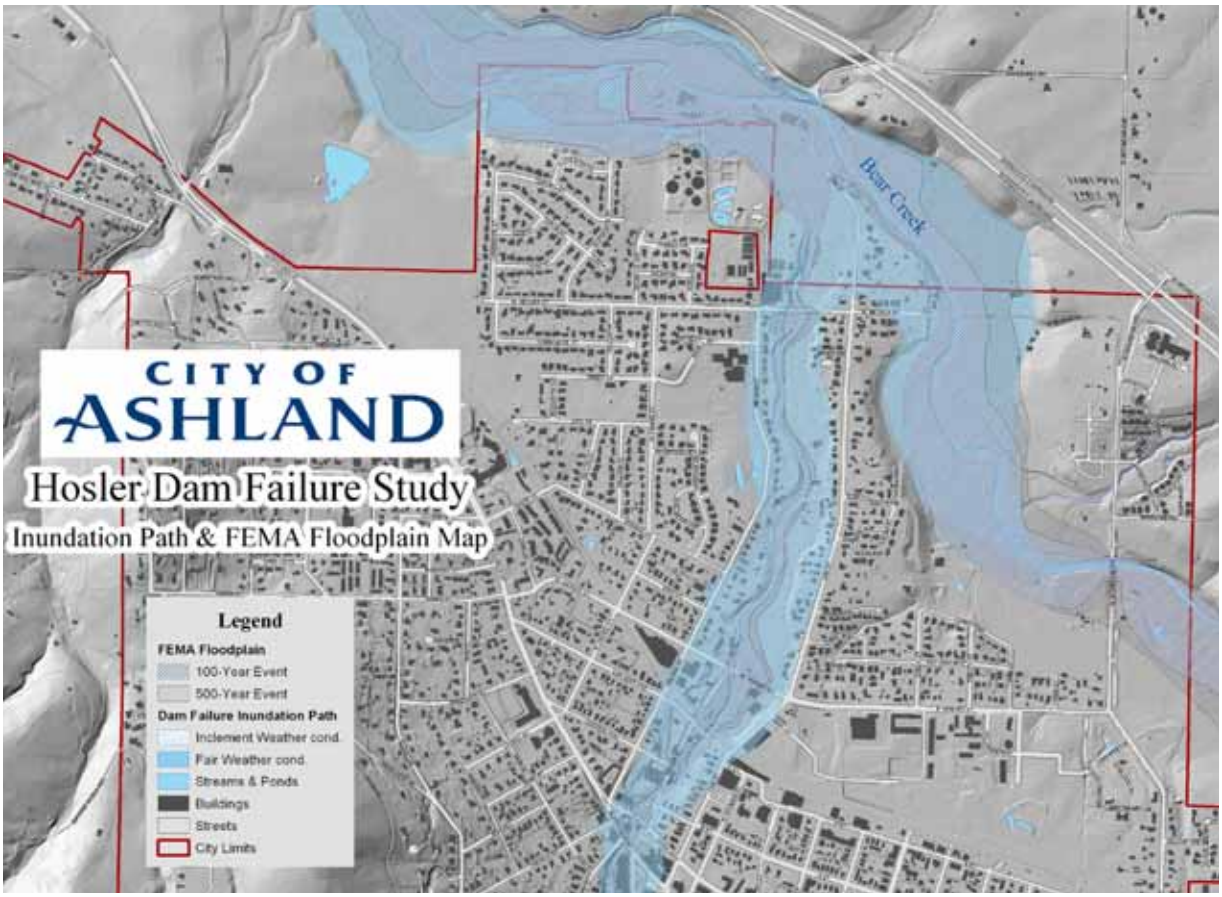


Figure 25. Example of a dam failure inundation map for the City of Ashland, Oregon (City of Ashland, 2005).

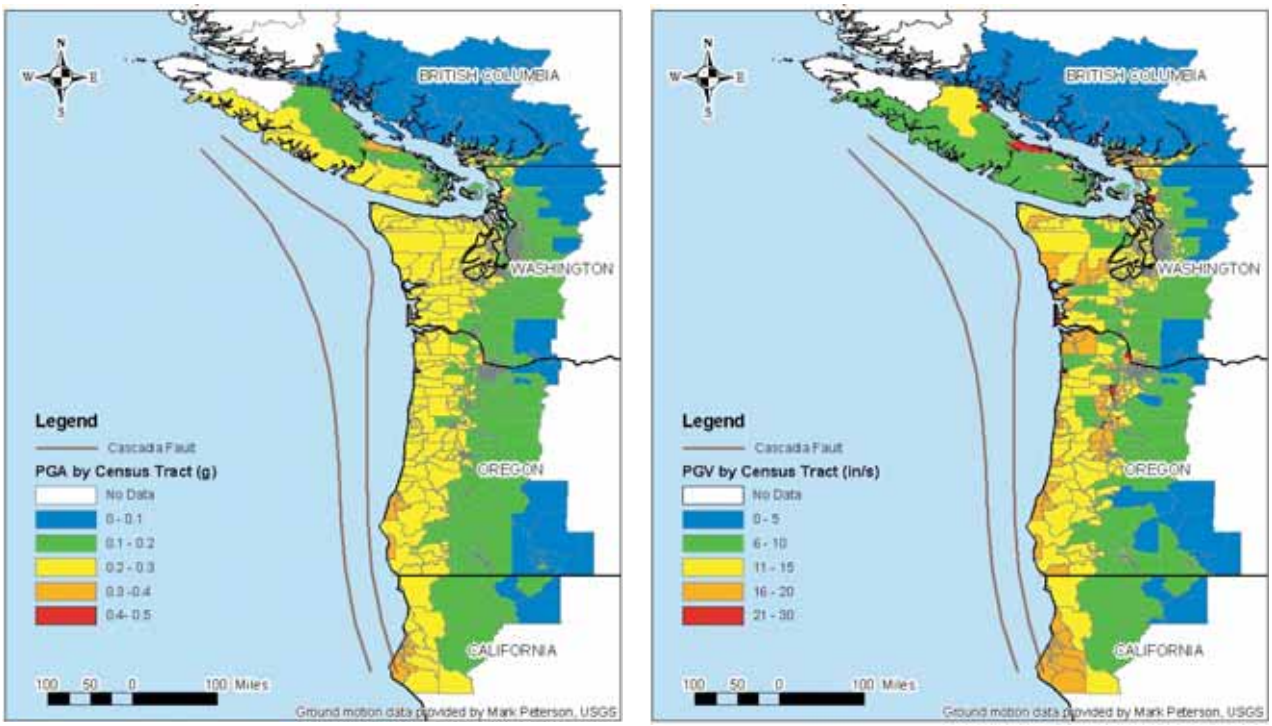


Figure 26. (left) Peak ground accelerations (PGA) and (right) peak ground velocities (PGV) on rock for the Cascadia Region Earthquake Workshop (CREW) magnitude 9.0 Cascadia Subduction Zone scenario. (CREW, 2003).

6.6 Map Limitations and Recommended Future Improvements

We developed the countywide earthquake hazards and landslide hazard maps with the best data available and the most appropriate models allowed by project funding. Several limitations are worth noting and underscore that any relative hazard map is generally useful for regional applications but should not be used as an alternative to site-specific studies in critical areas.

1. Although it is possible to check for errors in the GIS and database operations, it is not feasible to verify completely the original data on which the analyses are based. Geologic data in less populated eastern portions of the counties were particularly limited in terms of scale. For example, the 500,000-scale geologic map of the state was used in some locations, and the available GIS layers were poorly georeferenced. We manually edited the layers to improve some areas, but time constraints prohibited extensive modifications.
2. We developed hazard layers from original sources that vary in scale, methods of development, and quality. Changes subsequent to the period of the original mapping — such as advancement of rock quarry boundaries, large-scale earthwork projects, large landfills, and other land modifications — could affect the hazard ratings in some areas. Land modification is not expected to be a significant source of error, but land modifications can be important locally in some areas.
3. We assigned hazard classes on the basis of regional data with substantial scatter. We selected the most representative values, but geologic materials do vary regionally and locally. Site-specific geologic features, such as the presence of daylighting discontinuities, unfavorably dipping bedding planes, seams of local weakness, and other causes of localized instability cannot realistically be determined on a regional basis for each cell. Yet these can be critical factors for particular areas.
4. We neither collected nor analyzed any new data to create these maps. Therefore these maps are snapshot views of the current data.

Because of these limitations and because the hazard zones are based on limited geologic data as described in this report, these maps are intended for regional purposes only and cannot replace site-specific investigations. However, the relative hazard maps can serve as useful tools for estimating the regional effects of future earthquake and landslide events.

6.6.1 Recommendations for Improvements (Action Items)

To improve the existing hazard maps and data, action items are provided in Appendix J. These action items range from identification of individual school buildings that have a high risk of collapse in an earthquake to identification of landslide hazard areas over large regions of the state. Table 4 lists the three multi-hazard action items:

Table 4. Multi-hazard action items.

Action Item	Goal	Partners
Identify and pursue funding opportunities to implement mitigation actions.	The switch from planning to implementation is the step that begins the reduction of risk.	Form partnerships with city, other county, and state agencies. Use these partnerships to apply for federal and local (local bonds, measures) mitigation grants.
Integrate the hazard data into planning ordinances and regulatory documents and programs.	Without ordinances and regulations, the hazard data are used by only few, instead of by all.	Work with local and regional governments.
Develop education programs aimed at mitigating the risk posed by hazards.	Education of the potential hazard and risk are sometimes the best way to reduce the risk.	Work with local and regional governments. Use internet websites, local fairs, news articles, brochures, etc to get the data to the public.

7.0 EARTHQUAKE DAMAGE AND LOSS MODELING

The second major component of this study was to perform earthquake-induced damage and loss modeling for each community partner involved in the Region 3 PDM Project: Yamhill, Marion, Polk, Benton, Linn, and Lane Counties and the City of Albany, Oregon. The general purpose of damage and loss estimation is to evaluate resource requirements for earthquake effects and to identify areas where planning and mitigation can be implemented most effectively.

The state of the science in earthquake damage and loss estimation has improved dramatically over the last several years, and new tools allow for relatively quick and reasonably accurate regional loss estimation. One such tool is the HAZUS-MH computer program developed by the Federal Emergency Management Agency (FEMA), the National Institute of Building Sciences (NIBS), and a host of other public and private partners (FEMA, 2003, 2005). The HAZUS-MH software can be used to model a variety of earthquake scenarios and to estimate regional damages such as building damage, lifeline damage (roads, utilities), and injuries.

A number of default databases are included with the HAZUS-MH program. Most data are based on national-scale information that often does not accurately reflect local conditions. To better account for local variability the software is designed to incorporate user-specific updates to the data inputs (FEMA, 2003). In this study, we incorporated the updated regional hazard maps presented in the preceding sections. With the HAZUS-MH study region geologic hazard data updated, a local crustal earthquake scenario and a Cascadia subduction zone scenario for each community were input (Table 5) and analyzed. The results are summarized in Table 6 and Appendices A–G.

Table 5. Earthquake scenarios input for HAZUS-MH analysis.

Community	Crustal Scenario	Magnitude	Subduction Zone Scenario	Magnitude
Benton County	Corvallis Fault	6.5	Cascadia	9.0
City of Albany	Mill Creek Fault	6.7	Cascadia	9.0
Lane County	Arbitrary "Eugene" Fault	6.5	Cascadia	9.0
Linn County	Mill Creek Fault	6.7	Cascadia	9.0
Marion County	Mt. Angel Fault	6.9	Cascadia	9.0
Polk County	Mill Creek Fault	6.7	Cascadia	9.0
Yamhill County	Newberg Fault	6.8	Cascadia	9.0

Table 6. Summary of estimated building related damage/losses from HAZUS-MH analysis.

County	Scenario	Estimated Moderately to Completely Damaged Buildings		Total Building-Related Losses (includes estimates caused by business interruption) (billions of dollars)
		Number of Buildings	Percent of Total Buildings	
Yamhill	Crustal / Cascadia	13,600 / 9,500	50% / 35%	1.5 / 1.2
Polk	Crustal / Cascadia	4,100 / 6,100	20% / 29%	0.4 / 0.6
Marion	Crustal / Cascadia	37,400 / 21,700	43% / 25%	3.9 / 2.6
Benton	Crustal / Cascadia	7,700 / 8,100	31% / 32%	0.8 / 1.1
Lane	Crustal / Cascadia	28,400 / 32,500	25% / 29%	3.4 / 5.0
Linn	Crustal / Cascadia	12,400 / 10,300	34% / 29%	1.3 / 1.2
Total	Crustal / Cascadia	NA / 88,200	—	NA / 11.7

NA: It is very unlikely that these events would happen at same time; therefore the values were not totaled.

7.1 Improvements to the HAZUS-MH Base Model

7.1.1 HAZUS-MH Compared to HAZUS-99

The HAZUS-MH (FEMA, 2003b) model was improved from the HAZUS-99 model by the addition of data and improvements to the methodology including:

- New 2002 aggregated data for square footage, building count, building exposure, content exposure, and demographics
- New site-specific inventory data (2000 or later)
- New 2002 USGS probabilistic ground-shaking maps and new USGS attenuation functions

7.1.2 Addition of Relative Earthquake Hazard Maps

We used the relative earthquake hazard maps described in section 6 to update the HAZUS-MH study region. To input the maps into HAZUS-MH, specific formats and classifications are required. For ground-shaking amplification hazard, we incorporated GIS polygons into HAZUS-MH by assigning the hazard polygons as shown below.

Amplification Class	Amplification Susceptibility	HAZUS-MH Input
a	very low	a
b	low	b
c	moderate	c
d	high	d
e	very high	e
f	site specific	f

For liquefaction, the layer hazard classes were assigned as shown in below.

Liquefaction Class	Liquefaction Susceptibility	HAZUS-MH Input
a	rare	0
b	very low	1
c	low	2
d	moderate	3
e	high	4
f	very high	5

For landslides, we tested a number of options for incorporating the detailed hazard map information into the HAZUS-MH program. For landslides, we broke down the relative zones into only four classes; HAZUS-MH classes 0, 2, 3, 5, 6, 8, and 9 were not used. We ended up with classes as shown below:

Landslide Class	Landslide Susceptibility	HAZUS-MH Input
—	—	0*
low	low	1
—	—	2*
—	—	3*
moderate	moderate	4
—	—	5*
—	—	6*
high	high	7
—	—	8*
—	—	9*
very high	very high	10

*HAZUS-MH class not used for input.

7.2 Earthquake Scenarios

The updated HAZUS-MH regions included with this report allow one to run any number of plausible earthquake scenarios in the study area. To test the model and to provide some examples, we have included results from two sample scenarios for each community:

1. Crustal earthquake with varying magnitude between 6.5 and 6.9
2. Subduction zone earthquake with magnitude 9.0 developed by the Cascadia Region Earthquake Workgroup (CREW, 2003).

Appendices A–G have details about the earthquake scenarios for each community. Table 5 summarizes the earthquake scenarios run as examples for this study.

The crustal earthquake event was chosen by examination of USGS data and data in the Geomatrix Consultants, Inc. (1995) report prepared for the Oregon Department of Transportation. A likely worst-case scenario was selected in each case. For Lane County, because no potentially active fault within or adjacent to the population center (Eugene-Springfield) has been identified yet, an arbitrary fault was developed (details are included in Appendix C).

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by CREW to model a magnitude 9.0 earthquake. Ground motion data provided by the U.S. Geological Survey are the basis for the CREW maps. Figure 26 shows CREW regional peak ground acceleration (PGA) and peak ground velocity (PGV) maps (CREW, 2003). The CREW earthquake scenario required input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 and 1.0 (CREW, 2003).

Two factors should be used to assess the risk posed by the scenarios: the amount of expected damage and the relative likelihood of an earthquake on these two faults. In the last two decades, the Cascadia Subduction Zone has been extensively studied; the average recurrence interval for this event is expected to be about 500 years. The recurrence interval for the crustal faults is far less constrained (Wang and others, 2001).

Another difference between the two earthquake scenarios is duration of shaking. Although the Cascadia Subduction Zone earthquake will not produce shaking as violent as a large-magnitude crustal earthquake in the near field, the duration of strong shaking will be much longer. Cascadia Subduction Zone earthquake shaking may last longer than 5 minutes, whereas strong shaking for crustal earthquakes may last 20–30 seconds. The 2004 Sumatra Subduction Zone Earthquake triggered shaking that lasted between 7 and 10 minutes (Park and others, 2005). Due to some limited scientific and engineering constraints on the effect of the longer duration Cascadia Subduction Zone shaking, HAZUS-MH damage estimates for this event have large uncertainty.

7.3 Summary of HAZUS-MH Results

Global summary results from running the model for these two earthquake scenarios are provided in Appendices A–G. The results from both models show that either earthquake would result in significant losses in all communities of the study. Results of the two scenarios for related damage/losses are compared in Table 6 and Table 7.

Table 7 shows roughly 1,000 casualties and 13,000 injured people would result in the study area from a Cascadia event. It also indicates that roughly 6,000 people would need shelter after a Cascadia event.

$12.5 billion in total economic losses from a Cascadia event is estimated. But, the total economic loss values are most likely underestimates due to the low quality and quantity of the input data, especially the lifeline data. Limitations of the data are discussed in more detail in section 7.5 of this report.

Table 8 shows a comparison of estimated available hospital beds in the study area before and after a Cascadia earthquake. HAZUS-MH estimated roughly 1,000 beds would be available the day after the earthquake and roughly 3,500 people would require hospitalization the day after.

Table 7. Estimated social impact of a crustal or Cascadia Subduction Zone earthquake from HAZUS-MH analysis.*

County	Earthquake Scenario	Fatalities During Late Afternoon Business Hours	Injuries from Minor to Life Threatening	Households Displaced	People Needing Shelter
Yamhill	Crustal / Cascadia	80 / 90	1,260 / 1,380	4,250 / 3,080	1,000 / 750
Polk	Crustal / Cascadia	20 / 50	280 / 720	1,410 / 1,820	360 / 460
Marion	Crustal / Cascadia	240 / 220	3,720 / 3,170	10,700 / 5,780	2,730 / 1,470
Benton	Crustal / Cascadia	40 / 120	590 / 1,560	1,750 / 2,370	500 / 660
Lane	Crustal / Cascadia	130 / 370	2,080 / 5,200	7,710 / 7,660	2,000 / 2,000
Linn	Crustal / Cascadia	70 / 90	1,120 / 1,290	3,680 / 2,560	920 / 650
Total	Crustal / Cascadia	NA / 940	NA / 13,320	NA / 23,270	NA / 5,990

*See Appendices A–G for detailed scenario input for each county.

NA: It is very unlikely that these events would happen at same time, and therefore the values were not totaled.

Table 8. Comparison of estimated hospital beds before and after a Cascadia Subduction Zone earthquake.

	Before Earthquake			After Cascadia Earthquake		
County	Number of Hospitals	Available Hospital Beds (approximate)	Average Beds per Hospital	Number of Hospitals Likely Functional Day After	Average Beds Available the Day After	Injuries Requiring Hospitalization
Benton	1	130	130	1	130	420
Lane	4	580	145	1	145	1350
Linn	1	70	70	1	70	340
Marion	5	1070	214	3	642	810
Polk	1	40	40	0	0	190
Yamhill	2	100	50	0	0	360
Total	14	1990	142	6	987	3470

7.4 Comparison of Results with Previous Studies

It is worth comparing the results of the current study with previous estimates of earthquake losses, including the statewide seismic risk assessment conducted by Wang and Clark (1999) and Wang (1998). In Marion County, for example, Wang and Clark (1999) used HAZUS-97 and its data, which indicated a magnitude 8.5 Cascadia Subduction Zone earthquake could cause nine fatalities, 1,241 displaced households, and $13 million in highway damage. Estimates for this study's scenario using HAZUS-MH and its data (2000 census data) for a magnitude 9.0 Cascadia Subduction Zone were 218 fatalities, 5,787 displaced households, and $127 million in highway damage. These increases in losses are mainly attributed to the addition of user-specified hazard layers, including liquefaction and landslides, the updated inventory data from the 2000 census, and a higher magnitude earthquake.

A second comparison worth looking at is between DOGAMI's Open-File Report O-01-05, *Preliminary Earthquake Hazard and Risk Assessment, Benton County* (Wang and others, 2001) and this study. The 2001 study used HAZUS-99 (FEMA, 1999) and augmented the default data with field survey data. The field survey resulted in, for example, a 22 percent improvement in single-family residential building area

data, an improvement in Oregon State University campus building data, and a 4 percent improvement in commercial building data. The estimates using the HAZUS-99 with the field data and a crustal scenario (Corvallis Fault) resulted in 0 fatalities, 695 displaced households, and $707 million in building damage. The estimates for this study using HAZUS-MH without the updated field survey data are 38 fatalities, 1,755 displaced households, and $762 million in building damage. These changes are mainly attributed to the 2002 aggregated data for square footage, building count, building exposure, content exposure, and demographics updated in the HAZUS-MH model and the updated program functions.

The HAZUS-MH study regions for each community in this study are included on the publication CD, so that users can run a variety of default and custom scenarios as well as evaluate probabilistic losses. This allows users a maximum amount of flexibility.

7.5 Uncertainties in Damage and Loss Estimation

Any city, county, or region studied will have huge varieties of population type and density, transportation and lifelines, structures, and type and level of hazard. Due to this complexity and uncertainties inherent in any estimation methodology (FEMA, 2003b), readers should bear in mind the limits of the estimates given here.

7.5.1 HAZUS-MH Modeling Limitations

Although the HAZUS-MH software allows us to analyze complex and extensive regional earthquake scenarios, which result in statistically reasonable loss estimates, it is important to note the potential uncertainties associated with this type of modeling. These uncertainties arise from such factors as incomplete scientific knowledge concerning earthquakes and their effects on structures, incomplete or inaccurate inventories of the built environment/demographic/economic parameters, and other simplifications and approximations necessary for comprehensive analyses (FEMA, 2003b). Some examples of these uncertainties include the spatial variability of ground motions, the averaged building data by census tracts, and variations or errors in empirically derived algorithms implemented within the program (FEMA, 1999). These factors all limit the ability to calculate precisely the regional damages and losses and therefore "can result in a range of uncertainty in loss estimates produced by the HAZUS-MH Earthquake Model, possibly *at best* a factor of two or more" (FEMA, 2003b, p. 6).

7.5.2 Specific HAZUS-MH Modeling Limitations

During the damage and loss modeling using HAZUS-MH, we noticed several results that are consistently incorrect or underestimated across all counties. Lifeline data (transportation and utilities) appear to be the least reliable, which is not surprising as these data are the most difficult to collect and analyze. An example of the inaccuracy of the data can be seen in the Lane County Cascadia Subduction Zone scenario results shown below:

Railways	0% with at least moderate damage
Highway Segments	0% with at least moderate damage
Natural Gas Facilities	0% with at least moderate damage
Electrical Power Facilities	0% with at least moderate damage
Electric Power Performance	0 households without service the day after

We also noticed the results related to critical facilities were underestimated across all counties. The Oregon Department of Geology and Mineral Industries is currently performing a statewide study of critical facilities, which will improve the portion of the data in HAZUS-MH.

8.0 POTENTIAL USES OF THE STUDY DATA

The primary purpose of this study's consolidation of geologic hazard maps and loss estimation tools is to enable follow-on risk assessments and to focus resource allocation toward vulnerable areas. In general, the relative hazard maps should serve as useful tools for differentiating areas of higher and lower hazards. This spatial information is basic to emergency and land-use applications, and the following sections provide an overview of some common uses of the relative hazard maps and the earthquake damage and loss data.

With the risk assessment (damage and loss) estimate results, one can begin to:

- Identify vulnerable areas that may require planning considerations
- Assess the level of readiness and preparedness to deal with a disaster before disaster occurs
- Estimate potential losses from specific hazard events (before or after a disaster hits)
- Decide how to allocate resources for most effective and efficient response and recovery
- Prioritize mitigation measures that need to be implemented to reduce future losses

An example of preparedness and post-event community recovery can be examined by looking at the Marion County crustal earthquake scenario results. The data indicate ~60% of the fire stations will be functional the day after the modeled event and 18 fires will be ignited. For this scenario, one can see the need to mitigate the 40% of the fire stations that are nonfunctional so they do not become the weak link in the community's response and recovery from a disaster.

The items discussed below are just a few potential applications. It is likely that individual communities will find unique and new applications to suit particular needs.

8.1 Emergency management applications

A valuable use of the maps and loss estimation products is as an aid in emergency management activities such as development and refinement of emergency response plans, public outreach activities, selection of appropriate safe-haven sites, hazard response drills, and estimation of resource impacts for various earthquake hazard scenarios (Spangle Associates, 1998). An example of useful output data to an emergency management application is the debris generation estimate. In Marion County for a crustal scenario, HAZUS-MH estimated roughly 1 million tons of debris would be generated and at 25 tons/dump truck load would result in the need for 40,000 truck loads for debris removal. These data can be used by Marion County to prepare a post-disaster recovery plan that might involve the temporary rental of trucks and additional landfill space for the generated debris.

In related applications, communities and others can use the landslide and liquefaction hazard maps to identify infrastructure that is more or less likely to be damaged by major earthquakes and/or landslide-producing storm events. For example, by combining the hazard maps with transportation layers, potential road blockages can be identified and alternative corridors can be located. Similarly, the hazard maps can be combined with other information (such as the locations of hazardous waste facilities) to evaluate potential effects and to plan for emergency response.

HAZUS-MH inputs and outputs are also tailored to address specific emergency management and emergency planning needs. HAZUS-MH results provide estimates for various earthquake scenarios of the number of displaced individuals needing shelter, medical facility needs (for minor and major injuries), locations to concentrate rescue and recovery vehicles to limit damages, and so on. These estimates can be compared with information on currently available facilities and resources within the county.

8.2 Land-use planning, zoning, and regulations

Common applications of the study outputs in the realm of land-use planning, zoning, and regulations include input to comprehensive planning and the development of hazard ordinances. We reiterate that the relative hazard maps are not appropriate for site-specific evaluations, but the maps are valuable for regional screening for hazards and the selection of appropriate areas on which to focus further site-specific studies.

The landslide layers are particularly suitable for incorporation into county and city hillside development ordinances. The liquefaction hazard map can be used for regional screening of locations where further review may be warranted, and the information could be integrated into relevant local ordinances. The amplification hazard map is not as well suited for ordinance implementations because site amplification can generally be accounted for in standard infrastructure design phases. Therefore, amplification hazards are typically addressed by the adoption and enforcement of building code standards (Spangle Associates, 1998).

8.3 Evaluations of lifelines and other regionally distributed infrastructure

"Lifelines" is a general term used to refer to critical transportation and utility infrastructure, including roads and highways, railroads, airports, bridges, overpasses and underpasses, natural gas pipelines, electric lines, and water distribution systems. Many lifelines are characterized by components that are dispersed over broad geographic areas that often require regional (as opposed to site-specific) risk assessments. The hazard maps presented in this report can be useful for estimating and mitigating damage to lifelines.

HAZUS-MH includes regional risk assessment algorithms for lifelines, but assessments can also be made outside the HAZUS-MH program and are not limited specifically to lifeline components. Any number of geographically dispersed infrastructure components can be evaluated by identifying the intersections of hazard zones with infrastructure inventories. It is relatively common in Oregon to incorporate regional hazard maps into the planning stages for lifelines such as natural gas pipelines and water distribution systems, and it is also appropriate in some cases to use the relative hazard maps to screen the planning process of larger developments. Comparing the maps to various development plans can provide valuable feedback on locations that may be worth avoiding (higher hazard areas) and locations where a denser concentration of structures may be preferable (in lower hazard areas).

8.4 Earthquake rehabilitation programs

While it is usually more cost effective to take steps toward mitigation before development occurs, the reality is that there are a lot of existing buildings and other infrastructure components built prior to the incorporation of earthquake design into the codes. With some existing infrastructure, it makes sense to upgrade (or "rehabilitate") to current earthquake design standards.

Critical and essential facilities including fire, hospital, police stations, emergency centers, and school buildings are particularly important to the community and, ideally, should be designed to withstand earthquake shaking. These buildings are catalogued in this study and are incorporated into the updated HAZUS-MH building database and study region on this CD-ROM. Using this compiled information, essential facilities can be more efficiently evaluated and prioritized for earthquake rehabilitation (by such methods as benefit-cost analyses).

8.5 Ongoing data consolidation efforts

The information included in this study is a substantial improvement upon previously available earthquake and landslide hazard information for each community. It is, however, based on data sources and evaluation techniques that will improve with time and attention. As reliable new information becomes available, we encourage county agencies and other users of this information to update the data and maps provided in this study.

With the landslide hazard data, in particular, the GIS layers for identified landslide areas and the landslide impact inventory can serve as an excellent starting point, but we encourage county agencies and other users to build on the data by incorporating any additional information that becomes available. We also hope that specific inventory efforts will be conducted to add to the available information base.

Similarly, the HAZUS-MH study regions should be updated with additional local information. We focused specifically on the hazard map parts of HAZUS-MH in this study, but many other default files in HAZUS-MH can be updated to take advantage of the many additional modeling capabilities within the program. For example, dam-break flood hazards can be evaluated using HAZUS-MH if a properly formatted dam inventory is developed. Similarly, other inventory files and other parameters (e.g., local economic variables) used by HAZUS-MH can be updated wherever and whenever more accurate local information is available for input.

These examples are just a few of many potential applications that can build on the results from this study. More information on these and other applications can be found in publications by Spangle Associates (1998), FEMA (2003b), and Turner and Schuster (1996).

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OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

APPENDIX A: BENTON COUNTY

CRUSTAL EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

SUBDUCTION ZONE EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

GEOLOGIC HAZARD MAPS
- Relative Ground-Shaking Amplification Susceptibility Map
- Relative Liquefaction Hazard Susceptibility Map
- Relative Earthquake-induced Landslide Susceptibility Map
- Identified Landslide Areas Map

HAZUS-MH GLOBAL REPORT FOR CRUSTAL SCENARIO
HAZUS-MH GLOBAL REPORT FOR SUBDUCTION ZONE SCENARIO

CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR BENTON COUNTY

Crustal Earthquake Scenario: A magnitude 6.5 earthquake on the Corvallis Fault.

For the magnitude 6.5 earthquake on the Corvallis Fault scenario, we defined the fault source using the "deterministic seismic source" option within HAZUS-MH (Figure A1) (FEMA, 2003b). The fault and earthquake event were chosen by examination of USGS (2004) data and data in the Geomatrix Consultants, Inc. (1995) *Seismic Design Mapping, State of Oregon* report prepared for the Oregon Department of Transportation. In general, a likely worst-case scenario was selected. In particular, this event was modeled after the scenario defined in DOGAMI Open-File Report O-01-05, titled *Preliminary Earthquake Hazard and Risk Assessment and Water-Induced Landslide Hazard in Benton County, Oregon*. Figure A1 has the location of the fault, shown as the dark line, within Benton County. Figure A2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Corvallis Fault M6.5
Type of Earthquake	Deterministic Seismic Source - Arbitrary
Fault Name	Corvallis Fault
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	–123.358
Latitude of Epicenter	44.5437
Earthquake Magnitude	6.5
Depth (Km)	10
Rupture Length (Km)	22.38
Rupture Orientation (degrees)	30
Attenuation Function	Reverse-Slip

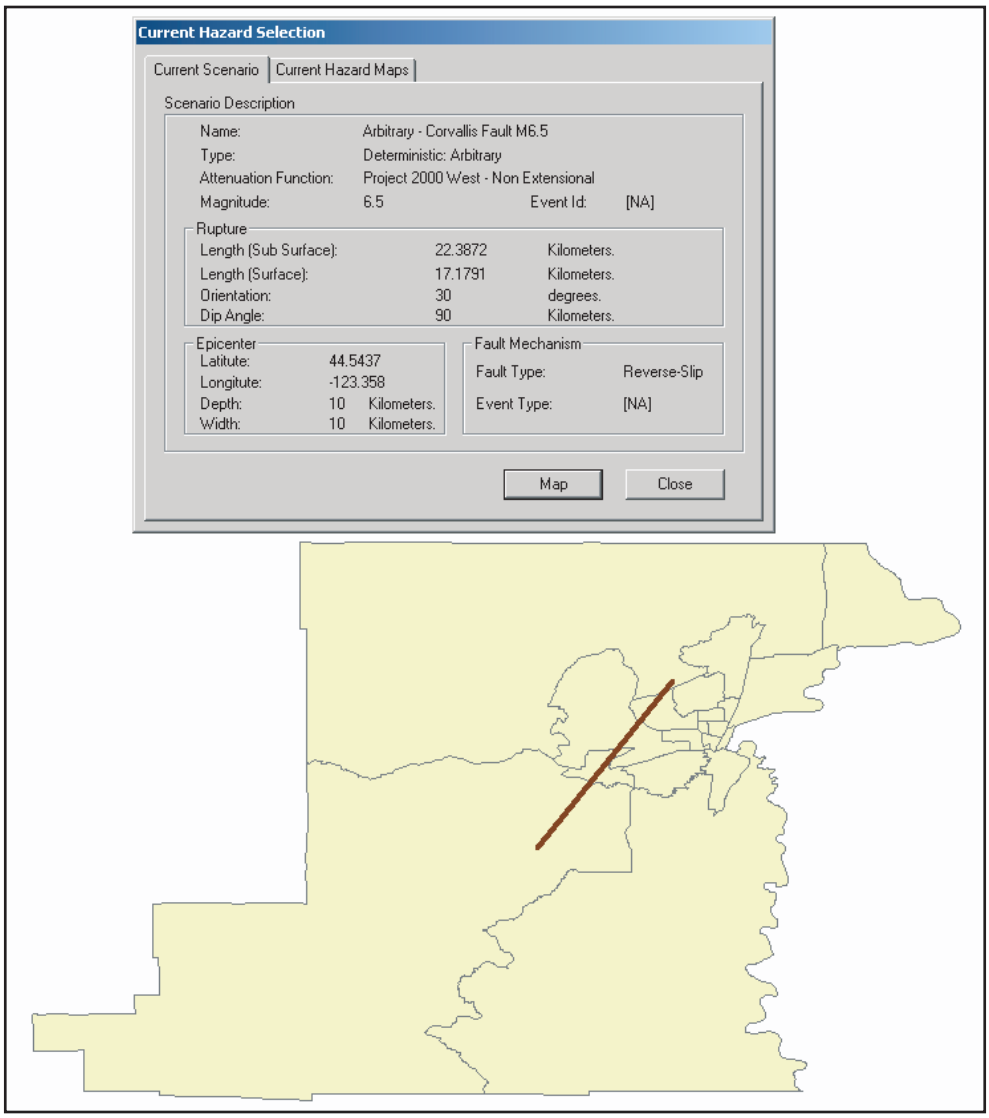

Figure A1. Corvallis Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dark line.

Crustal Earthquake Scenario Ground Motion Map

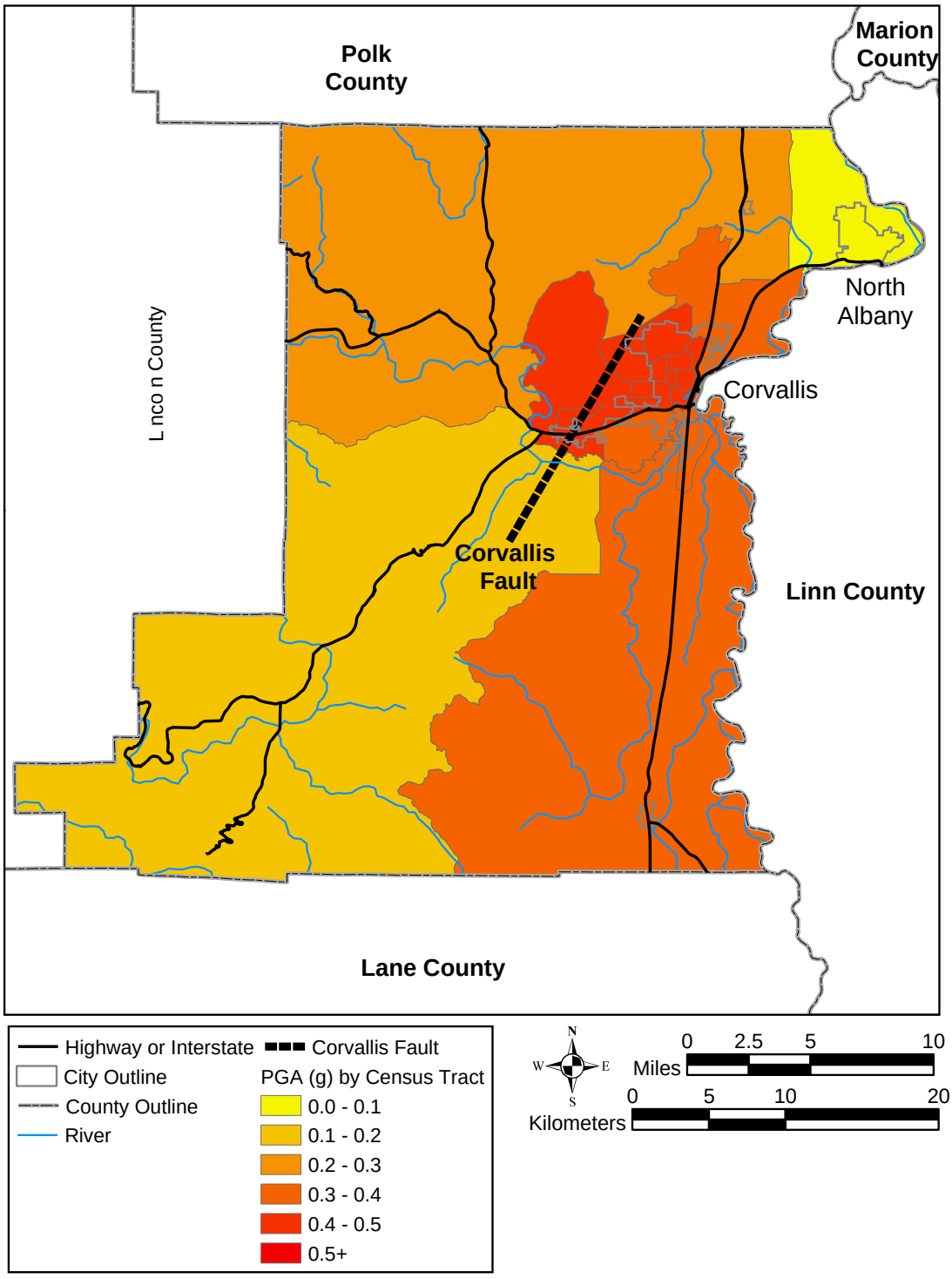

Figure A2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, Benton County, Oregon (FEMA, 2003b).

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR BENTON COUNTY

Subduction Zone Scenario: A magnitude 9.0 earthquake on the Cascadia Subduction Zone was selected for the subduction zone earthquake scenario.

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by the Cascadia Region Earthquake Workgroup (CREW, 2003) to model damage and loss from a magnitude 9.0 earthquake (Figure A3). The CREW maps were developed from ground motion data provided by the U.S. Geological Survey. The CREW earthquake scenario required the input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 s and 1.0 s (CREW, 2003). Figure A4 displays the PGA for the subduction zone scenario.

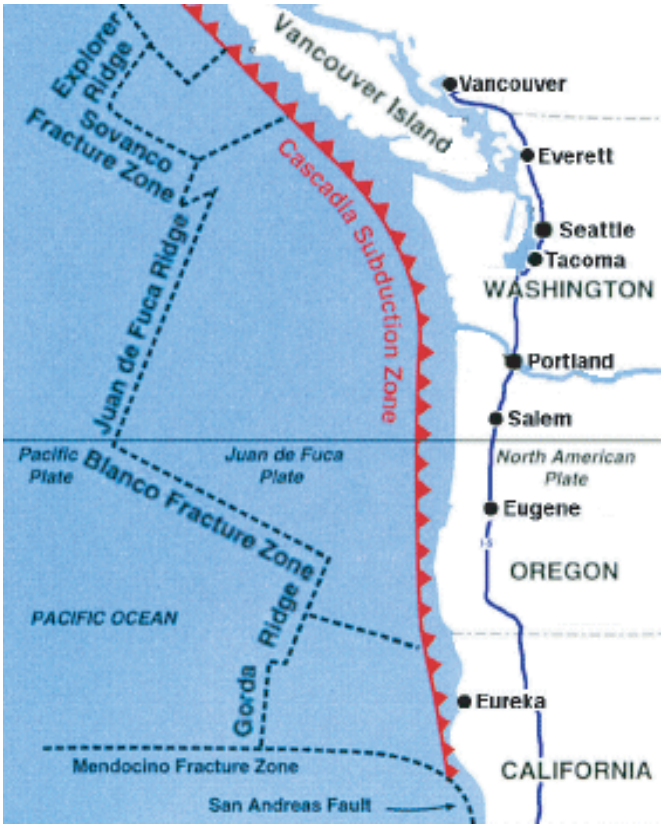

Figure A3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

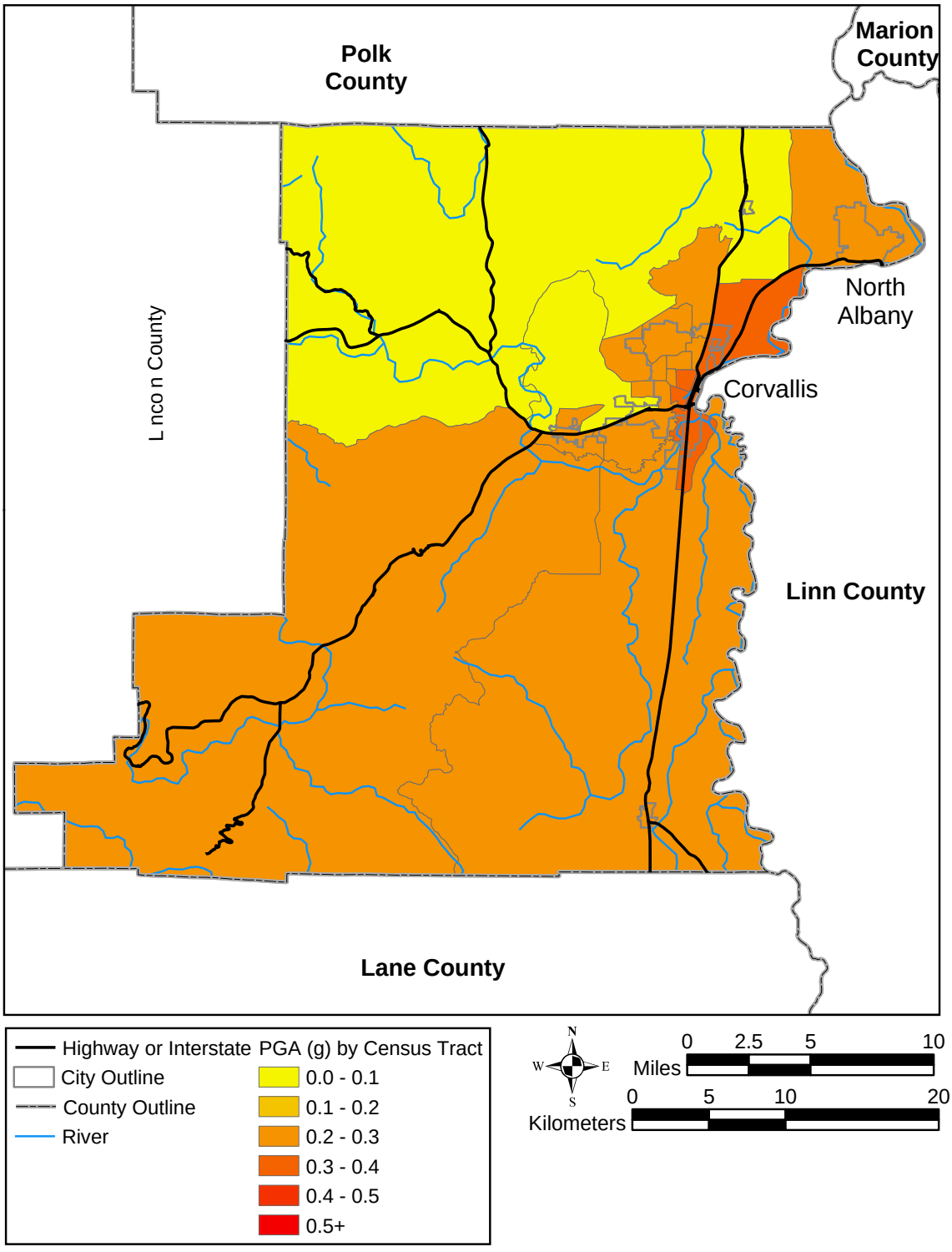

Figure A4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, Benton County, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS FOR BENTON COUNTY

Relative Ground-Shaking Amplification Susceptibility Map

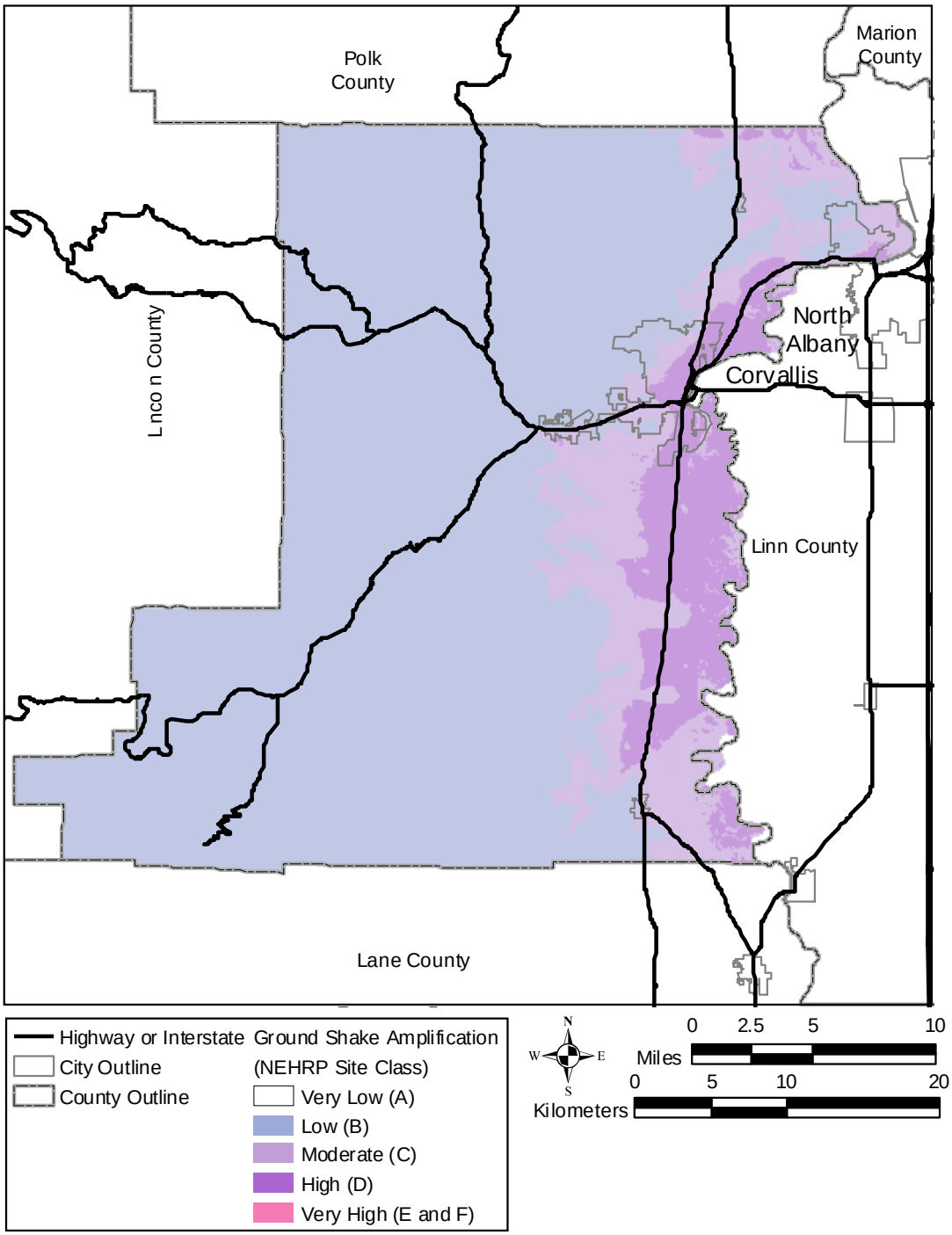

Figure A5. Relative ground-shaking amplification susceptibility map for Benton County, Oregon. Data were modified after Wang and others (2001).

Relative Liquefaction Hazard Susceptibility Map

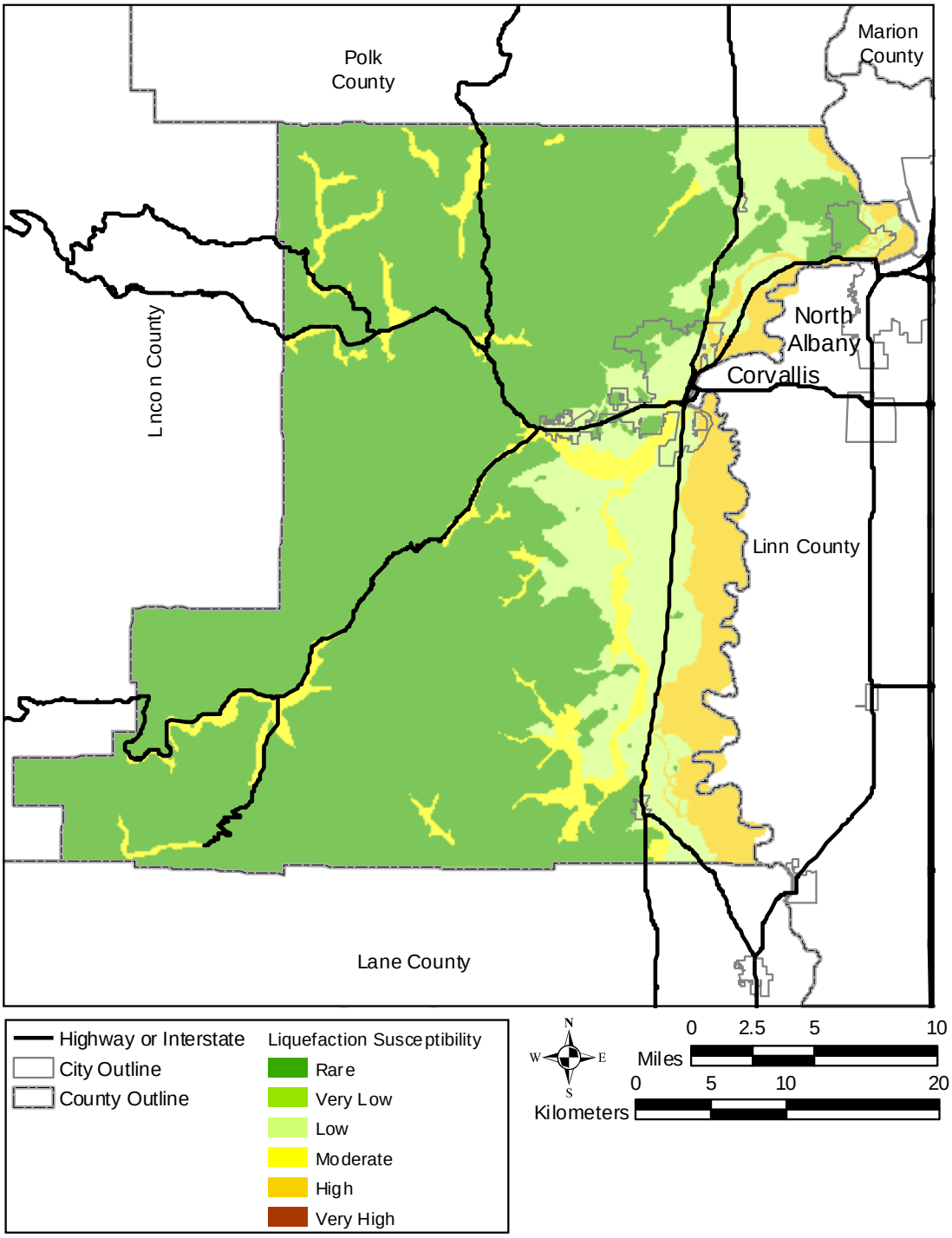

Figure A6. Relative liquefaction susceptibility map for Benton County, Oregon. Data were modified after Wang and others (2001).

Relative Earthquake-induced Landslide Susceptibility Map

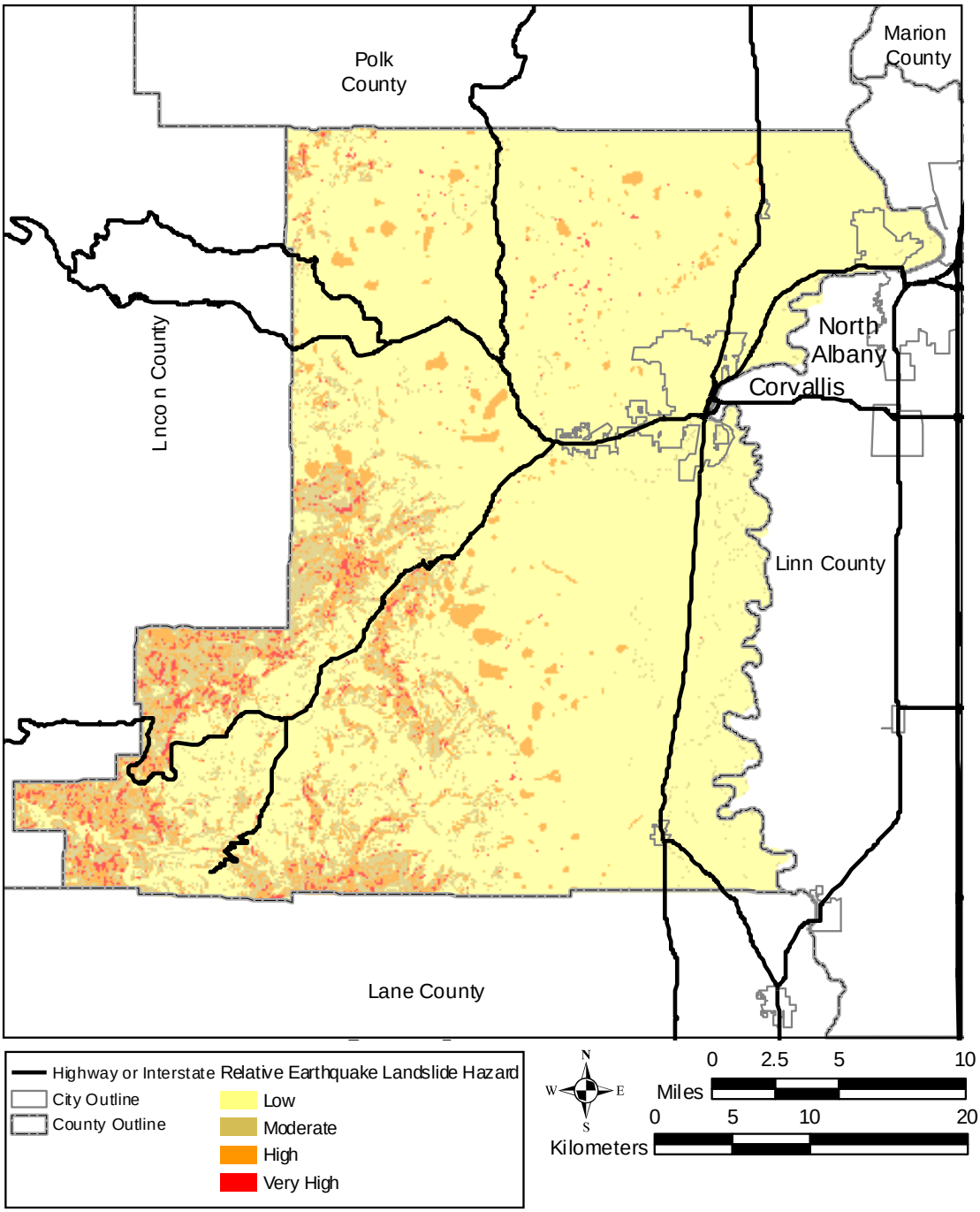

Figure A7. Relative earthquake-induced landslide susceptibility map for Benton County, Oregon. Data were modified after Wang and others (2001).

Identified Landslide Areas Map

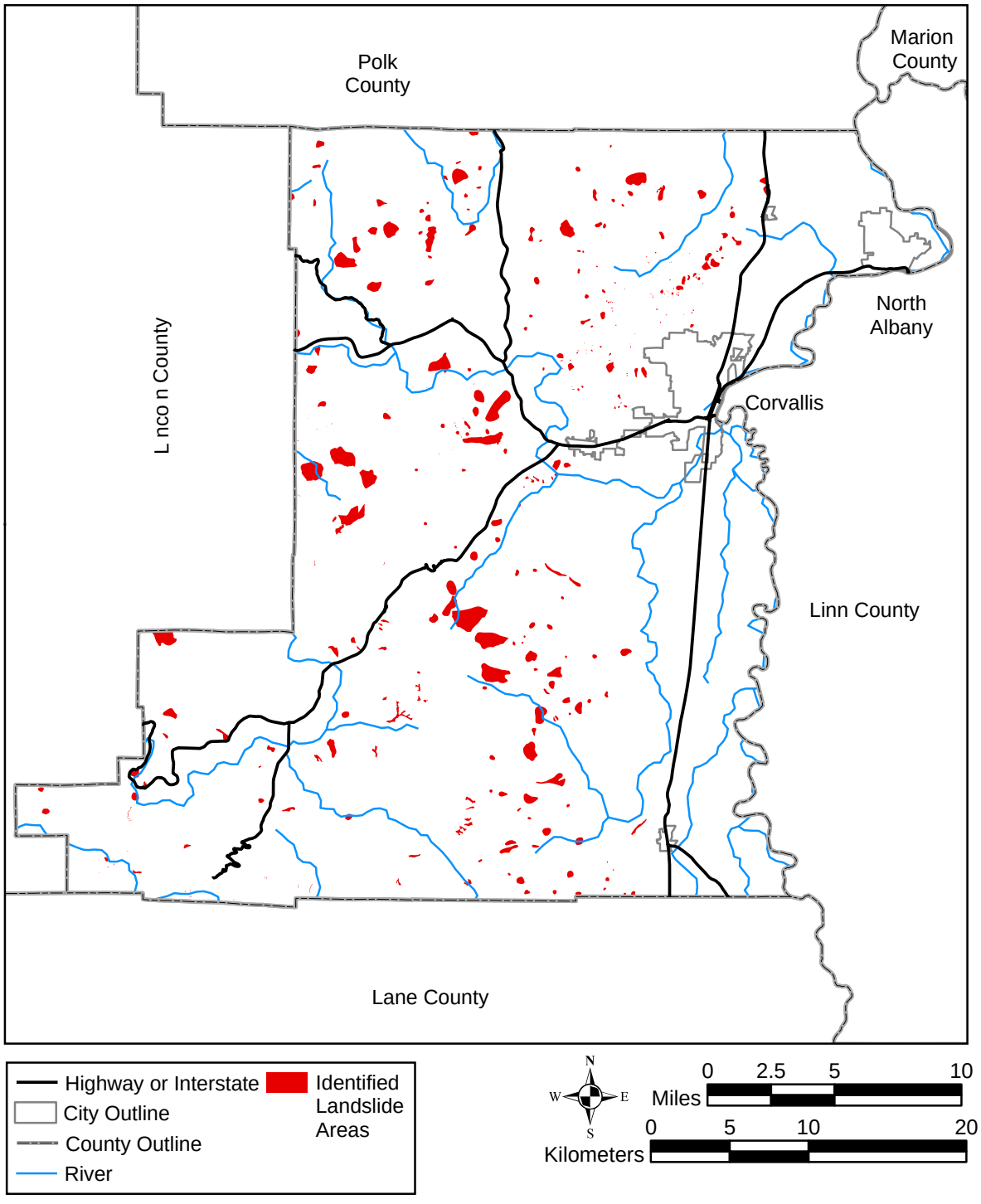

Figure A8. Identified landslide areas map for Benton County, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Benton_Crustal_OFR_3***

Earthquake Scenario: ***Arbitrary - Corvallis Fault M6.5***

Print Date: ***August 24, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 677.35 square miles and contains 19 census tracts. There are over 30 thousand households in the region and has a total population of 78,153 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 24 thousand buildings in the region with a total building replacement value (excluding contents) of 4,850 (millions of dollars). Approximately 99.00 % of the buildings (and 89.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,526 and 689 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 24 thousand buildings in the region which have an aggregate total replacement value of 4,850 (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 88% 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 1 hospitals in the region with a total bed capacity of 134 beds. There are 44 schools, 4 fire stations, 4 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 9 dams identified within the region. Of these, 1 of the dams are classified as 'high hazard'. The inventory also includes 10 hazardous material sites, 0 military installations and 0 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 2,215.00 (millions of dollars). This inventory includes over 168 kilometers of highways, 22 bridges, 6,578 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	22	438.00
	Segments	35	569.00
	Tunnels	0	0.00
		Subtotal	**1,007.00**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	40	106.30
	Tunnels	0	0.00
		Subtotal	**108.80**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	3	3.70
		Subtotal	**3.70**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	9	55.40
	Runways	10	351.20
		Subtotal	**406.60**
		Total	**1,526.10**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.80
	Facilities	3	112.90
	Pipelines	0	0.00
		Subtotal	**178.70**
Waste Water	Distribution Lines	NA	39.50
	Facilities	6	451.50
	Pipelines	0	0.00
		Subtotal	**491.00**
Natural Gas	Distribution Lines	NA	26.30
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**26.30**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	10	1.10
		Subtotal	**1.10**
		Total	**821.40**

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	Arbitrary - Corvallis Fault M6.5
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-123.36
Latitude of Epicenter	44.54
Earthquake Magnitude	6.50
Depth (Km)	10.00
Rupture Length (Km)	17.18
Rupture Orientation (degrees)	30.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 7,759 thousand buildings will be at least moderately damaged. This is over 31.00 % of the total number of buildings in the region. There are an estimated 416 buildings that will be completely destroyed. 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	1	0.01	0	0.01	0	0.01	0	0.02	0	0.03
Commercial	23	0.24	26	0.35	53	0.95	46	2.64	29	7.05
Education	1	0.01	1	0.01	2	0.04	2	0.11	1	0.23
Government	2	0.02	2	0.02	3	0.06	2	0.14	1	0.29
Industrial	1	0.01	1	0.01	2	0.04	2	0.11	1	0.23
Other Residential	693	7.26	762	9.99	1,062	18.92	652	37.68	235	56.42
Religion	1	0.02	1	0.01	1	0.02	1	0.04	0	0.08
Single Family	8,834	92.44	6,833	89.59	4,488	79.96	1,025	59.26	149	35.67
Total	**9,557**		**7,627**		**5,613**		**1,730**		**417**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	21	0.01	1	0.01	3	0.05	3	0.17	2	0.43
MH*	422	4.41	401	5.26	707	12.60	493	28.49	168	40.22
Precast	4	0.03	2	0.02	5	0.09	6	0.34	3	0.77
RM*	3	0.03	2	0.02	5	0.09	6	0.33	2	0.56
Steel	13	0.02	1	0.02	6	0.11	10	0.56	8	1.91
UM*	65	0.68	70	0.91	111	1.97	89	5.13	70	16.79
Wood	9,029	94.42	7111	93.24	4,691	83.57	1,050	60.70	127	30.60
Total	**9,557**		**7,627**		**5,613**		**1,730**		**417**	

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

Essential Facility Damage

Before the earthquake, the region had 134 hospital beds available for use. On the day of the earthquake, the model estimates that only 63 hospital beds (47.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 81.00% of the beds will be back in service. By 30 days, 99.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	0	0	1
Schools	44	4	0	40
EOCs	0	0	0	0
PoliceStations	4	1	0	3
FireStations	4	1	0	3

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	35	0	0	35	35
	Bridges	22	1	0	22	22
	Tunnels	0	0	0	0	0
Railways	Segments	40	0	0	40	40
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	1	0	1	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	3	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	9	0	0	9	9
	Runways	10	0	0	10	10

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	3	2	0	1	3
Waste Water	6	4	0	1	6
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	1	0	0	1
Communication	10	9	0	10	10

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,289	107	27
Waste Water	1,974	85	21
Natural Gas	1,316	91	23
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	30,145	0	0	0	0	0
Electric Power		10,550	5,835	2,019	333	16

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 3 ignitions that will burn about 0.09 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 169 people and burn about 10 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 41.00% 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 0 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 (1,755 households to be displaced due to the earthquake. Of these, 501 people (out of a total population of 78,153 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	5	1	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	4	1	0	0
	Industrial	10	3	0	1
	Other-Residential	198	50	7	13
	Single Family	90	13	1	1
	Total	**307**	**68**	**8**	**16**
2 PM	Commercial	275	78	12	24
	Commuting	0	0	0	0
	Educational	86	24	4	7
	Hotels	1	0	0	0
	Industrial	73	20	3	6
	Other-Residential	7	1	0	0
	Single Family	10	2	0	0
	Total	**452**	**125**	**19**	**38**
5 PM	Commercial	230	65	10	20
	Commuting	2	2	3	1
	Educational	33	9	1	3
	Hotels	1	0	0	0
	Industrial	45	12	2	4
	Other-Residential	77	20	3	5
	Single Family	35	5	0	1
	Total	**423**	**114**	**20**	**33**

Economic Loss

The total economic loss estimated for the earthquake is 952.37 (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 762.25 (millions of dollars); 12 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 72 % 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	1.66	21.90	0.43	1.35	25.34
	Capital-Related	0.00	0.71	20.89	0.25	0.46	22.32
	Rental	8.37	20.89	9.41	0.12	0.74	39.53
	Relocation	1.00	0.53	0.54	0.01	0.22	2.30
	Subtotal	**9.37**	**23.79**	**52.75**	**0.81**	**2.77**	**89.49**
Capital Stock Loses							
	Structural	42.67	33.86	22.78	1.97	4.21	105.50
	Non_Structural	193.66	154.65	62.57	6.27	14.34	431.50
	Content	58.74	34.20	29.11	4.04	7.51	133.59
	Inventory	0.00	0.00	1.03	1.03	0.11	2.16
	Subtotal	**295.08**	**222.71**	**115.49**	**13.31**	**26.17**	**672.76**
	Total	**304.45**	**246.50**	**168.24**	**14.12**	**28.94**	**762.25**

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	568.98	$4.07	0.72
	Bridges	438.01	$14.61	3.34
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1007.00**	**18.70**	
Railways	Segments	106.31	$0.08	0.08
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.87	35.38
	Subtotal	**108.80**	**1.00**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.70	$1.35	36.56
	Subtotal	**3.70**	**1.40**	
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	55.43	$15.77	28.44
	Runways	351.20	$3.50	1.00
	Subtotal	**406.60**	**19.30**	
	Total	**1526.10**	**40.30**	

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	112.90	$26.16	23.17
	Distribution Line	65.80	$0.97	1.47
	Subtotal	**178.67**	**$27.12**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	451.50	$89.90	19.91
	Distribution Line	39.50	$0.76	1.94
	Subtotal	**491.02**	**$90.67**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	26.30	$0.82	3.10
	Subtotal	**26.31**	**$0.82**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$31.02	24.95
	Subtotal	**124.30**	**$31.02**	
Communication	Facilities	1.10	$0.24	21.38
	Subtotal	**1.13**	**$0.24**	
	Total	**821.44**	**$149.86**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(23)	-2.91
Second Year			
	Employment Impact	0	0.00
	Income Impact	(37)	-4.57
Third Year			
	Employment Impact	0	0.00
	Income Impact	(42)	-5.28
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(42)	-5.28
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(42)	-5.28
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(42)	-5.28

Appendix A: County Listing for the Region

Benton,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Benton	78,153	4,305	544	4,850
Total State		**78,153**	**4,305**	**544**	**4,850**
Total Region		**78,153**	**4,305**	**544**	**4,850**

HAZUS-MH: Earthquake Event Report

Region Name: ***Benton_Cascadia_OFR_3***

Earthquake Scenario: ***Cascadia M9.0***

Print Date: ***August 24, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 677.35 square miles and contains 19 census tracts. There are over 30 thousand households in the region and has a total population of 78,153 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 24 thousand buildings in the region with a total building replacement value (excluding contents) of 4,850 (millions of dollars). Approximately 99.00 % of the buildings (and 89.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,526 and 689 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 24 thousand buildings in the region which have an aggregate total replacement value of 4,850 (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 88% 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 1 hospitals in the region with a total bed capacity of 134 beds. There are 44 schools, 4 fire stations, 4 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 9 dams identified within the region. Of these, 1 of the dams are classified as 'high hazard'. The inventory also includes 10 hazardous material sites, 0 military installations and 0 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 2,215.00 (millions of dollars). This inventory includes over 168 kilometers of highways, 22 bridges, 6,578 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	22	438.00
	Segments	35	569.00
	Tunnels	0	0.00
		Subtotal	**1,007.00**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	40	106.30
	Tunnels	0	0.00
		Subtotal	**108.80**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	3	3.70
		Subtotal	**3.70**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	9	55.40
	Runways	10	351.20
		Subtotal	**406.60**
		Total	**1,526.10**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.80
	Facilities	3	112.90
	Pipelines	0	0.00
		Subtotal	**178.70**
Waste Water	Distribution Lines	NA	39.50
	Facilities	6	451.50
	Pipelines	0	0.00
		Subtotal	**491.00**
Natural Gas	Distribution Lines	NA	26.30
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**26.30**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	10	1.10
		Subtotal	**1.10**
		Total	**821.40**

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	Cascadia M9.0
Type of Earthquake	User-defined
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 7,897 thousand buildings will be at least moderately damaged. This is over 32.00 % of the total number of buildings in the region. There are an estimated 1,159 buildings that will be completely destroyed. 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	1	0.01	0	0.01	0	0.01	0	0.02	0	0.03
Commercial	17	0.17	10	0.14	31	0.64	46	2.52	74	6.39
Education	0	0.00	1	0.01	1	0.03	2	0.11	3	0.22
Government	1	0.01	1	0.01	2	0.04	3	0.15	4	0.37
Industrial	2	0.02	0	0.00	1	0.01	1	0.07	3	0.27
Other Residential	527	5.35	465	6.45	737	14.97	802	44.15	874	75.41
Religion	1	0.01	1	0.01	1	0.02	1	0.06	1	0.10
Single Family	9,292	94.42	6,728	93.38	4,149	84.29	961	52.91	200	17.22
Total	**9,841**		**7,205**		**4,922**		**1,816**		**1,159**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	12	0.00	0	0.00	1	0.02	3	0.15	5	0.44
MH*	180	1.83	166	2.30	467	9.48	662	36.46	716	61.77
Precast	4	0.02	1	0.01	2	0.05	5	0.25	9	0.74
RM*	2	0.02	1	0.01	3	0.05	5	0.27	8	0.67
Steel	10	0.02	0	0.00	2	0.03	4	0.23	19	1.62
UM*	42	0.43	37	0.52	81	1.65	94	5.18	149	12.87
Wood	9,591	97.44	6989	97.00	4,323	87.83	970	53.39	133	11.47
Total	**9,841**		**7,205**		**4,922**		**1,816**		**1,159**	

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

Essential Facility Damage

Before the earthquake, the region had 134 hospital beds available for use. On the day of the earthquake, the model estimates that only 134 hospital beds (100.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 100.00% of the beds will be back in service. By 30 days, 100.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	0	0	1
Schools	44	4	0	40
EOCs	0	0	0	0
PoliceStations	4	0	0	4
FireStations	4	0	0	4

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	35	0	0	35	35
	Bridges	22	3	0	20	21
	Tunnels	0	0	0	0	0
Railways	Segments	40	0	0	40	40
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	0	0	1	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	0	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	9	0	0	9	9
	Runways	10	0	0	10	10

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	3	0	0	3	3
Waste Water	6	0	0	6	6
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	0	0	1	1
Communication	10	0	0	10	10

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,289	335	84
Waste Water	1,974	265	66
Natural Gas	1,316	283	71
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	30,145	644	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 2 ignitions that will burn about 0.05 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 41 people and burn about 2 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 34.00% 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 0 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 (2,375 households to be displaced due to the earthquake. Of these, 669 people (out of a total population of 78,153 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	12	4	1	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	8	2	0	1
	Industrial	32	10	2	3
	Other-Residential	411	118	17	32
	Single Family	97	17	1	3
	Total	**560**	**151**	**21**	**40**
2 PM	Commercial	647	202	34	67
	Commuting	0	0	0	0
	Educational	232	73	12	24
	Hotels	2	0	0	0
	Industrial	235	74	12	24
	Other-Residential	18	4	0	1
	Single Family	12	2	0	0
	Total	**1,146**	**357**	**59**	**116**
5 PM	Commercial	570	178	30	58
	Commuting	3	4	7	1
	Educational	76	24	4	8
	Hotels	2	1	0	0
	Industrial	147	46	8	15
	Other-Residential	158	46	7	12
	Single Family	38	7	1	1
	Total	**995**	**305**	**56**	**96**

Economic Loss

The total economic loss estimated for the earthquake is 1,091.14 (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 1,049.51 (millions of dollars); 13 % 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 61 % 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	2.27	38.51	0.78	2.51	44.08
	Capital-Related	0.00	0.97	35.69	0.46	0.87	37.99
	Rental	8.15	28.95	15.35	0.21	1.37	54.04
	Relocation	0.97	0.67	0.89	0.01	0.40	2.95
	Subtotal	**9.12**	**32.86**	**90.45**	**1.47**	**5.15**	**139.06**
Capital Stock Loses							
	Structural	42.30	53.77	42.77	4.06	8.64	151.54
	Non_Structural	174.64	234.55	128.13	15.53	30.68	583.53
	Content	43.25	47.20	56.35	9.55	14.32	170.65
	Inventory	0.00	0.00	2.12	2.39	0.22	4.73
	Subtotal	**260.18**	**335.52**	**229.36**	**31.53**	**53.86**	**910.45**
	Total	**269.31**	**368.38**	**319.82**	**32.99**	**59.01**	**1,049.51**

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	568.98	$9.01	1.58
	Bridges	438.01	$24.47	5.59
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1007.00**	**33.50**	
Railways	Segments	106.31	$0.20	0.19
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.00	0.00
	Subtotal	**108.80**	**0.20**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.70	$0.00	0.00
	Subtotal	**3.70**	**0.00**	
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	55.43	$0.00	0.00
	Runways	351.20	$0.00	0.00
	Subtotal	**406.60**	**0.00**	
	Total	**1526.10**	**33.70**	

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	112.90	$0.00	0.00
	Distribution Line	65.80	$3.01	4.58
	Subtotal	**178.67**	**$3.01**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	451.50	$0.00	0.00
	Distribution Line	39.50	$2.38	6.04
	Subtotal	**491.02**	**$2.38**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	26.30	$2.55	9.68
	Subtotal	**26.31**	**$2.55**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$0.00	0.00
	Subtotal	**124.30**	**$0.00**	
Communication	Facilities	1.10	$0.00	0.00
	Subtotal	**1.13**	**$0.00**	
	Total	**821.44**	**$7.94**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(26)	-3.21
Second Year			
	Employment Impact	0	0.00
	Income Impact	(44)	-5.47
Third Year			
	Employment Impact	0	0.00
	Income Impact	(52)	-6.43
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(52)	-6.43
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(52)	-6.43
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(52)	-6.43

Appendix A: County Listing for the Region

Benton,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Benton	78,153	4,305	544	4,850
Total State		**78,153**	**4,305**	**544**	**4,850**
Total Region		**78,153**	**4,305**	**544**	**4,850**

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

APPENDIX B: CITY OF ALBANY

CRUSTAL EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

SUBDUCTION ZONE EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

GEOLOGIC HAZARD MAPS
- Relative Ground-Shaking Amplification Susceptibility Map
- Relative Liquefaction Hazard Susceptibility Map
- Relative Earthquake-induced Landslide Susceptibility Map
- Identified Landslide Areas Map

HAZUS-MH GLOBAL REPORT FOR CRUSTAL SCENARIO

HAZUS-MH GLOBAL REPORT FOR SUBDUCTION ZONE SCENARIO

CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR CITY OF ALBANY

Crustal Earthquake Scenario: A magnitude 6.7 earthquake on the Mill Creek Fault.

For the magnitude 6.7 Mill Creek Fault earthquake scenario, we defined the fault source using the "deterministic seismic source" option within HAZUS-MH (Figure B1) (FEMA, 2003b). The fault and earthquake event were chosen by examination of USGS (2004a) data and data in the Geomatrix Consultants, Inc. (1995) *Seismic Design Mapping, State of Oregon* report prepared for the Oregon Department of Transportation. In general, a likely worst-case scenario was incorporated. Figure B1 has the location of the fault, shown as the dark line, and the census tracts that contain the City of Albany. Figure B2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Mill Creek M6.7
Type of Earthquake	Source
Fault Name	Mill Creek Fault
Historical Epicenter ID #	70
Probabilistic Return Period	NA
Longitude of Epicenter	–123.015
Latitude of Epicenter	44.7428
Earthquake Magnitude	6.7
Depth (km)	0.00
Rupture Length (km)	27.11
Rupture Orientation (degrees)	0.00
Attenuation Function	Reverse-Slip

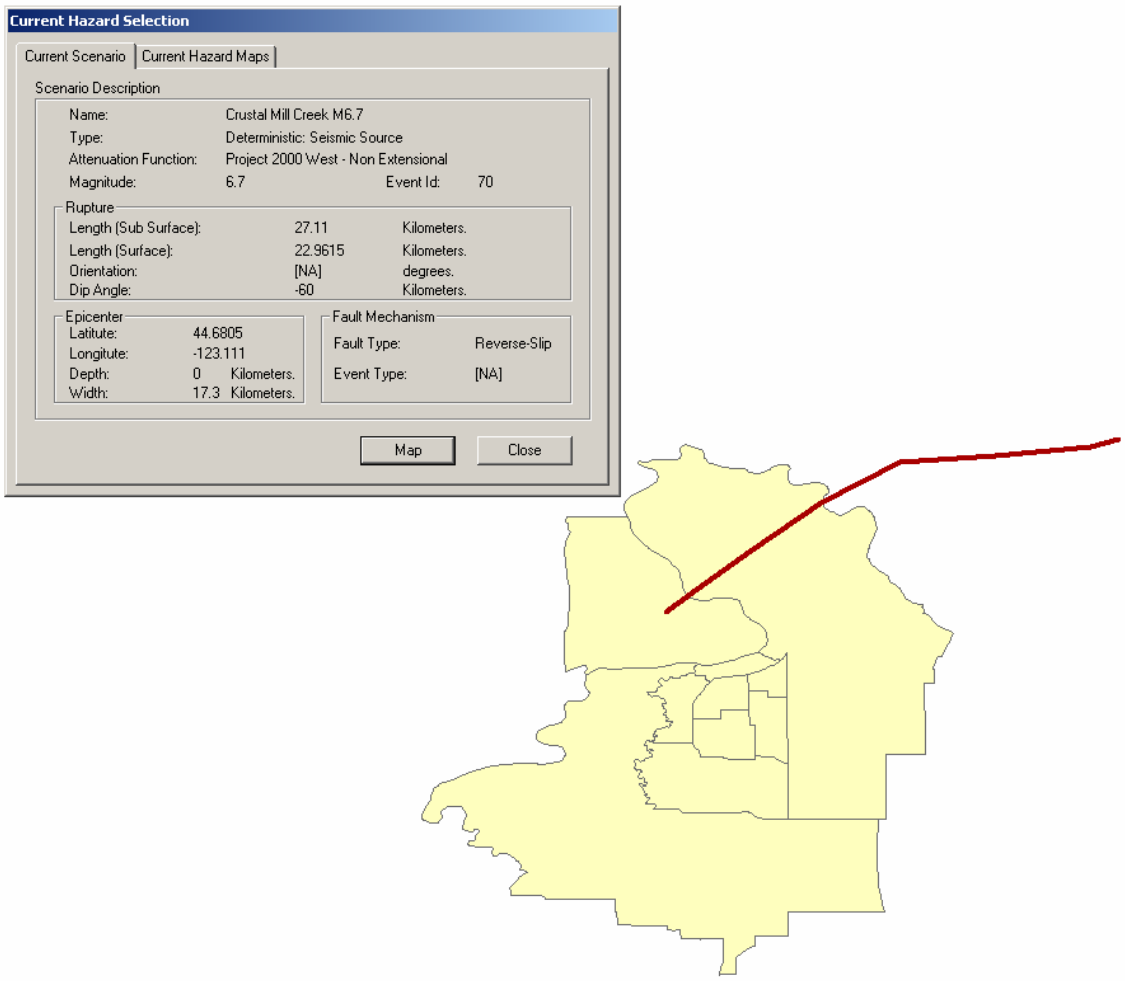

Figure B1. Mill Creek Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dark line.

Crustal Earthquake Scenario Ground Motion Map

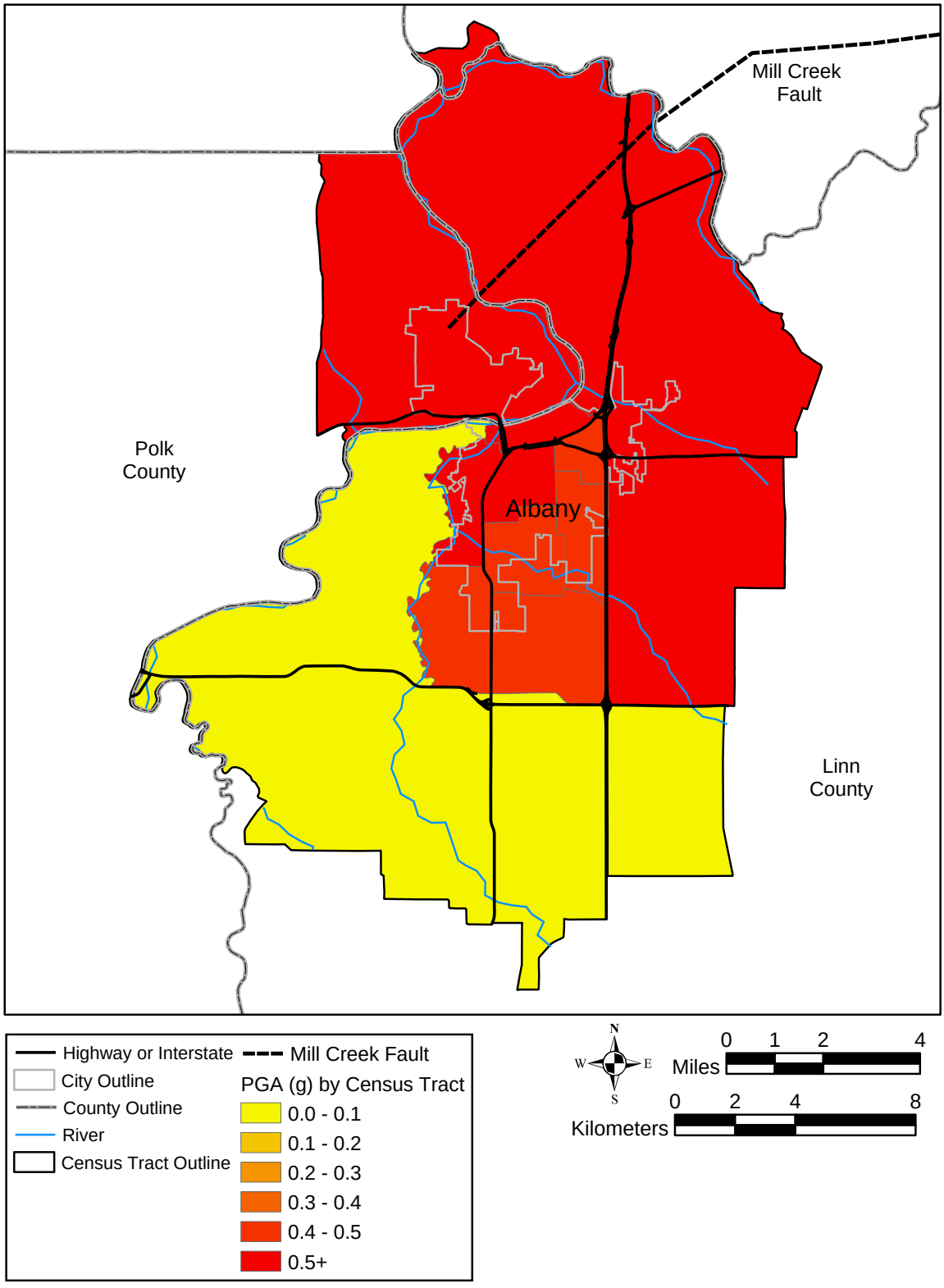

Figure B2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, City of Albany, Oregon (FEMA, 2003b).

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR CITY OF ALBANY

Subduction Zone Scenario: A magnitude 9.0 earthquake on the Cascadia Subduction Zone was selected for the subduction zone earthquake scenario.

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by the Cascadia Region Earthquake Workgroup (CREW, 2003) to model damage and loss from a magnitude 9.0 earthquake (Figure B3). The CREW maps were developed from ground motion data provided by the U.S. Geological Survey. The CREW earthquake scenario required the input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 s and 1.0 s (CREW, 2003). Figure B4 displays the PGA for the subduction zone scenario.

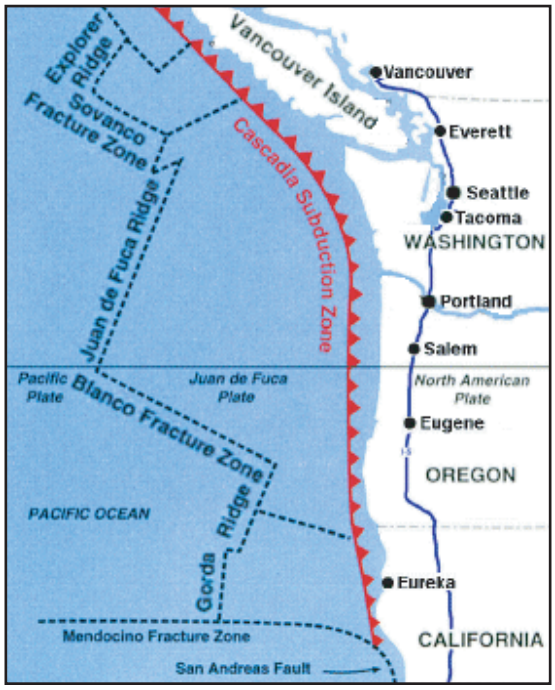

Figure B3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

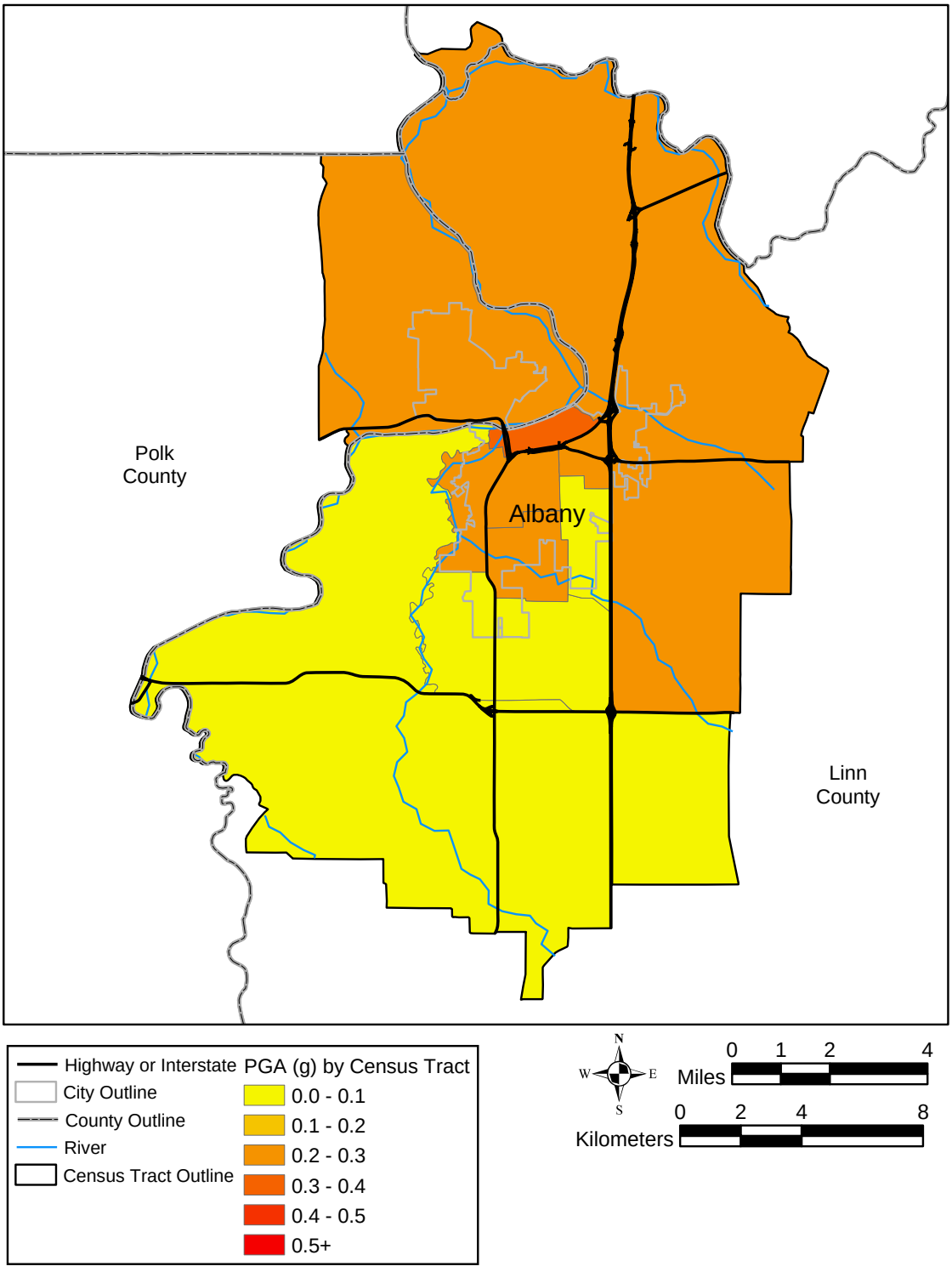

Figure B4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, City of Albany, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS

Relative Ground-Shaking Amplification Susceptibility Map

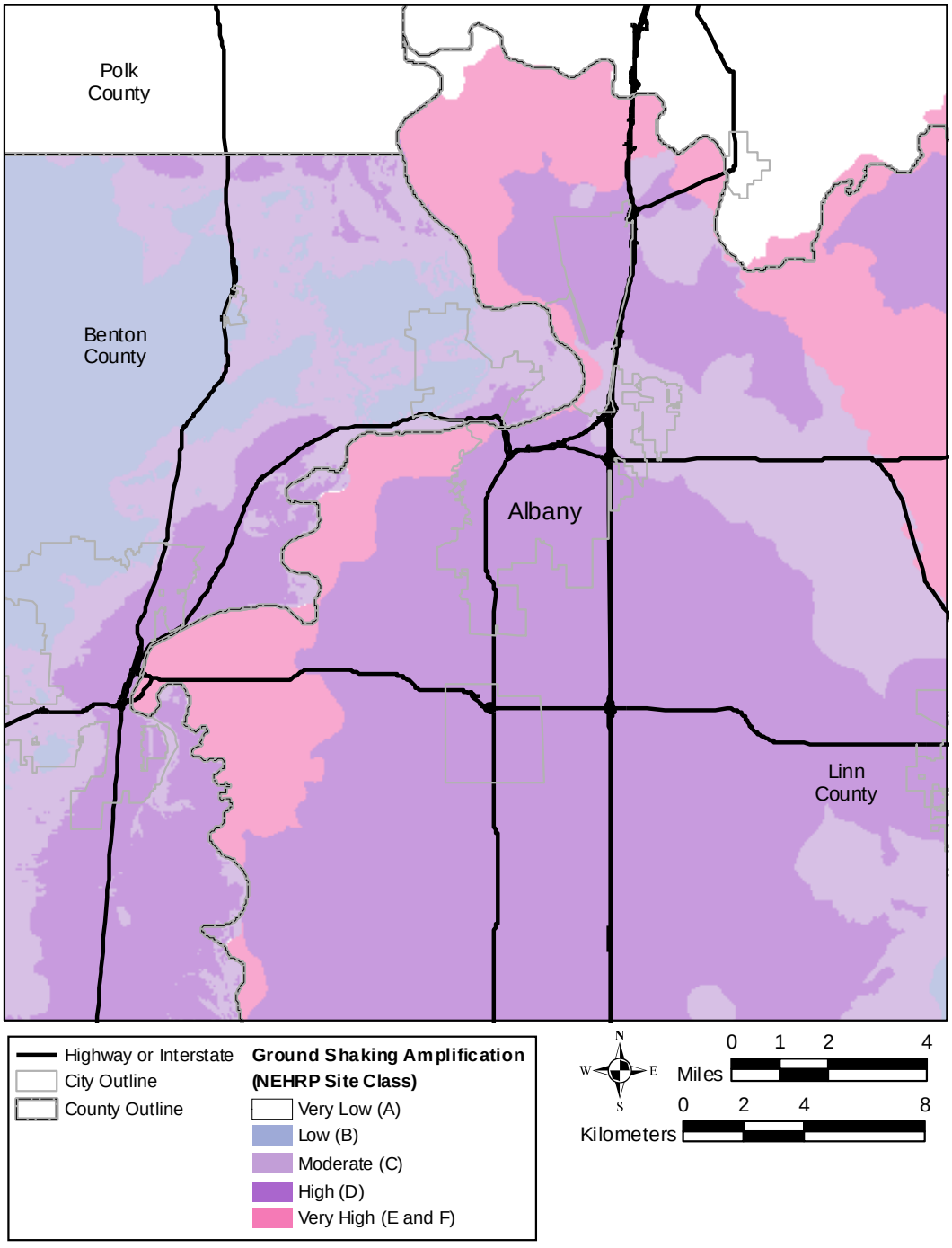

Figure B5. Relative ground-shaking amplification susceptibility map for City of Albany, Oregon. Benton County data were modified after Wang and others, 2001.

Relative Liquefaction Hazard Susceptibility Map

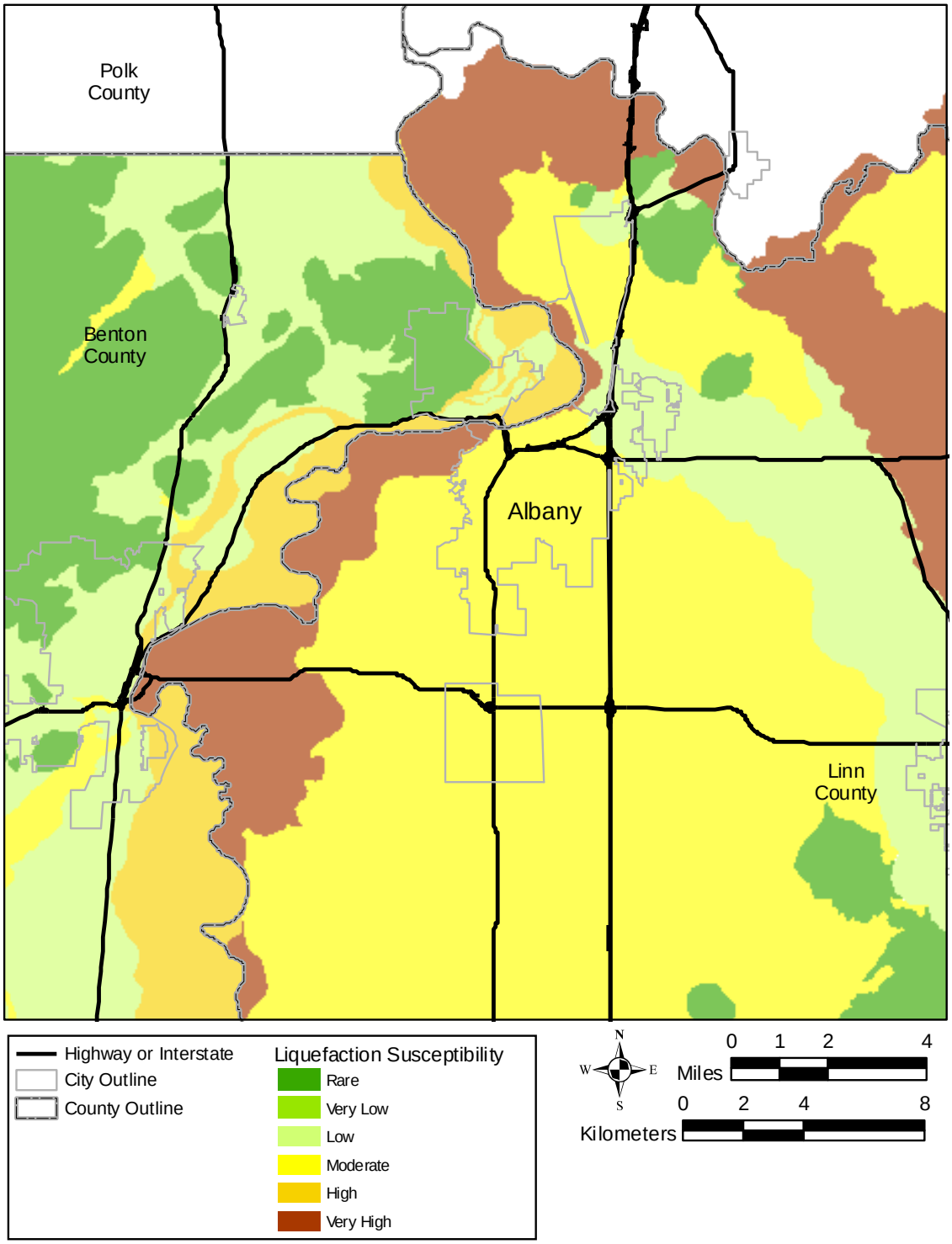

Figure B6. Relative liquefaction susceptibility map for City of Albany, Oregon. Benton County data were modified after Wang and others, 2001.

Relative Earthquake-induced Landslide Susceptibility Map

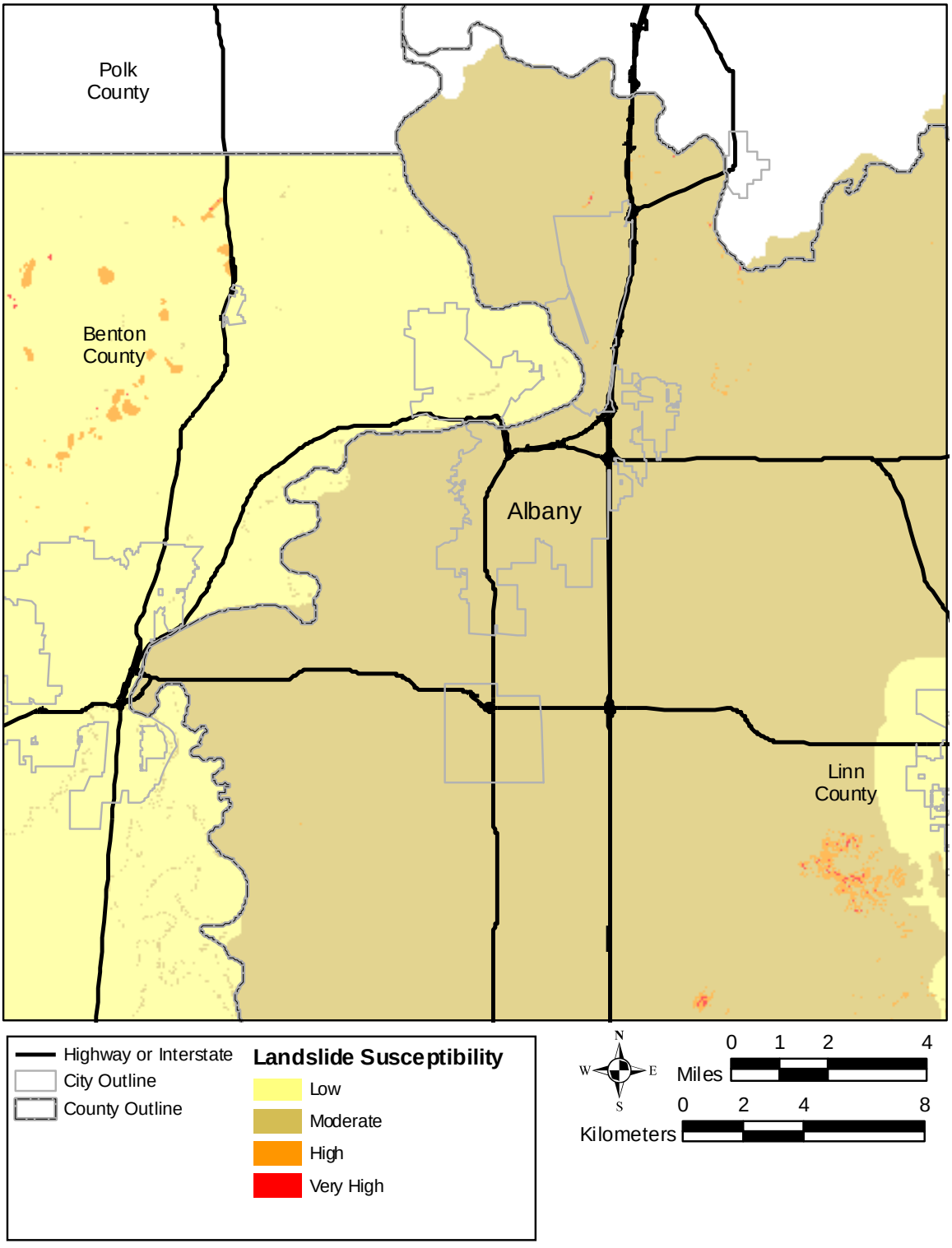

Figure B7. Relative earthquake-induced landslide susceptibility map for the City of Albany, Oregon. Benton County data were modified after Wang and others, 2001.

Identified Landslide Areas Map

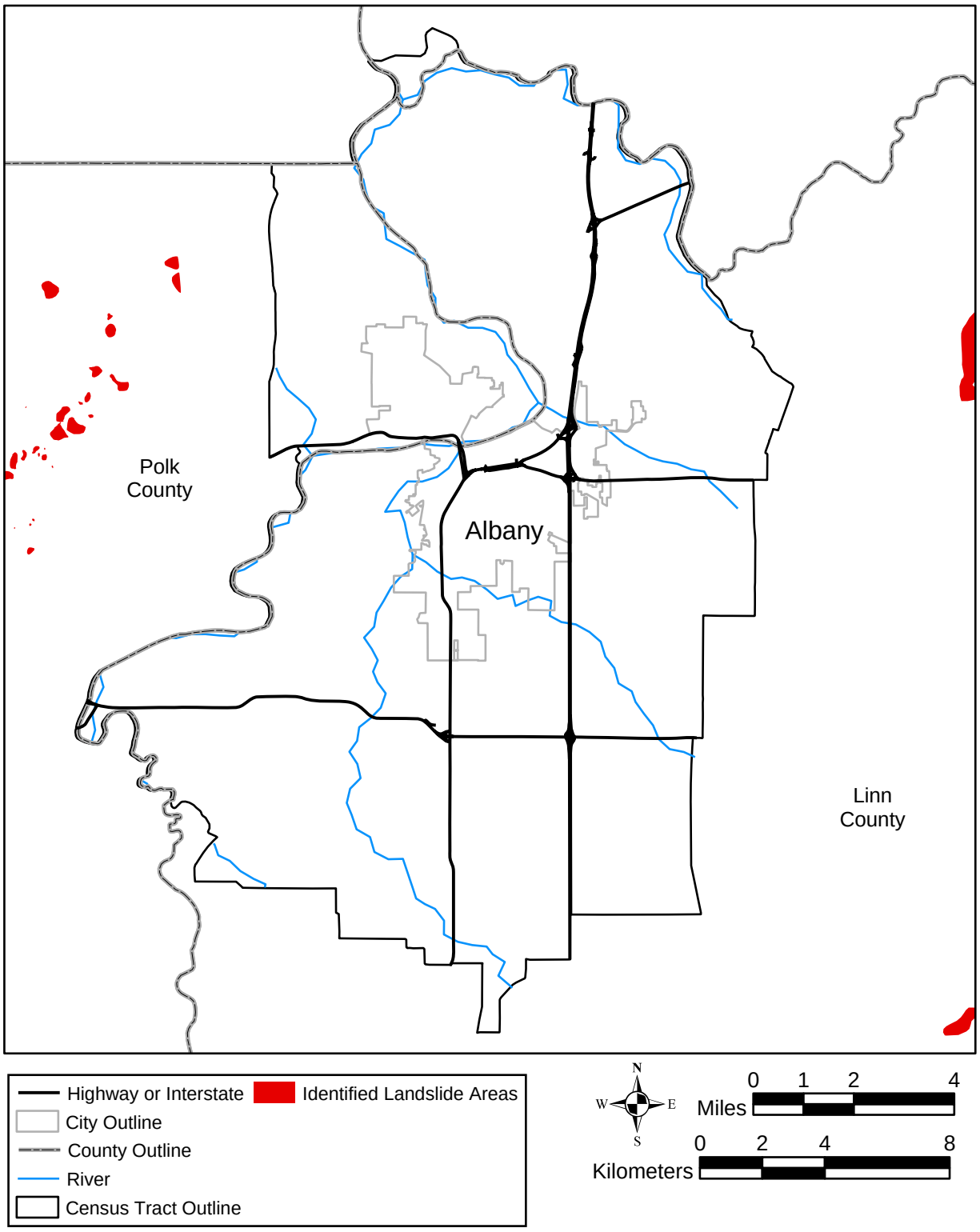

Figure B8. Identified landslide map for the City of Albany, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Albany Census Crustal***

Earthquake Scenario: ***Crustal Mill Creek M6.7***

Print Date: ***March 29, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 2 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 158.25 square miles and contains 10 census tracts. There are over 20 thousand households in the region and has a total population of 50,972 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 17 thousand buildings in the region with a total building replacement value (excluding contents) of 3,155 (millions of dollars). Approximately 99.00 % of the buildings (and 82.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,948 and 350 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 17 thousand buildings in the region which have an aggregate total replacement value of 3,155 (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 85% 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 1 hospitals in the region with a total bed capacity of 71 beds. There are 26 schools, 2 fire stations, 3 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 0 dams identified within the region. Of these, 0 of the dams are classified as 'high hazard'. The inventory also includes 40 hazardous material sites, 0 military installations and 0 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 2,298.00 (millions of dollars). This inventory includes over 131 kilometers of highways, 52 bridges, 1,880 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	52	960.60
	Segments	26	548.80
	Tunnels	0	0.00
		Subtotal	**1,509.30**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	59	98.90
	Tunnels	0	0.00
		Subtotal	**101.30**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	1	1.20
		Subtotal	**1.20**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	9	55.40
	Runways	8	281.00
		Subtotal	**336.40**
		Total	**1,948.30**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	18.80
	Facilities	2	75.30
	Pipelines	0	0.00
		Subtotal	**94.10**
Waste Water	Distribution Lines	NA	11.30
	Facilities	2	150.50
	Pipelines	0	0.00
		Subtotal	**161.80**
Natural Gas	Distribution Lines	NA	7.50
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**7.50**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	2	0.20
		Subtotal	**0.20**
		Total	**387.90**

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	Crustal Mill Creek M6.7
Type of Earthquake	Source
Fault Name	Mill Creek Fault
Historical Epicenter ID #	70
Probabilistic Return Period	NA
Longitude of Epicenter	-123.11
Latitude of Epicenter	44.68
Earthquake Magnitude	6.70
Depth (Km)	0.00
Rupture Length (Km)	22.96
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 11,742 thousand buildings will be at least moderately damaged. This is over 67.00 % of the total number of buildings in the region. There are an estimated 2,525 buildings that will be completely destroyed. 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	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	3	0.25	12	0.27	36	0.58	46	1.47	62	2.44
Education	1	0.04	1	0.02	2	0.04	3	0.09	3	0.12
Government	0	0.00	0	0.01	1	0.01	1	0.03	1	0.04
Industrial	0	0.03	2	0.04	6	0.10	8	0.27	10	0.41
Other Residential	87	6.47	346	7.83	773	12.62	873	28.20	809	32.02
Religion	0	0.01	0	0.01	1	0.02	1	0.03	1	0.06
Single Family	1,260	93.20	4,055	91.83	5,301	86.63	2,165	69.90	1,639	64.89
Total	**1,352**		**4,416**		**6,119**		**3,097**		**2,526**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	2	0.00	0	0.00	1	0.01	2	0.05	2	0.10
MH*	44	3.27	181	4.10	539	8.82	745	24.05	662	26.20
Precast	1	0.04	1	0.03	5	0.08	8	0.26	10	0.42
RM*	0	0.03	1	0.01	2	0.04	4	0.12	5	0.19
Steel	1	0.01	0	0.01	2	0.03	5	0.15	12	0.47
UM*	5	0.40	21	0.48	55	0.90	69	2.22	120	4.74
Wood	1,298	95.94	4199	95.08	5,472	89.43	2,207	71.24	1,642	65.01
Total	**1,352**		**4,416**		**6,119**		**3,097**		**2,526**	

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

Essential Facility Damage

Before the earthquake, the region had 71 hospital beds available for use. On the day of the earthquake, the model estimates that only 3 hospital beds (4.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 20.00% of the beds will be back in service. By 30 days, 62.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	1	0	0
Schools	26	23	0	3
EOCs	0	0	0	0
PoliceStations	3	3	0	0
FireStations	2	2	0	0

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	26	0	0	26	26
	Bridges	52	11	0	41	49
	Tunnels	0	0	0	0	0
Railways	Segments	59	0	0	59	59
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	1	0	0	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	1	0	0	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	9	7	0	5	8
	Runways	8	0	0	8	8

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	2	2	0	0	2
Waste Water	2	2	0	0	2
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	1	0	0	1
Communication	2	2	0	1	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	940	266	192
Waste Water	564	210	152
Natural Gas	376	225	162
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	20,002	13,645	10,780	0	0	0
Electric Power		14,034	9,312	4,465	1,125	18

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 7 ignitions that will burn about 0.07 sq. mi 0.04 % of the region's total area.) The model also estimates that the fires will displace about 109 people and burn about 6 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 42.00% 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 0 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 (3,569 households to be displaced due to the earthquake. Of these, 894 people (out of a total population of 50,972 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	8	2	0	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	3	1	0	0
	Industrial	12	4	1	1
	Other-Residential	253	66	7	14
	Single Family	350	78	5	8
	Total	**626**	**151**	**14**	**24**
2 PM	Commercial	508	158	26	52
	Commuting	0	1	1	0
	Educational	96	30	5	9
	Hotels	1	0	0	0
	Industrial	88	27	4	8
	Other-Residential	57	15	2	3
	Single Family	76	17	1	2
	Total	**827**	**248**	**40**	**75**
5 PM	Commercial	405	126	21	41
	Commuting	9	11	19	4
	Educational	12	4	1	1
	Hotels	1	0	0	0
	Industrial	55	17	3	5
	Other-Residential	97	26	3	5
	Single Family	140	31	2	3
	Total	**719**	**214**	**49**	**60**

Economic Loss

The total economic loss estimated for the earthquake is 1,626.16 (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 1,333.69 (millions of dollars); 10 % 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 68 % 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	2.99	28.98	1.29	2.64	35.90
	Capital-Related	0.00	1.27	25.87	1.02	1.03	29.18
	Rental	20.91	21.66	14.30	0.56	1.31	58.73
	Relocation	2.26	0.54	0.74	0.06	0.45	4.05
	Subtotal	**23.17**	**26.46**	**69.89**	**2.92**	**5.42**	**127.86**
Capital Stock Loses							
	Structural	111.72	31.05	40.93	9.95	6.81	200.46
	Non_Structural	422.05	153.14	117.28	39.18	31.18	762.84
	Content	105.12	32.48	54.98	25.85	16.62	235.05
	Inventory	0.00	0.00	2.51	4.83	0.14	7.48
	Subtotal	**638.90**	**216.68**	**215.71**	**79.80**	**54.75**	**1,205.83**
	Total	**662.06**	**243.13**	**285.60**	**82.72**	**60.18**	**1,333.69**

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	548.75	$11.68	2.13
	Bridges	960.57	$111.07	11.56
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1509.30**	**122.80**	
Railways	Segments	98.87	$1.55	1.57
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$1.21	48.95
	Subtotal	**101.30**	**2.80**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	1.23	$0.63	51.16
	Subtotal	**1.20**	**0.60**	
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	55.43	$24.22	43.69
	Runways	280.96	$1.66	0.59
	Subtotal	**336.40**	**25.90**	
	Total	**1948.30**	**152.00**	

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	75.30	$25.97	34.50
	Distribution Line	18.80	$4.90	26.06
	Subtotal	**94.06**	**$30.87**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	150.50	$46.73	31.05
	Distribution Line	11.30	$3.88	34.35
	Subtotal	**161.80**	**$50.61**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	7.50	$4.14	55.08
	Subtotal	**7.52**	**$4.14**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$54.75	44.05
	Subtotal	**124.30**	**$54.75**	
Communication	Facilities	0.20	$0.07	32.04
	Subtotal	**0.23**	**$0.07**	
	Total	**387.91**	**$140.44**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(37)	-8.05
Second Year			
	Employment Impact	0	0.00
	Income Impact	(61)	-13.21
Third Year			
	Employment Impact	0	0.00
	Income Impact	(72)	-15.39
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(72)	-15.39
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(72)	-15.39
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(72)	-15.39

Appendix A: County Listing for the Region

Benton, OR

Linn, OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon					
	Benton	6,984	445	8	454
	Linn	43,988	2,155	545	2,701
Total State		**50,972**	**2,600**	**553**	**3,155**
Total Region		**50,972**	**2,600**	**553**	**3,155**

HAZUS-MH: Earthquake Event Report

Region Name: ***Albany Cencus Cascadia***

Earthquake Scenario: ***Cascadia M8.5***

Print Date: ***March 29, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 2 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 158.25 square miles and contains 10 census tracts. There are over 20 thousand households in the region and has a total population of 50,972 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 17 thousand buildings in the region with a total building replacement value (excluding contents) of 3,155 (millions of dollars). Approximately 99.00 % of the buildings (and 82.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,948 and 350 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 17 thousand buildings in the region which have an aggregate total replacement value of 3,155 (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 85% 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 1 hospitals in the region with a total bed capacity of 71 beds. There are 26 schools, 2 fire stations, 3 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 0 dams identified within the region. Of these, 0 of the dams are classified as 'high hazard'. The inventory also includes 40 hazardous material sites, 0 military installations and 0 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 2,298.00 (millions of dollars). This inventory includes over 131 kilometers of highways, 52 bridges, 1,880 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	52	960.60
	Segments	26	548.80
	Tunnels	0	0.00
		Subtotal	**1,509.30**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	59	98.90
	Tunnels	0	0.00
		Subtotal	**101.30**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	1	1.20
		Subtotal	**1.20**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	9	55.40
	Runways	8	281.00
		Subtotal	**336.40**
		Total	**1,948.30**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	18.80
	Facilities	2	75.30
	Pipelines	0	0.00
		Subtotal	**94.10**
Waste Water	Distribution Lines	NA	11.30
	Facilities	2	150.50
	Pipelines	0	0.00
		Subtotal	**161.80**
Natural Gas	Distribution Lines	NA	7.50
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**7.50**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	2	0.20
		Subtotal	**0.20**
		Total	**387.90**

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	Cascadia M8.5
Type of Earthquake	User-defined
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 6,022 thousand buildings will be at least moderately damaged. This is over 34.00 % of the total number of buildings in the region. There are an estimated 1,628 buildings that will be completely destroyed. 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	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	20	0.30	8	0.17	26	0.82	37	3.00	67	4.09
Education	1	0.01	1	0.02	2	0.07	3	0.22	3	0.20
Government	0	0.00	0	0.00	0	0.01	1	0.05	1	0.09
Industrial	1	0.01	1	0.03	4	0.14	8	0.62	13	0.80
Other Residential	701	10.32	291	6.20	490	15.57	644	51.74	762	46.78
Religion	0	0.01	0	0.01	1	0.02	1	0.07	2	0.09
Single Family	6,069	89.35	4,394	93.57	2,625	83.37	551	44.28	781	47.95
Total	**6,793**		**4,696**		**3,149**		**1,245**		**1,629**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	5	0.01	0	0.00	0	0.01	1	0.11	3	0.18
MH*	503	7.41	107	2.28	352	11.17	577	46.32	633	38.86
Precast	5	0.07	1	0.01	3	0.09	6	0.45	11	0.70
RM*	1	0.01	0	0.01	2	0.05	3	0.27	5	0.34
Steel	4	0.01	0	0.00	1	0.03	3	0.24	14	0.86
UM*	26	0.39	22	0.47	52	1.64	61	4.92	109	6.67
Wood	6,248	91.95	4558	97.07	2,708	86.00	541	43.46	764	46.93
Total	**6,793**		**4,696**		**3,149**		**1,245**		**1,629**	

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

Essential Facility Damage

Before the earthquake, the region had 71 hospital beds available for use. On the day of the earthquake, the model estimates that only 63 hospital beds (90.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 90.00% of the beds will be back in service. By 30 days, 90.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	0	0	1
Schools	26	1	0	25
EOCs	0	0	0	0
PoliceStations	3	0	0	3
FireStations	2	0	0	2

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	26	0	0	26	26
	Bridges	52	4	0	48	52
	Tunnels	0	0	0	0	0
Railways	Segments	59	0	0	59	59
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	0	0	1	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	0	0	1	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	9	0	0	9	9
	Runways	8	0	0	8	8

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	2	1	0	1	2
Waste Water	2	0	0	0	2
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	0	0	0	1
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	940	166	83
Waste Water	564	131	65
Natural Gas	376	140	70
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	20,002	5,155	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 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (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 0 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 0 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 (2,166 households to be displaced due to the earthquake. Of these, 558 people (out of a total population of 50,972 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	8	2	0	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	3	1	0	0
	Industrial	12	4	1	1
	Other-Residential	223	61	7	14
	Single Family	163	37	3	5
	Total	**409**	**105**	**11**	**21**
2 PM	Commercial	499	158	27	52
	Commuting	0	0	1	0
	Educational	86	27	5	9
	Hotels	1	0	0	0
	Industrial	88	27	4	9
	Other-Residential	51	14	2	3
	Single Family	36	8	1	1
	Total	**760**	**235**	**39**	**74**
5 PM	Commercial	392	124	21	41
	Commuting	4	5	9	2
	Educational	11	3	1	1
	Hotels	1	0	0	0
	Industrial	55	17	3	5
	Other-Residential	85	23	3	5
	Single Family	65	15	1	2
	Total	**613**	**188**	**38**	**56**

Economic Loss

The total economic loss estimated for the earthquake is 1,000.46 (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 890.63 (millions of dollars); 12 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 52 % 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	2.28	29.42	1.34	2.60	35.65
	Capital-Related	0.00	0.97	26.80	1.09	1.02	29.88
	Rental	8.78	16.70	13.94	0.59	1.32	41.33
	Relocation	0.98	0.42	0.71	0.06	0.45	2.63
	Subtotal	**9.76**	**20.37**	**70.88**	**3.08**	**5.39**	**109.49**
Capital Stock Loses							
	Structural	47.00	25.47	39.84	10.84	6.55	129.69
	Non_Structural	176.68	118.16	115.97	41.32	30.44	482.57
	Content	44.45	24.08	51.68	26.32	15.06	161.59
	Inventory	0.00	0.00	2.26	4.92	0.11	7.29
	Subtotal	**268.13**	**167.71**	**209.75**	**83.39**	**52.16**	**781.14**
	Total	**277.89**	**188.08**	**280.63**	**86.48**	**57.55**	**890.63**

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	548.75	$2.90	0.53
	Bridges	960.57	$45.10	4.70
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1509.30**	**48.00**	
Railways	Segments	98.87	$0.36	0.36
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.65	26.32
	Subtotal	**101.30**	**1.00**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	1.23	$0.34	27.99
	Subtotal	**1.20**	**0.30**	
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	55.43	$9.43	17.02
	Runways	280.96	$0.34	0.12
	Subtotal	**336.40**	**9.80**	
	Total	**1948.30**	**59.10**	

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	75.30	$10.51	13.96
	Distribution Line	18.80	$2.32	12.33
	Subtotal	**94.06**	**$12.83**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	150.50	$18.09	12.02
	Distribution Line	11.30	$1.83	16.26
	Subtotal	**161.80**	**$19.93**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	7.50	$1.96	26.07
	Subtotal	**7.52**	**$1.96**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$15.97	12.84
	Subtotal	**124.30**	**$15.97**	
Communication	Facilities	0.20	$0.02	8.41
	Subtotal	**0.23**	**$0.02**	
	Total	**387.91**	**$50.70**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(33)	-7.14
Second Year			
	Employment Impact	0	0.00
	Income Impact	(49)	-10.45
Third Year			
	Employment Impact	0	0.00
	Income Impact	(55)	-11.83
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(55)	-11.83
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(55)	-11.83
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(55)	-11.83

Appendix A: County Listing for the Region

Benton, OR

Linn, OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon					
	Benton	6,984	445	8	454
	Linn	43,988	2,155	545	2,701
Total State		**50,972**	**2,600**	**553**	**3,155**
Total Region		**50,972**	**2,600**	**553**	**3,155**

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

APPENDIX C:
LANE COUNTY

CRUSTAL EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

SUBDUCTION ZONE EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

GEOLOGIC HAZARD MAPS
- Relative Ground-Shaking Amplification Susceptibility Map
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- Identified Landslide Areas Map

HAZUS-MH GLOBAL REPORT FOR CRUSTAL SCENARIO
HAZUS-MH GLOBAL REPORT FOR SUBDUCTION ZONE SCENARIO

CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR LANE COUNTY

Crustal Earthquake Scenario: A magnitude 6.5 earthquake on an Arbitrary Eugene Fault.

For the magnitude 6.5 earthquake on the Arbitrary Eugene Fault scenario, we defined the fault source using the "deterministic arbitrary" option within HAZUS-MH (Figure C1) (FEMA, 2003b). In general, a worst-case scenario was developed. In particular, this event was selected because of the proximity to the major metropolitan area in Lane County (Eugene-Springfield). Figure C1 has the location of the fault, shown as the dark line, and the census tracts within Lane County. Figure C2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Corvallis Fault M6.5
Type of Earthquake	Arbitrary
Fault Name	Arbitrary Eugene Fault
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	–123.053
Latitude of Epicenter	44.085
Earthquake Magnitude	6.5
Depth (km)	10
Rupture Length (km)	22.38
Rupture Orientation (degrees)	165
Attenuation Function	Reverse-Slip

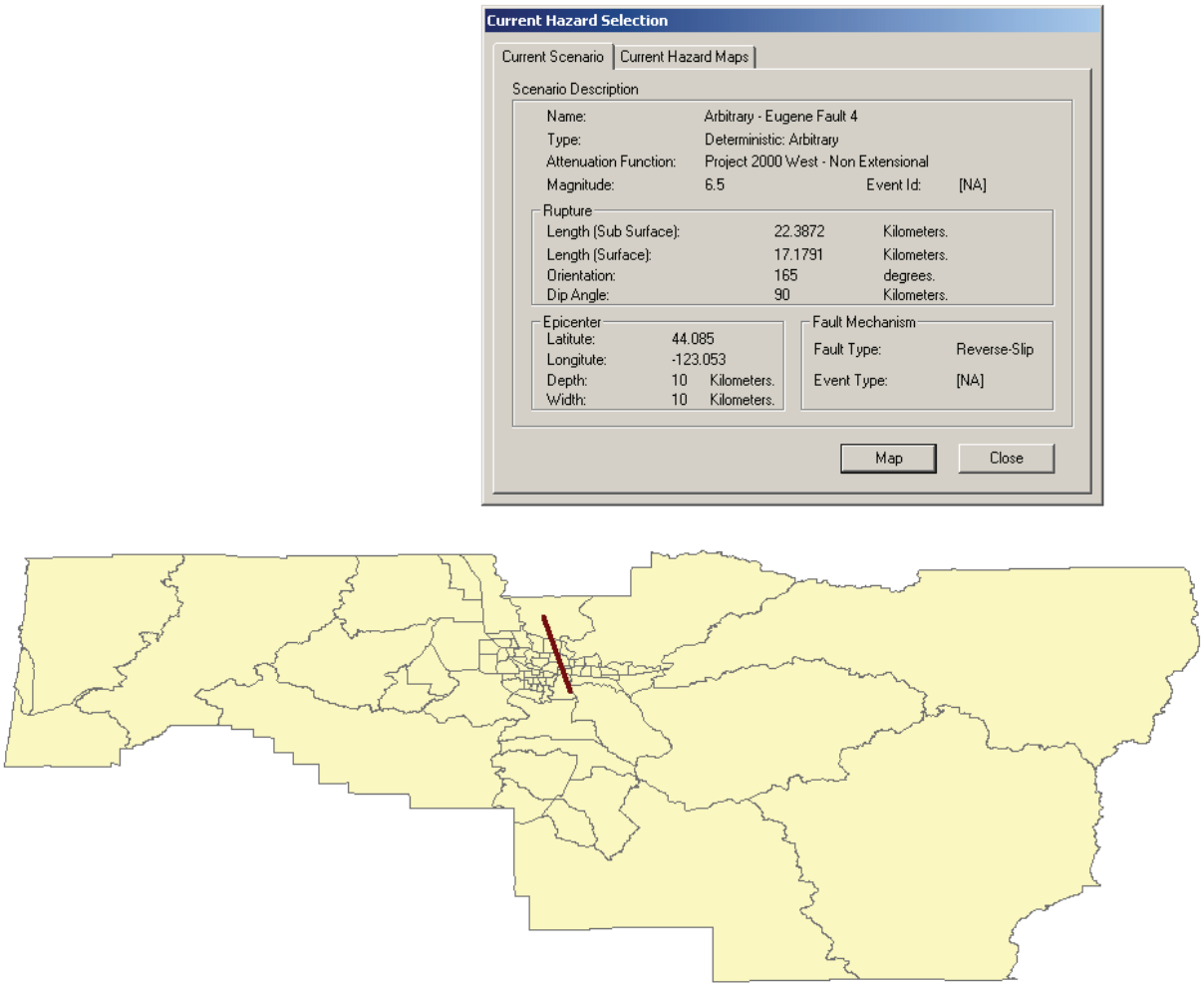

Figure C1. Arbitrary Eugene Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dark line.

Crustal Earthquake Scenario Ground Motion Map

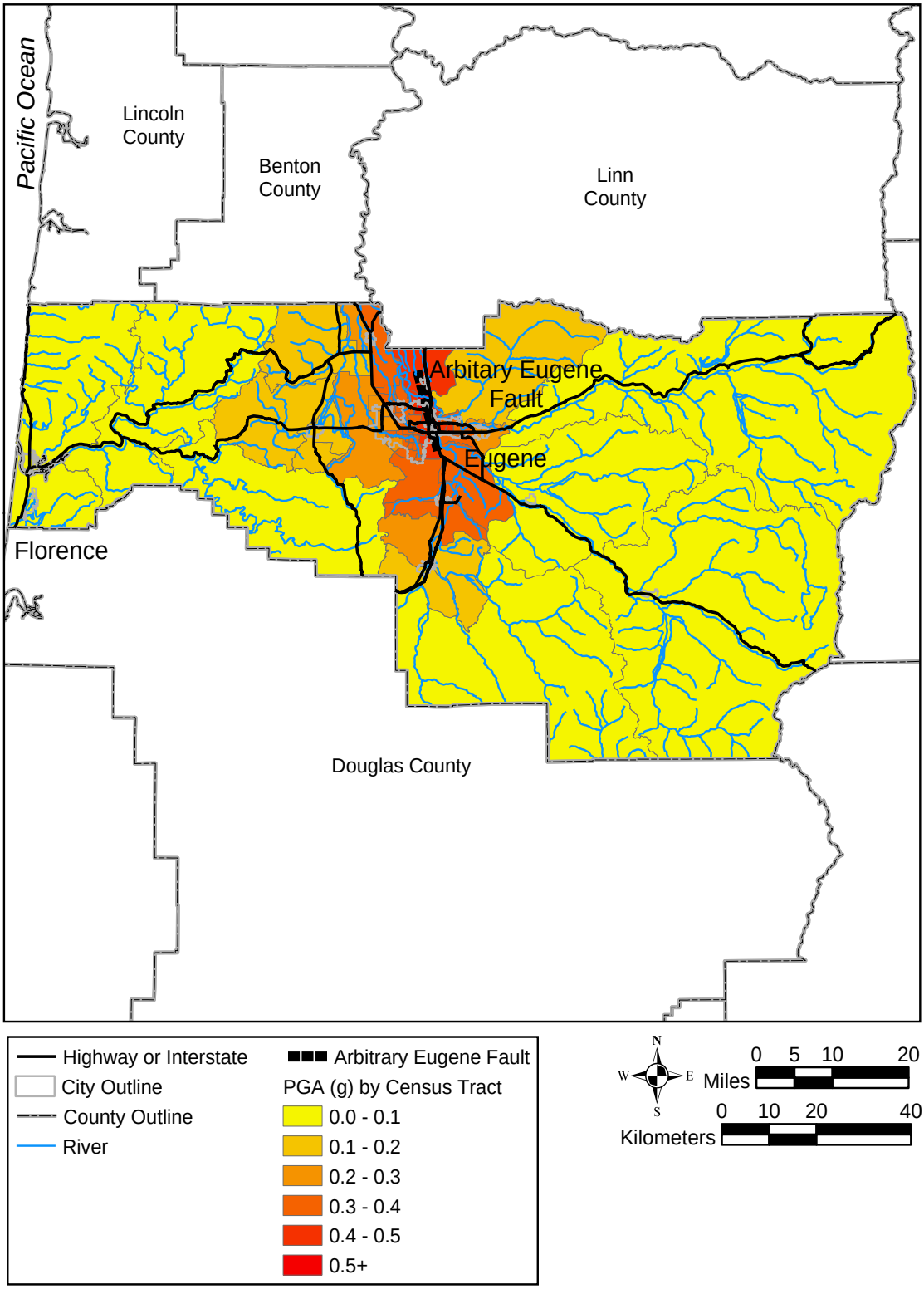

Figure C2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, Lane County, Oregon (FEMA, 2003b).

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR LANE COUNTY

Subduction Zone Scenario: A magnitude 9.0 earthquake on the Cascadia Subduction Zone was selected for the subduction zone earthquake scenario.

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by the Cascadia Region Earthquake Workgroup (CREW) to model damage and loss from a magnitude 9.0 earthquake (Figure C3). The CREW maps were developed from ground motion data provided by the U.S. Geological Survey. The CREW earthquake scenario required the input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 s and 1.0 s (CREW, 2003). Figure C4 displays the PGA for the subduction zone scenario.

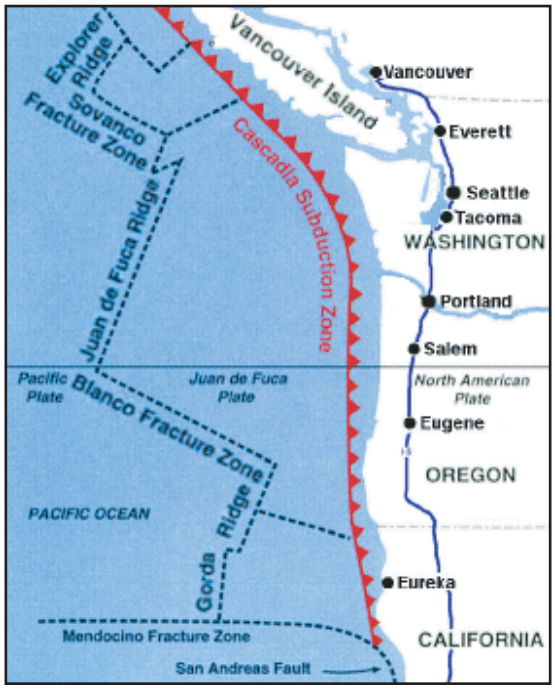

Figure C3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

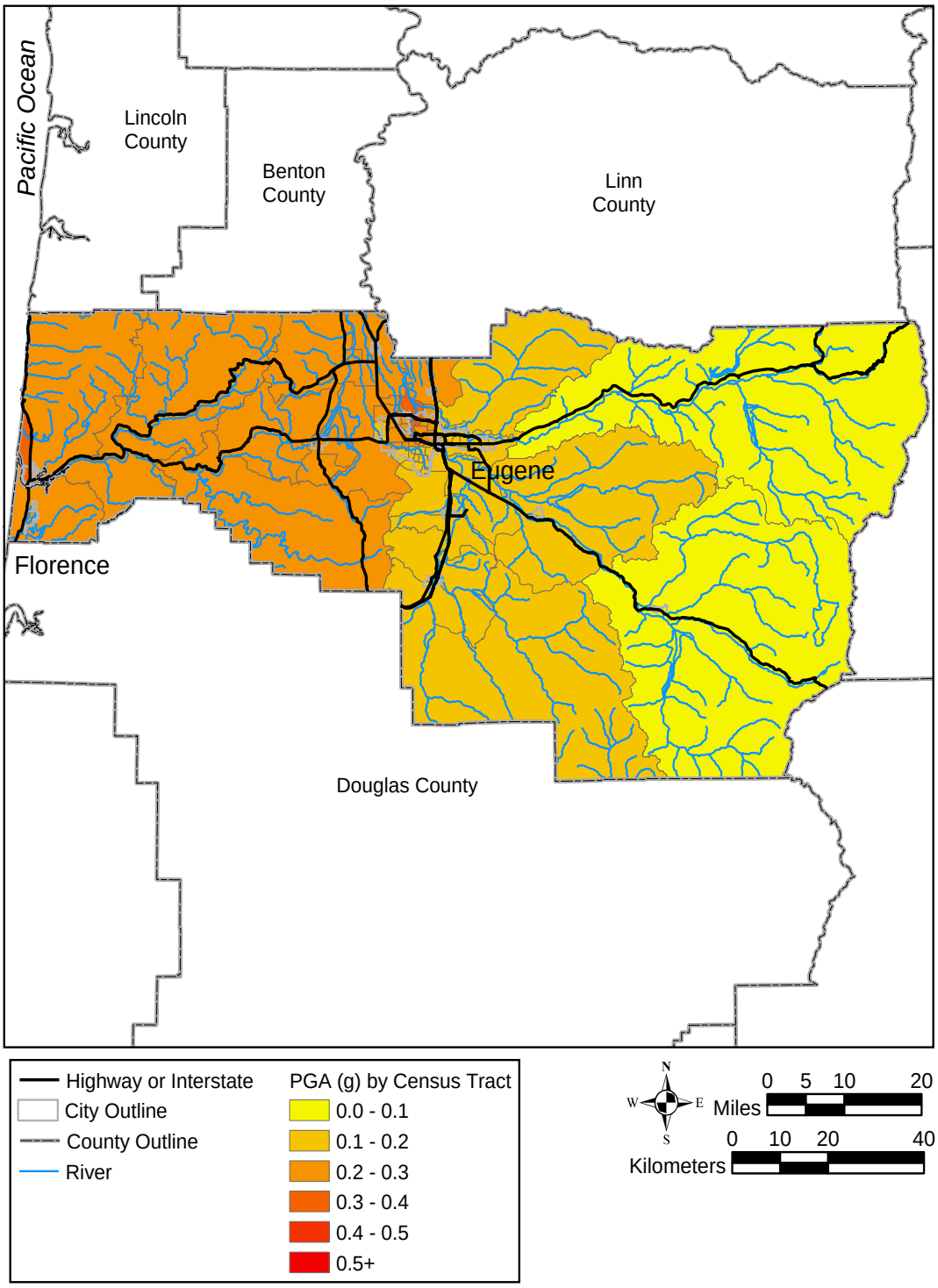

Figure C4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, Lane County, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS

Relative Ground-Shaking Amplification Susceptibility Map

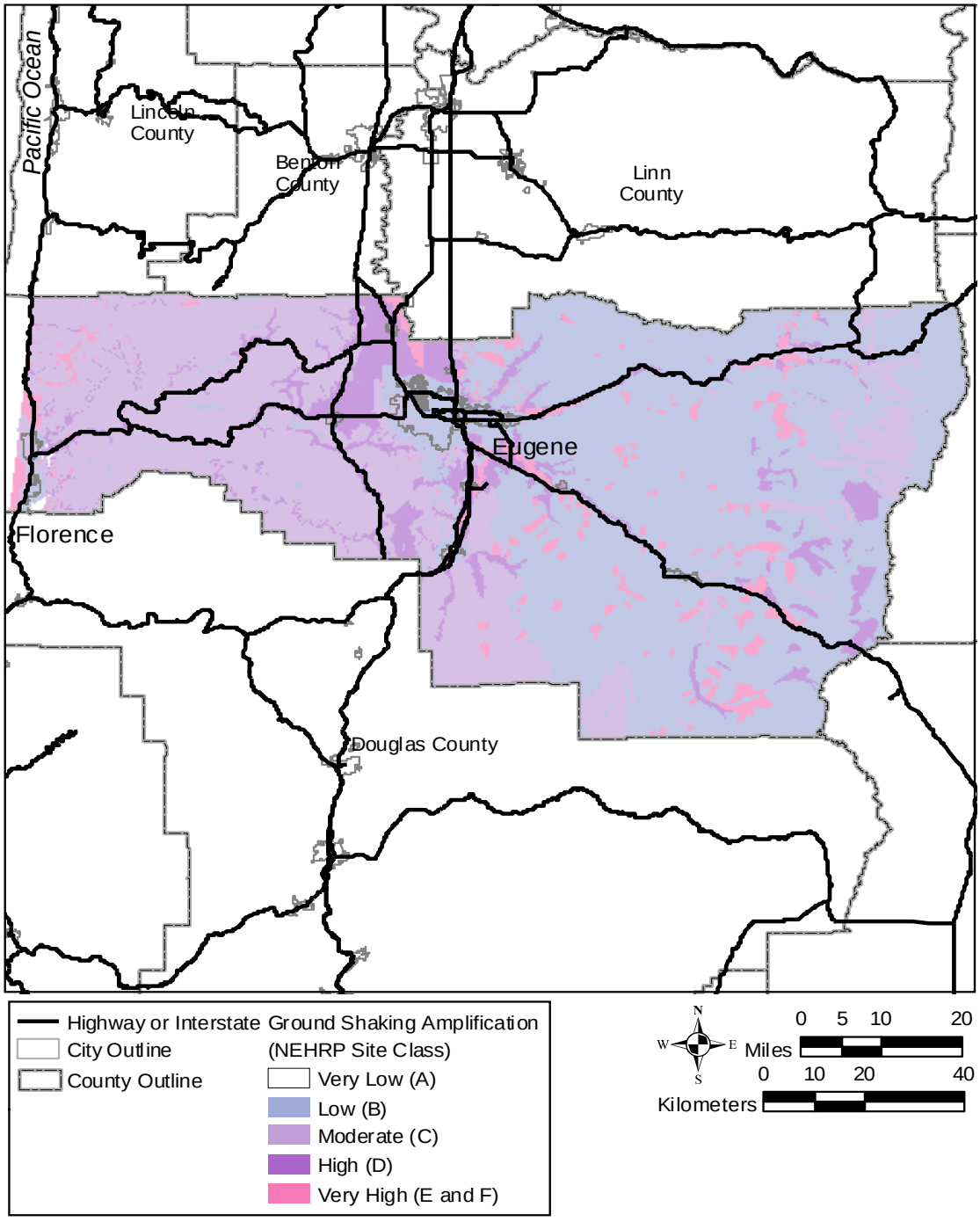

Figure C5. Relative ground-shaking amplification susceptibility map for Lane County, Oregon.

Relative Liquefaction Hazard Susceptibility Map

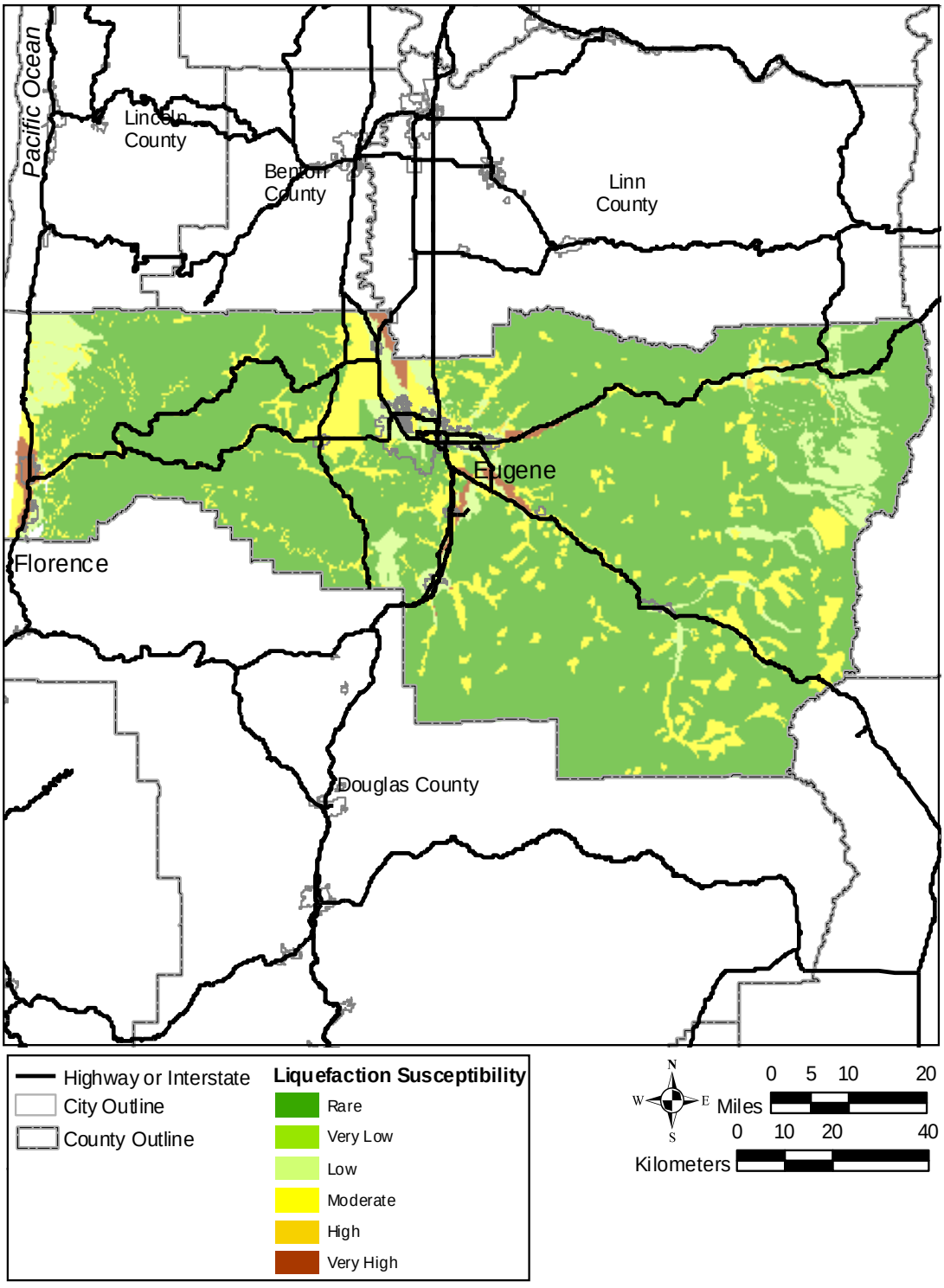

Figure C6. Relative liquefaction susceptibility map for Lane County, Oregon.

Relative Earthquake-induced Landslide Susceptibility Map

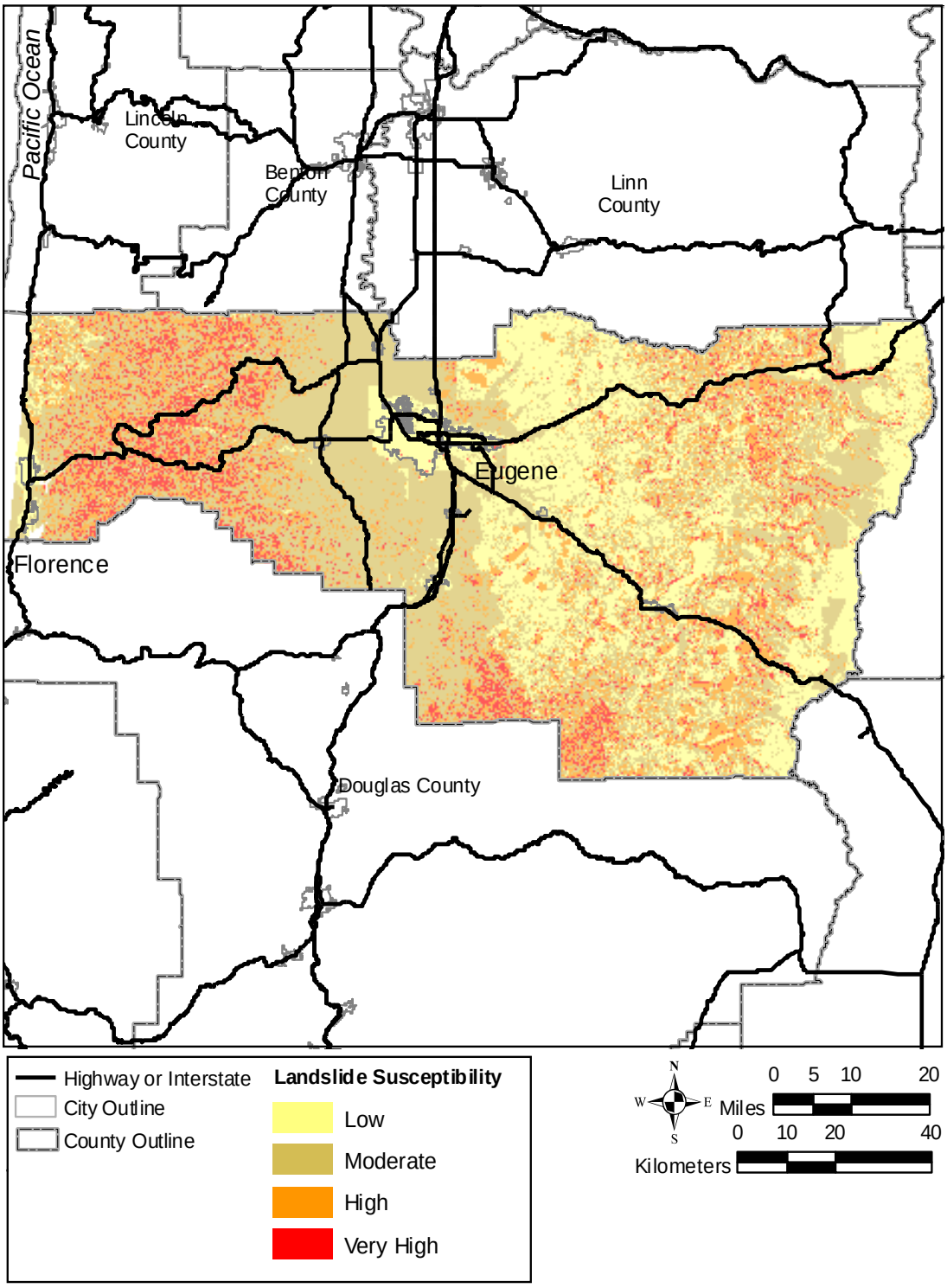

Figure C7. Relative earthquake-induced landslide susceptibility map for Lane County, Oregon.

Identified Landslide Areas Map

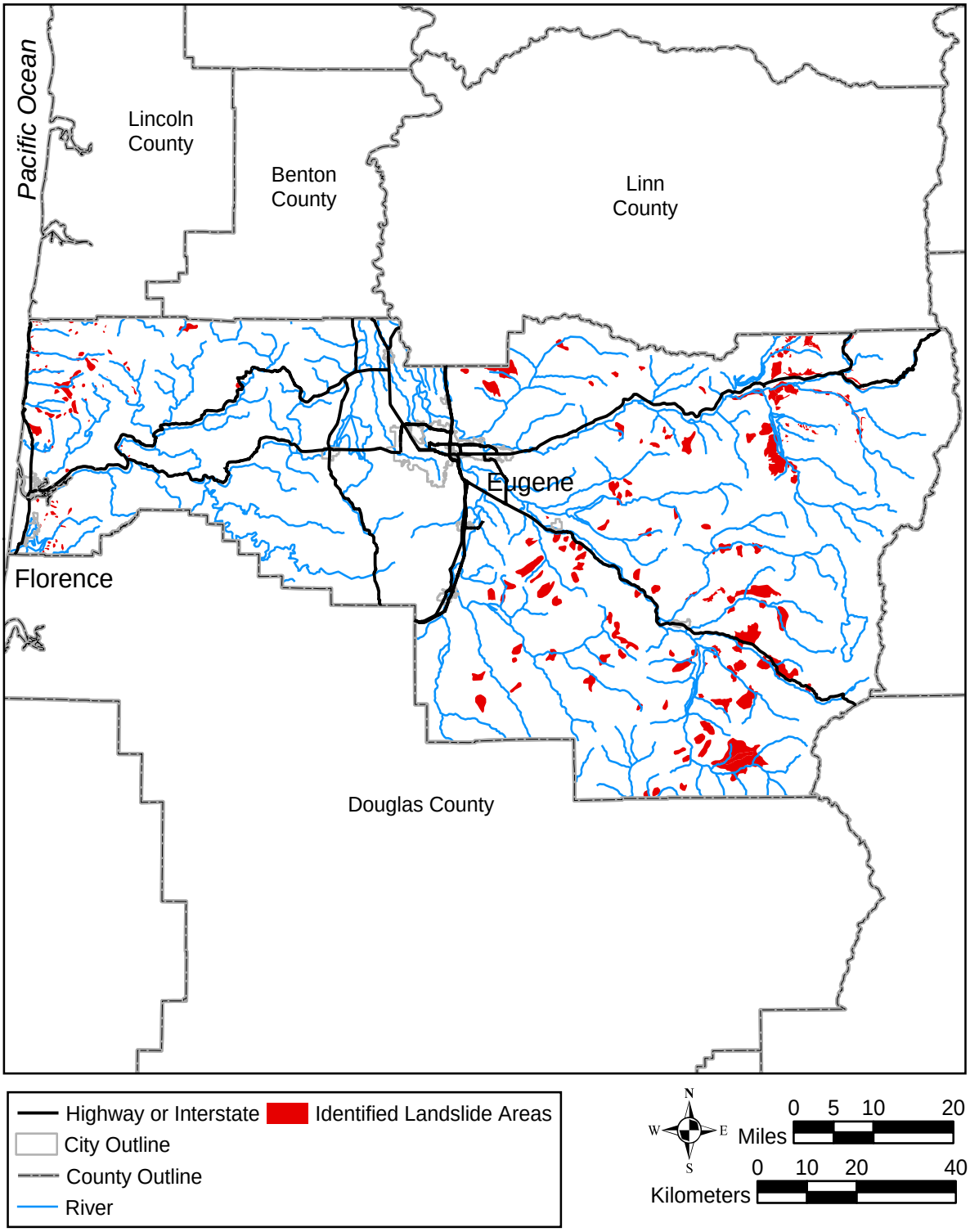

Figure C8. Identified landslide map for Lane County, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Lane Crustal 3***

Earthquake Scenario: ***Arbitrary - Eugene Fault 4***

Print Date: ***September 07, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 4,607.85 square miles and contains 78 census tracts. There are over 130 thousand households in the region and has a total population of 322,959 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 113 thousand buildings in the region with a total building replacement value (excluding contents) of 21,055 (millions of dollars). Approximately 98.00 % of the buildings (and 79.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 6,494 and 1,372 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 113 thousand buildings in the region which have an aggregate total replacement value of 21,055 (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 83% 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 4 hospitals in the region with a total bed capacity of 586 beds. There are 158 schools, 12 fire stations, 11 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 35 dams identified within the region. Of these, 10 of the dams are classified as 'high hazard'. The inventory also includes 91 hazardous material sites, 0 military installations and 0 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 7,866.00 (millions of dollars). This inventory includes over 614 kilometers of highways, 199 bridges, 34,067 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	199	3,407.20
	Segments	83	2,094.40
	Tunnels	2	10.40
		Subtotal	**5,512.00**
Railways	Bridges	0	0.00
	Facilities	4	9.90
	Segments	146	355.60
	Tunnels	0	0.00
		Subtotal	**365.50**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	3	3.70
		Subtotal	**3.70**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	14	86.20
	Runways	15	526.80
		Subtotal	**613.00**
		Total	**6,494.20**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	340.70
	Facilities	7	263.40
	Pipelines	0	0.00
		Subtotal	**604.10**
Waste Water	Distribution Lines	NA	204.40
	Facilities	13	978.40
	Pipelines	0	0.00
		Subtotal	**1,182.80**
Natural Gas	Distribution Lines	NA	136.30
	Facilities	2	2.50
	Pipelines	0	0.00
		Subtotal	**138.70**
Oil Systems	Facilities	1	0.10
	Pipelines	0	0.00
		Subtotal	**0.10**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	37	4.20
		Subtotal	**4.20**
		Total	**2,054.20**

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	Arbitrary - Eugene Fault 4
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-123.05
Latitude of Epicenter	44.08
Earthquake Magnitude	6.50
Depth (Km)	10.00
Rupture Length (Km)	17.18
Rupture Orientation (degrees)	165.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 28,447 thousand buildings will be at least moderately damaged. This is over 25.00 % of the total number of buildings in the region. There are an estimated 4,874 buildings that will be completely destroyed. 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	2	0.00	2	0.01	3	0.01	2	0.03	1	0.03
Commercial	464	0.82	307	1.08	447	2.41	266	5.30	195	4.01
Education	1	0.00	1	0.00	1	0.01	1	0.01	1	0.01
Government	19	0.03	11	0.04	16	0.09	8	0.16	5	0.10
Industrial	41	0.07	25	0.09	39	0.21	26	0.51	23	0.48
Other Residential	7,951	14.03	3,643	12.76	4,502	24.26	2,010	40.09	1,107	22.71
Religion	17	0.03	11	0.04	13	0.07	7	0.13	5	0.09
Single Family	48,165	85.00	24,551	85.99	13,540	72.95	2,694	53.76	3,538	72.57
Total	**56,661**		**28,551**		**18,561**		**5,012**		**4,875**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	195	0.03	8	0.03	16	0.09	8	0.15	5	0.11
MH*	6,510	11.49	2591	9.08	3,743	20.17	1,760	35.11	882	18.09
Precast	117	0.16	55	0.19	115	0.62	100	2.00	61	1.25
RM*	28	0.05	10	0.04	20	0.11	15	0.30	6	0.13
Steel	182	0.04	13	0.05	35	0.19	34	0.68	16	0.33
UM*	522	0.92	341	1.19	430	2.32	267	5.32	223	4.57
Wood	49,108	86.53	25263	88.48	13,834	74.53	2,659	53.05	3,566	73.15
Total	**56,661**		**28,551**		**18,561**		**5,012**		**4,875**	

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

Essential Facility Damage

Before the earthquake, the region had 586 hospital beds available for use. On the day of the earthquake, the model estimates that only 293 hospital beds (50.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 75.00% of the beds will be back in service. By 30 days, 94.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	4	0	0	4
Schools	158	2	0	156
EOCs	2	0	0	2
PoliceStations	11	1	0	10
FireStations	12	0	0	12

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	83	0	0	83	83
	Bridges	199	6	0	193	195
	Tunnels	2	0	0	2	2
Railways	Segments	146	0	0	146	146
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	4	1	0	4	4
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	1	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	14	2	0	14	14
	Runways	15	0	0	15	15

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	7	3	0	4	7
Waste Water	13	4	0	8	13
Natural Gas	2	2	0	0	2
Oil Systems	1	1	0	0	1
Electrical Power	1	1	0	0	1
Communication	37	28	0	37	37

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	17,034	284	225
Waste Water	10,220	225	178
Natural Gas	6,813	240	190
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	130,453	774	288	0	0	0
Electric Power		16,489	9,155	3,223	553	26

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 8 ignitions that will burn about 0.16 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 525 people and burn about 46 (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 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 40.00% 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 (7,716 households to be displaced due to the earthquake. Of these, 2,030 people (out of a total population of 322,959 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	16	5	1	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	19	5	1	1
	Industrial	22	6	1	2
	Other-Residential	491	119	12	23
	Single Family	738	163	10	17
	Total	**1,285**	**297**	**25**	**45**
2 PM	Commercial	958	271	43	83
	Commuting	0	0	0	0
	Educational	237	67	10	20
	Hotels	4	1	0	0
	Industrial	163	48	8	15
	Other-Residential	79	19	2	3
	Single Family	142	31	2	3
	Total	**1,582**	**436**	**65**	**125**
5 PM	Commercial	736	209	33	64
	Commuting	4	5	9	2
	Educational	56	16	2	5
	Hotels	6	2	0	0
	Industrial	102	30	5	9
	Other-Residential	188	46	5	9
	Single Family	295	65	5	7
	Total	**1,388**	**373**	**60**	**96**

Economic Loss

The total economic loss estimated for the earthquake is 3,615.77 (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 3,351.03 (millions of dollars); 10 % 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 61 % 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	9.16	99.92	4.22	3.14	116.43
	Capital-Related	0.00	3.90	72.07	2.52	0.87	79.36
	Rental	42.08	51.12	46.46	1.47	1.69	142.81
	Relocation	4.78	1.40	2.93	0.08	0.47	9.65
	Subtotal	**46.85**	**65.57**	**221.38**	**8.28**	**6.17**	**348.25**
Capital Stock Loses							
	Structural	224.12	75.01	203.64	18.97	14.09	535.83
	Non_Structural	902.65	374.64	413.39	71.38	37.33	1,799.39
	Content	263.96	88.87	217.32	47.02	19.73	636.89
	Inventory	0.00	0.00	17.38	12.69	0.59	30.66
	Subtotal	**1,390.73**	**538.53**	**851.72**	**150.06**	**71.74**	**3,002.77**
	Total	**1,437.59**	**604.10**	**1,073.10**	**158.33**	**77.91**	**3,351.03**

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	2,094.41	$6.69	0.32
	Bridges	3,407.19	$99.51	2.92
	Tunnels	10.38	$0.00	0.00
	Subtotal	**5512.00**	**106.20**	
Railways	Segments	355.60	$0.13	0.04
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	9.85	$1.74	17.67
	Subtotal	**365.50**	**1.90**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.70	$0.85	23.10
	Subtotal	**3.70**	**0.90**	
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	86.22	$14.78	17.14
	Runways	526.81	$1.22	0.23
	Subtotal	**613.00**	**16.00**	
	Total	**6494.20**	**124.90**	

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	263.40	$20.44	7.76
	Distribution Line	340.70	$5.63	1.65
	Subtotal	**604.07**	**$26.07**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	978.40	$82.32	8.41
	Distribution Line	204.40	$4.45	2.18
	Subtotal	**1,182.76**	**$86.77**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	2.50	$0.67	27.03
	Distribution Line	136.30	$4.76	3.49
	Subtotal	**138.73**	**$5.43**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.10	$0.03	22.48
	Subtotal	**0.11**	**$0.03**	
Electrical Power	Facilities	124.30	$20.89	16.80
	Subtotal	**124.30**	**$20.89**	
Communication	Facilities	4.20	$0.63	15.01
	Subtotal	**4.18**	**$0.63**	
	Total	**2,054.16**	**$139.81**	

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

	LOSS	Total	%
First Year			
	Employment Impact	827	0.87
	Income Impact	(188)	-4.40
Second Year			
	Employment Impact	346	0.37
	Income Impact	(248)	-5.81
Third Year			
	Employment Impact	8	0.01
	Income Impact	(274)	-6.41
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(275)	-6.42
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(275)	-6.42
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(275)	-6.42

Appendix A: County Listing for the Region

Lane,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Lane	322,959	16,735	4,319	21,055
Total State		**322,959**	**16,735**	**4,319**	**21,055**
Total Region		**322,959**	**16,735**	**4,319**	**21,055**

HAZUS-MH: Earthquake Event Report

Region Name: ***Lane Cascadia 2***

Earthquake Scenario: ***Cascadia***

Print Date: ***September 20, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 4,607.85 square miles and contains 78 census tracts. There are over 130 thousand households in the region and has a total population of 322,959 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 113 thousand buildings in the region with a total building replacement value (excluding contents) of 21,055 (millions of dollars). Approximately 98.00 % of the buildings (and 79.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 6,494 and 1,372 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 113 thousand buildings in the region which have an aggregate total replacement value of 21,055 (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 83% 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 4 hospitals in the region with a total bed capacity of 586 beds. There are 158 schools, 12 fire stations, 11 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 35 dams identified within the region. Of these, 10 of the dams are classified as 'high hazard'. The inventory also includes 91 hazardous material sites, 0 military installations and 0 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 7,866.00 (millions of dollars). This inventory includes over 614 kilometers of highways, 199 bridges, 34,067 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	199	3,407.20
	Segments	83	2,094.40
	Tunnels	2	10.40
		Subtotal	**5,512.00**
Railways	Bridges	0	0.00
	Facilities	4	9.90
	Segments	146	355.60
	Tunnels	0	0.00
		Subtotal	**365.50**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	3	3.70
		Subtotal	**3.70**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	14	86.20
	Runways	15	526.80
		Subtotal	**613.00**
		Total	**6,494.20**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	340.70
	Facilities	7	263.40
	Pipelines	0	0.00
		Subtotal	**604.10**
Waste Water	Distribution Lines	NA	204.40
	Facilities	13	978.40
	Pipelines	0	0.00
		Subtotal	**1,182.80**
Natural Gas	Distribution Lines	NA	136.30
	Facilities	2	2.50
	Pipelines	0	0.00
		Subtotal	**138.70**
Oil Systems	Facilities	1	0.10
	Pipelines	0	0.00
		Subtotal	**0.10**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	37	4.20
		Subtotal	**4.20**
		Total	**2,054.20**

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	Cascadia
Type of Earthquake	User-defined
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 32,521 thousand buildings will be at least moderately damaged. This is over 29.00 % of the total number of buildings in the region. There are an estimated 6,688 buildings that will be completely destroyed. 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	2	0.00	2	0.01	2	0.01	2	0.02	3	0.04
Commercial	105	0.20	155	0.53	396	2.24	479	5.88	545	8.14
Education	1	0.00	1	0.00	1	0.01	1	0.02	1	0.02
Government	4	0.01	5	0.02	13	0.08	17	0.21	19	0.28
Industrial	7	0.01	11	0.04	34	0.19	46	0.57	55	0.82
Other Residential	2,450	4.74	2,555	8.67	4,620	26.14	5,321	65.20	4,267	63.81
Religion	8	0.02	7	0.02	10	0.06	12	0.15	14	0.22
Single Family	49,086	95.01	26,740	90.72	12,597	71.28	2,281	27.95	1,783	26.66
Total	**51,662**		**29,477**		**17,673**		**8,160**		**6,688**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	28	0.00	1	0.00	8	0.04	17	0.21	24	0.36
MH*	931	1.80	1615	5.48	4,013	22.71	4,999	61.26	3,928	58.73
Precast	15	0.03	19	0.06	78	0.44	135	1.66	177	2.64
RM*	5	0.01	4	0.01	17	0.10	28	0.34	26	0.39
Steel	14	0.00	1	0.00	12	0.07	30	0.36	75	1.12
UM*	272	0.53	296	1.01	460	2.60	373	4.57	380	5.68
Wood	50,396	97.52	27438	93.08	12,759	72.20	2,151	26.36	1,617	24.18
Total	**51,662**		**29,477**		**17,673**		**8,160**		**6,688**	

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

Essential Facility Damage

Before the earthquake, the region had 586 hospital beds available for use. On the day of the earthquake, the model estimates that only 193 hospital beds (33.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 53.00% of the beds will be back in service. By 30 days, 87.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	4	3	0	1
Schools	158	0	0	158
EOCs	2	0	0	2
PoliceStations	11	0	0	11
FireStations	12	0	0	12

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	83	0	0	83	83
	Bridges	199	32	0	167	190
	Tunnels	2	0	0	2	2
Railways	Segments	146	0	0	146	146
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	0	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	14	0	0	14	14
	Runways	15	0	0	15	15

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	7	1	0	5	7
Waste Water	13	2	0	3	13
Natural Gas	2	0	0	2	2
Oil Systems	1	0	0	1	1
Electrical Power	1	0	0	1	1
Communication	37	2	0	37	37

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	17,034	1177	419
Waste Water	10,220	931	331
Natural Gas	6,813	995	354
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	130,453	5,543	3,903	1,457	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 11 ignitions that will burn about 0.10 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 149 people and burn about 11 (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 2 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 30.00% 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 80,000 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 (7,663 households to be displaced due to the earthquake. Of these, 2,021 people (out of a total population of 322,959 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	42	13	2	4
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	31	9	1	3
	Industrial	58	18	3	6
	Other-Residential	1,009	260	29	55
	Single Family	463	95	7	12
	Total	**1,603**	**395**	**43**	**80**
2 PM	Commercial	2,557	786	132	259
	Commuting	1	1	1	0
	Educational	585	180	30	59
	Hotels	6	2	0	1
	Industrial	425	130	21	42
	Other-Residential	185	47	5	9
	Single Family	94	19	2	3
	Total	**3,852**	**1,164**	**191**	**371**
5 PM	Commercial	1,956	599	101	194
	Commuting	10	13	22	4
	Educational	119	36	6	12
	Hotels	9	3	0	1
	Industrial	266	82	13	26
	Other-Residential	376	98	11	21
	Single Family	184	38	3	5
	Total	**2,919**	**868**	**158**	**264**

Economic Loss

The total economic loss estimated for the earthquake is 5,042.48 (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 4,652.34 (millions of dollars); 14 % 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 40 % 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	12.33	225.67	8.70	7.66	254.37
	Capital-Related	0.00	5.26	168.55	5.18	1.98	180.97
	Rental	29.97	72.32	96.95	3.01	4.18	206.44
	Relocation	3.56	2.03	5.66	0.16	1.10	12.51
	Subtotal	**33.53**	**91.94**	**496.84**	**17.06**	**14.93**	**654.29**
Capital Stock Loses							
	Structural	156.80	135.69	428.49	42.65	33.26	796.88
	Non_Structural	627.30	550.18	906.13	151.70	89.33	2,324.64
	Content	165.25	107.23	413.67	94.27	39.64	820.07
	Inventory	0.00	0.00	31.68	23.75	1.03	56.46
	Subtotal	**949.35**	**793.10**	**1,779.96**	**312.37**	**163.26**	**3,998.05**
	Total	**982.88**	**885.04**	**2,276.80**	**329.43**	**178.19**	**4,652.34**

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	2,094.41	$4.96	0.24
	Bridges	3,407.19	$205.83	6.04
	Tunnels	10.38	$0.18	1.77
	Subtotal	**5512.00**	**211.00**	
Railways	Segments	355.60	$0.46	0.13
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	9.85	$1.89	19.14
	Subtotal	**365.50**	**2.30**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.70	$0.52	14.08
	Subtotal	**3.70**	**0.50**	
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	86.22	$12.55	14.55
	Runways	526.81	$0.72	0.14
	Subtotal	**613.00**	**13.30**	
	Total	**6494.20**	**227.10**	

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	263.40	$23.99	9.11
	Distribution Line	340.70	$13.08	3.84
	Subtotal	**604.07**	**$37.07**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	978.40	$98.57	10.08
	Distribution Line	204.40	$10.34	5.06
	Subtotal	**1,182.76**	**$108.91**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	2.50	$0.19	7.55
	Distribution Line	136.30	$11.06	8.11
	Subtotal	**138.73**	**$11.24**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.10	$0.01	8.41
	Subtotal	**0.11**	**$0.01**	
Electrical Power	Facilities	124.30	$5.45	4.39
	Subtotal	**124.30**	**$5.45**	
Communication	Facilities	4.20	$0.33	7.90
	Subtotal	**4.18**	**$0.33**	
	Total	**2,054.16**	**$163.02**	

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

	LOSS	Total	%
First Year			
	Employment Impact	1,098	1.16
	Income Impact	(197)	-4.60
Second Year			
	Employment Impact	464	0.49
	Income Impact	(277)	-6.47
Third Year			
	Employment Impact	10	0.01
	Income Impact	(311)	-7.27
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(312)	-7.28
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(312)	-7.28
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(312)	-7.28

Appendix A: County Listing for the Region

Lane,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Lane	322,959	16,735	4,319	21,055
Total State		**322,959**	**16,735**	**4,319**	**21,055**
Total Region		**322,959**	**16,735**	**4,319**	**21,055**

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

APPENDIX D:
LINN COUNTY

CRUSTAL EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

SUBDUCTION ZONE EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

GEOLOGIC HAZARD MAPS
- Relative Ground-Shaking Amplification Susceptibility Map
- Relative Liquefaction Hazard Susceptibility Map
- Relative Earthquake-induced Landslide Susceptibility Map
- Identified Landslide Areas Map

HAZUS-MH GLOBAL REPORT FOR CRUSTAL SCENARIO
HAZUS-MH GLOBAL REPORT FOR SUBDUCTION ZONE SCENARIO

CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR LINN COUNTY

Crustal Earthquake Scenario: A magnitude 6.7 earthquake on the Mill Creek Fault.

For the magnitude 6.7 earthquake on the Mill Creek Fault scenario, we defined the fault source using the "deterministic seismic source" option within HAZUS-MH (Figure D1) (FEMA, 2003b). The fault and earthquake event were chosen by examination of USGS (2004) data and data in the Geomatrix Consultants, Inc. (1995) *Seismic Design Mapping, State of Oregon* report prepared for the Oregon Department of Transportation. In general, a likely worst-case scenario was selected. Figure D1 has the location of the fault, shown as the dark line, and the census tracts within Linn County. Figure D2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Mill Creek M6.7
Type of Earthquake	Source
Fault Name	Mill Creek Fault
Historical Epicenter ID #	70
Probabilistic Return Period	NA
Longitude of Epicenter	–123.015
Latitude of Epicenter	44.7428
Earthquake Magnitude	6.7
Depth (km)	0.00
Rupture Length (km)	27.11
Rupture Orientation (degrees)	0.00
Attenuation Function	Reverse-Slip

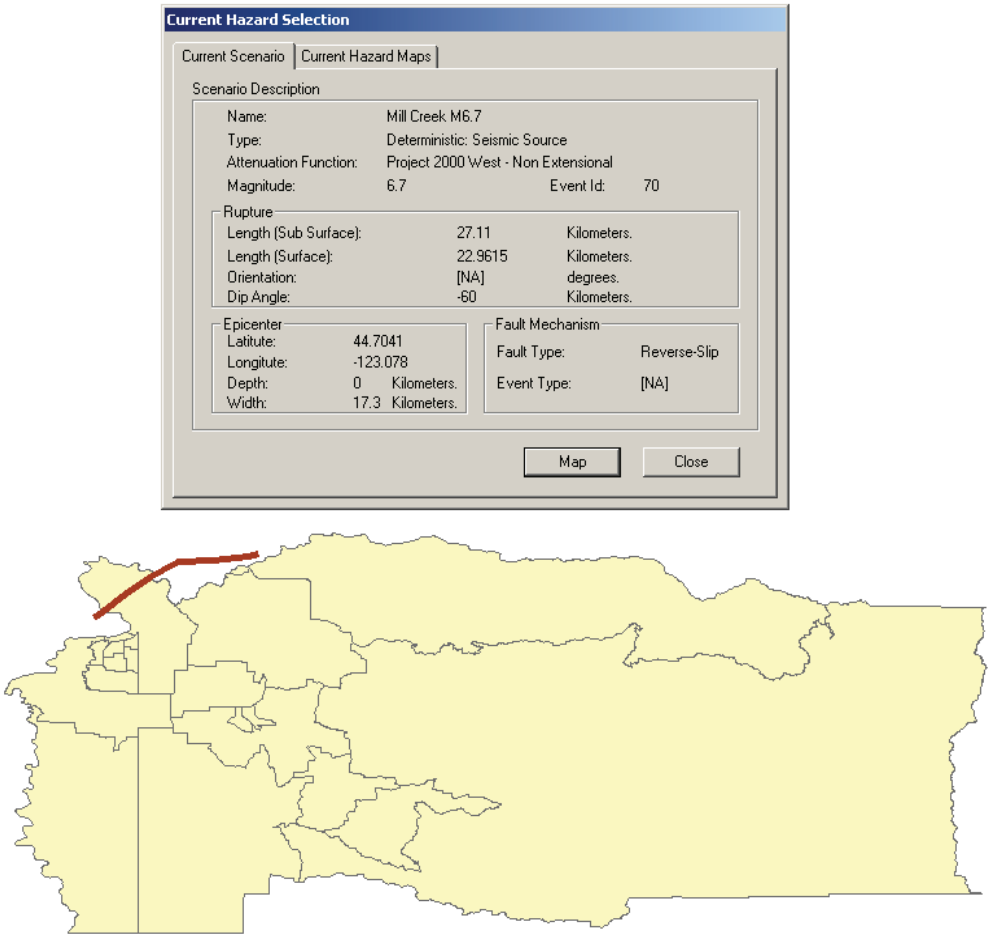

Figure D1. Mill Creek Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dark line.

Crustal Earthquake Scenario Ground Motion Map

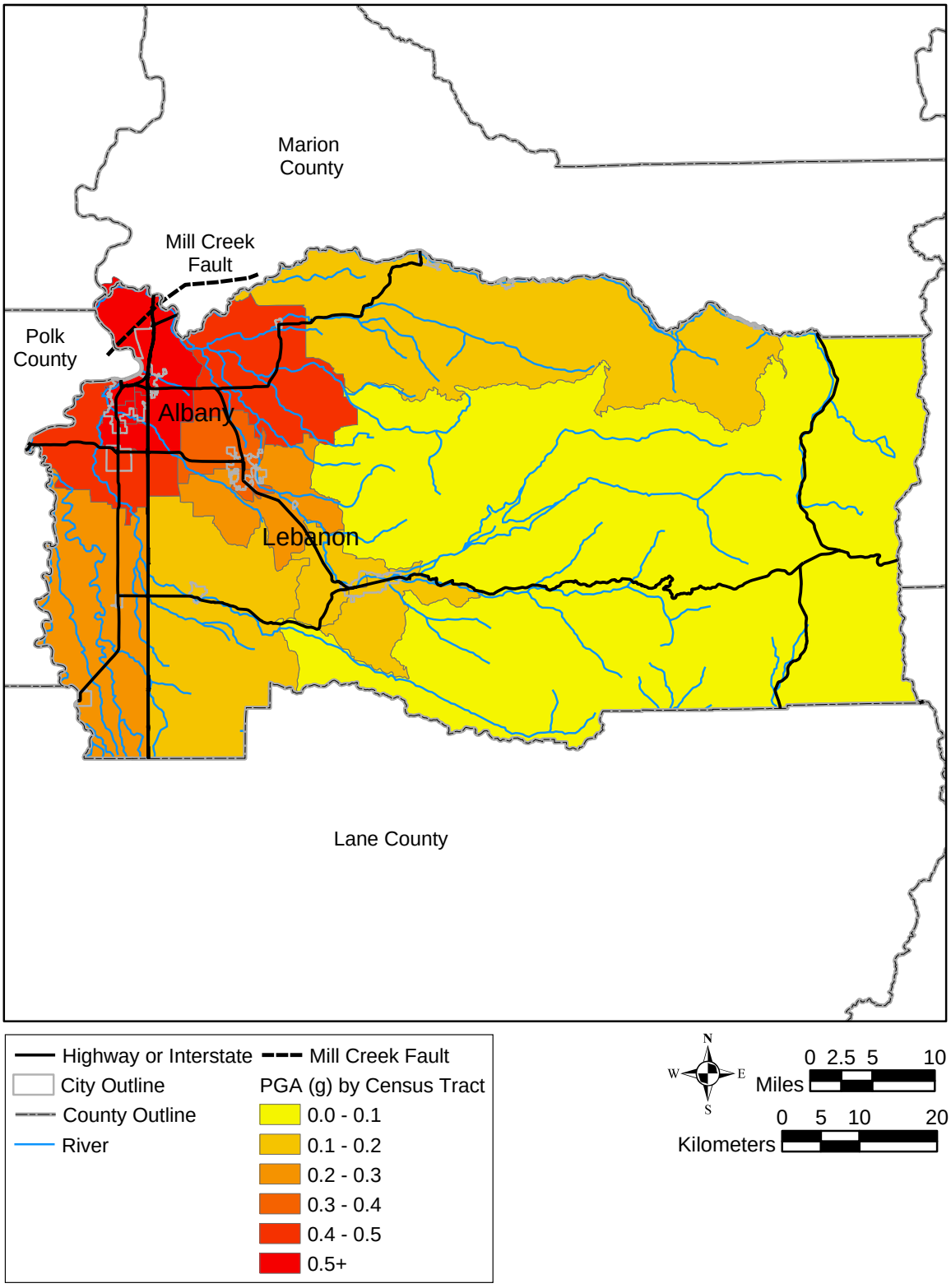

Figure D2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, Linn County, Oregon (FEMA, 2003b).

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR LINN COUNTY

Subduction Zone Scenario: A magnitude 9.0 earthquake on the Cascadia Subduction Zone was selected for the subduction zone earthquake scenario.

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by the Cascadia Region Earthquake Workgroup (CREW, 2003) to model damage and loss from a magnitude 9.0 earthquake (Figure D3). The CREW maps were developed from ground motion data provided by the U.S. Geological Survey. The CREW earthquake scenario required the input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 s and 1.0 s (CREW, 2003). Figure D4 displays the PGA for the subduction zone scenario.

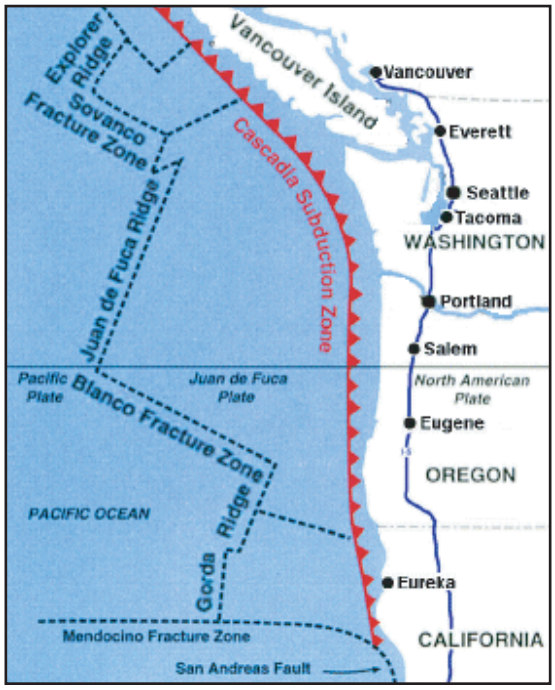

Figure D3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

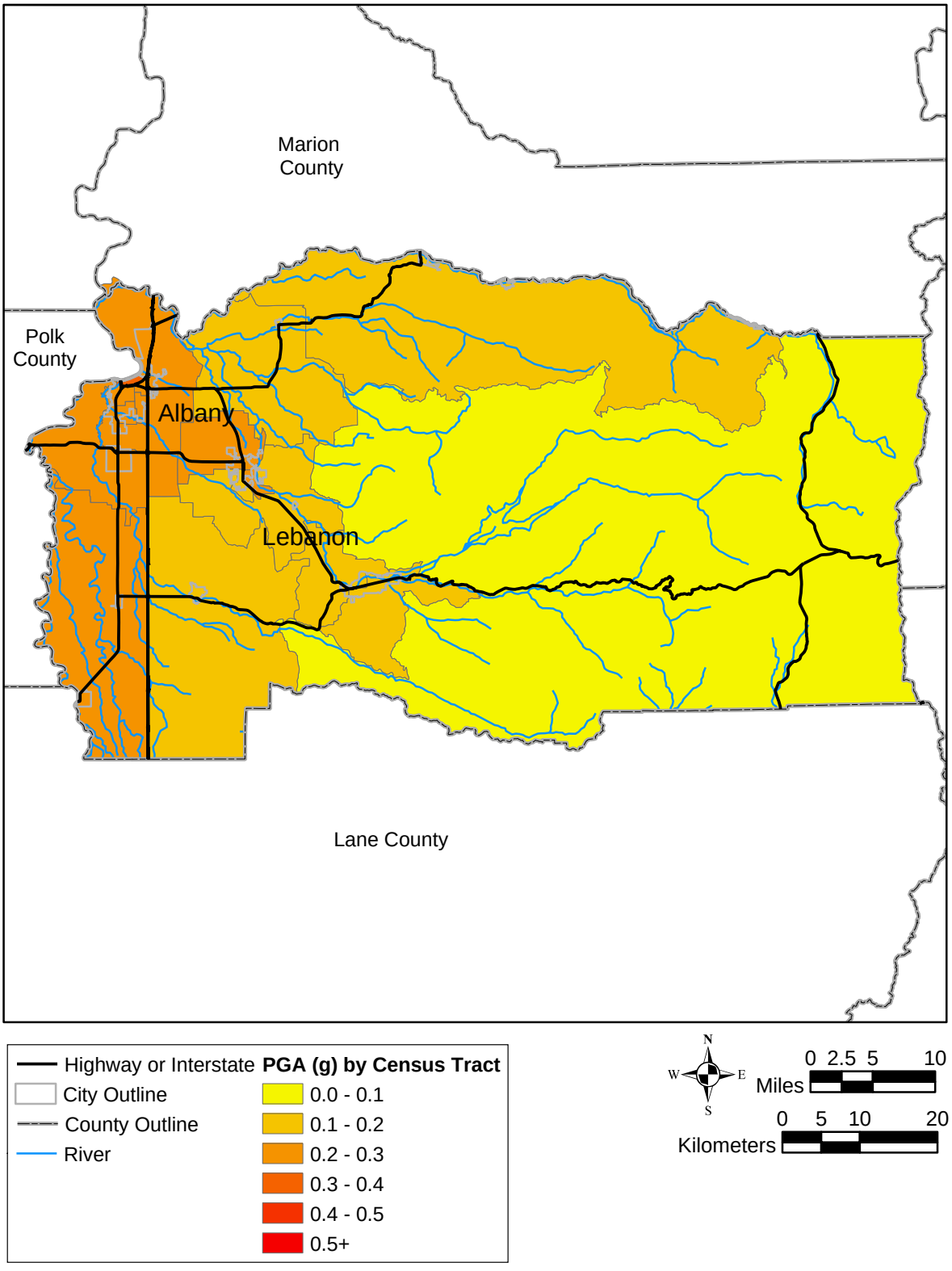

Figure D4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, Linn County, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS

Relative Ground-Shaking Amplification Susceptibility Map

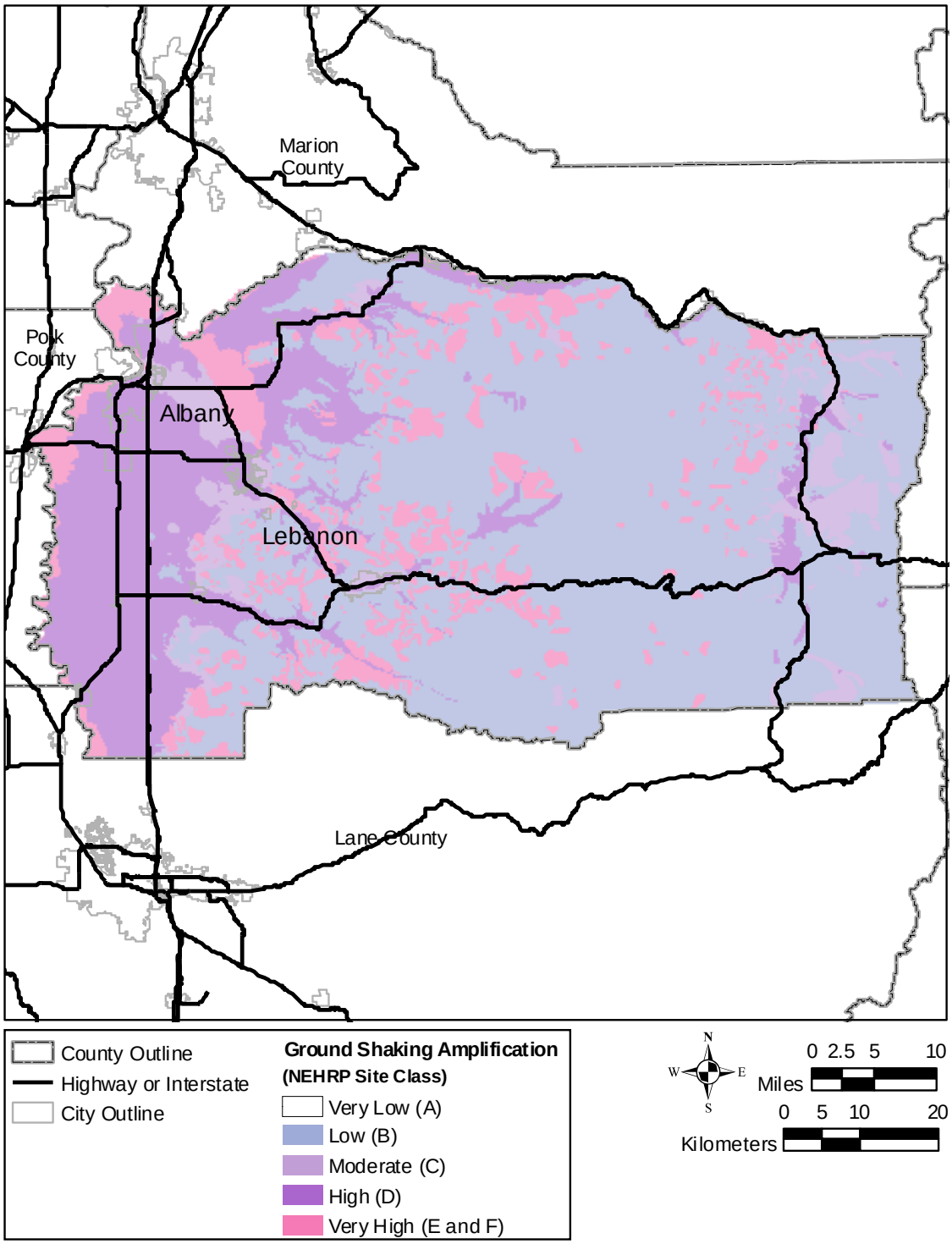

Figure D5. Relative ground-shaking amplification susceptibility map for Linn County, Oregon.

Relative Liquefaction Hazard Susceptibility Map

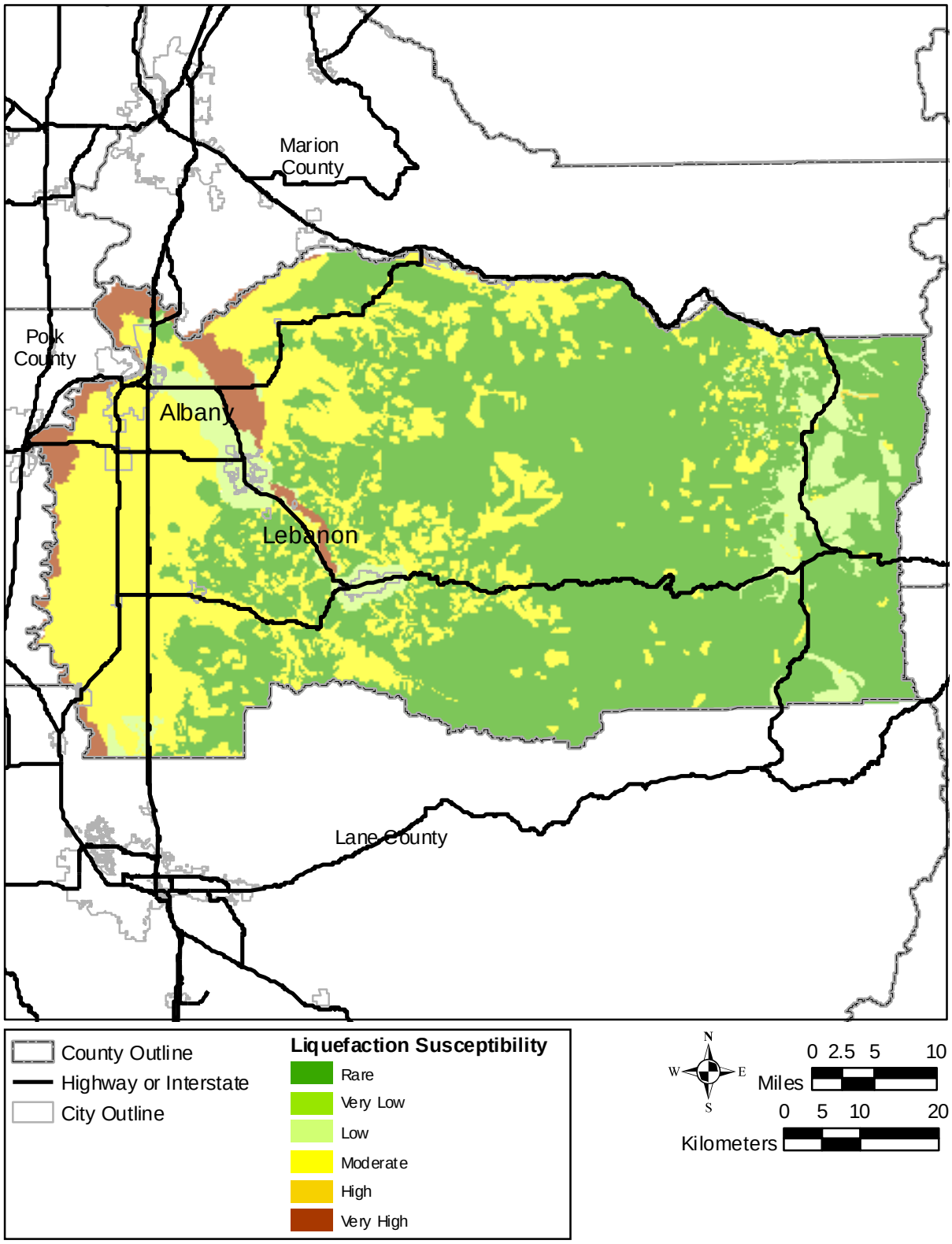

Figure D6. Relative liquefaction susceptibility map for Linn County, Oregon.

Relative Earthquake-induced Landslide Susceptibility Map

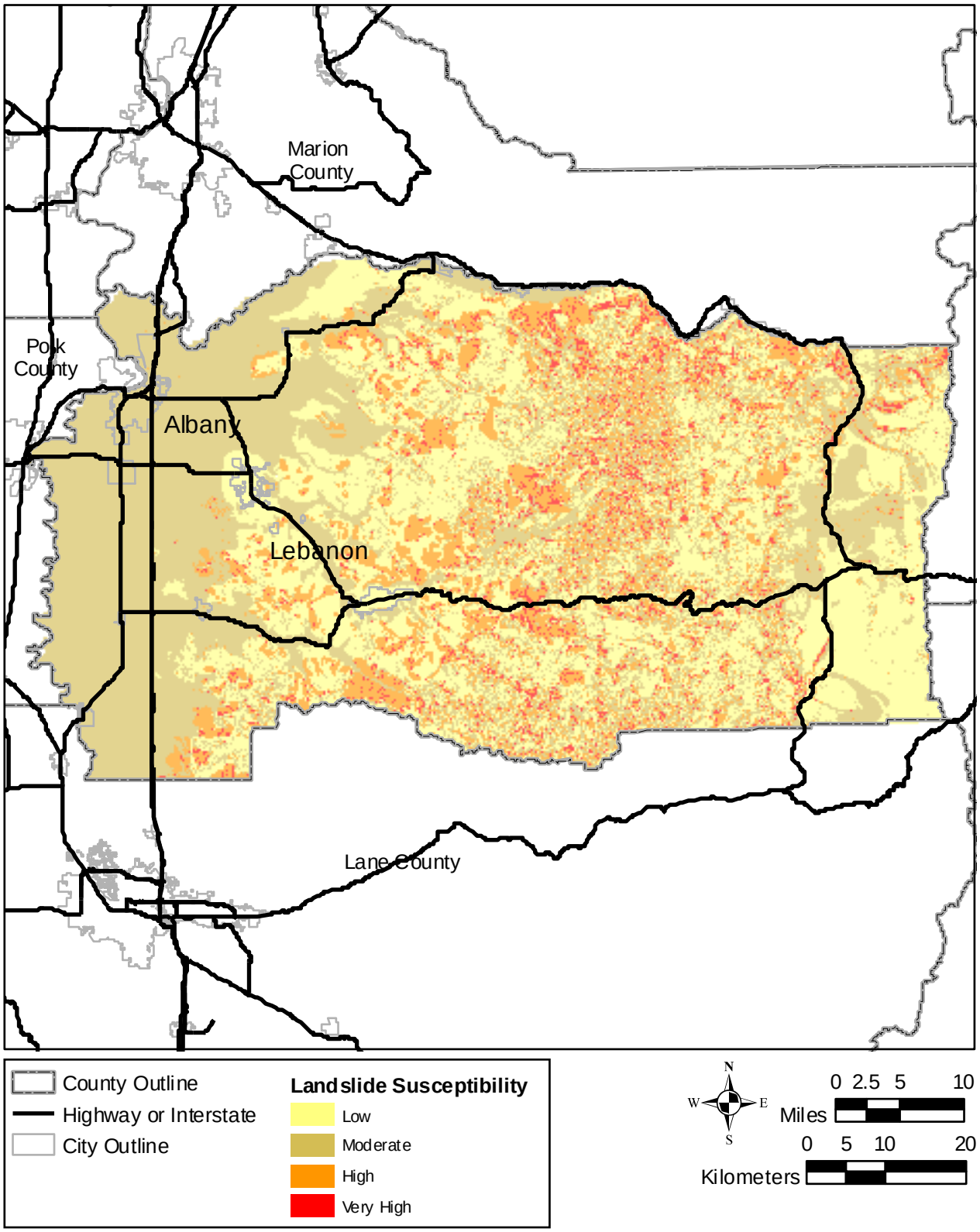

Figure D7. Relative earthquake-induced landslide susceptibility map for Linn County, Oregon.

Identified Landslide Areas Map

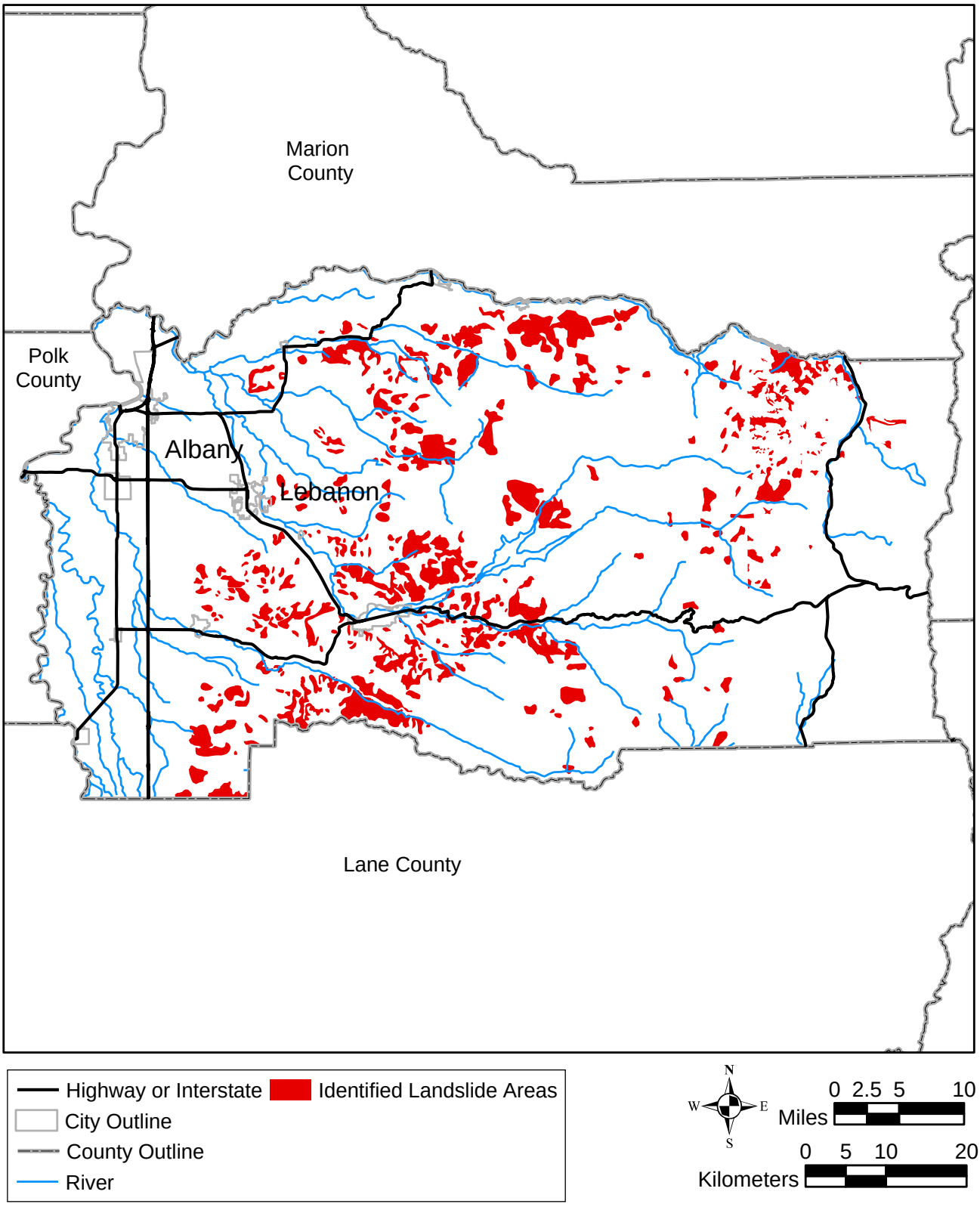

Figure D8. Identified landslide map for Linn County, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Linn Crustal***

Earthquake Scenario: ***Mill Creek M6.7***

Print Date: ***March 18, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 2,304.63 square miles and contains 20 census tracts. There are over 39 thousand households in the region and has a total population of 103,069 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 36 thousand buildings in the region with a total building replacement value (excluding contents) of 5,669 (millions of dollars). Approximately 99.00 % of the buildings (and 85.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 4,440 and 1,278 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 36 thousand buildings in the region which have an aggregate total replacement value of 5,669 (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 80% 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 1 hospitals in the region with a total bed capacity of 71 beds. There are 64 schools, 13 fire stations, 5 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 11 dams identified within the region. Of these, 6 of the dams are classified as 'high hazard'. The inventory also includes 69 hazardous material sites, 0 military installations and 0 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 5,718.00 (millions of dollars). This inventory includes over 400 kilometers of highways, 122 bridges, 19,117 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	122	1,732.10
	Segments	71	1,421.20
	Tunnels	0	0.00
		Subtotal	**3,153.30**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	110	209.90
	Tunnels	0	0.00
		Subtotal	**212.40**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	1	1.20
		Subtotal	**1.20**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	26	160.10
	Runways	26	913.10
		Subtotal	**1,073.30**
		Total	**4,440.10**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	191.20
	Facilities	4	150.50
	Pipelines	0	0.00
		Subtotal	**341.70**
Waste Water	Distribution Lines	NA	114.70
	Facilities	10	752.60
	Pipelines	0	0.00
		Subtotal	**867.30**
Natural Gas	Distribution Lines	NA	76.50
	Facilities	1	1.20
	Pipelines	0	0.00
		Subtotal	**77.70**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	3	372.90
		Subtotal	**372.90**
Communication	Facilities	7	0.80
		Subtotal	**0.80**
		Total	**1,660.40**

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	Mill Creek M6.7
Type of Earthquake	Source
Fault Name	Mill Creek Fault
Historical Epicenter ID #	70
Probabilistic Return Period	NA
Longitude of Epicenter	-123.08
Latitude of Epicenter	44.70
Earthquake Magnitude	6.70
Depth (Km)	0.00
Rupture Length (Km)	22.96
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 12,431 thousand buildings will be at least moderately damaged. This is over 34.00 % of the total number of buildings in the region. There are an estimated 2,671 buildings that will be completely destroyed. 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	1	0.00	0	0.01	0	0.01	0	0.01	0	0.01
Commercial	46	0.28	27	0.39	52	0.77	52	1.72	63	2.35
Education	1	0.00	1	0.01	2	0.04	3	0.09	3	0.12
Government	4	0.02	1	0.01	1	0.02	1	0.03	1	0.04
Industrial	6	0.04	4	0.05	8	0.11	9	0.30	11	0.39
Other Residential	2,583	15.40	1,122	16.05	1,648	24.46	1,241	41.07	962	35.99
Religion	2	0.01	1	0.01	1	0.02	1	0.04	1	0.05
Single Family	14,124	84.24	5,832	83.46	5,026	74.58	1,714	56.74	1,631	61.04
Total	**16,767**		**6,988**		**6,739**		**3,021**		**2,672**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	20	0.01	1	0.01	1	0.02	2	0.06	3	0.09
MH*	2,390	14.26	924	13.22	1,404	20.84	1,111	36.79	817	30.58
Precast	7	0.03	3	0.04	7	0.10	9	0.30	11	0.40
RM*	3	0.02	1	0.02	3	0.05	4	0.14	5	0.17
Steel	22	0.01	1	0.02	3	0.05	6	0.19	12	0.44
UM*	124	0.74	58	0.83	84	1.25	77	2.55	115	4.29
Wood	14,201	84.65	5973	85.48	5,177	76.82	1,747	57.85	1,638	61.32
Total	**16,767**		**6,988**		**6,739**		**3,021**		**2,672**	

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

Essential Facility Damage

Before the earthquake, the region had 71 hospital beds available for use. On the day of the earthquake, the model estimates that only 3 hospital beds (4.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 20.00% of the beds will be back in service. By 30 days, 62.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	1	0	0
Schools	64	22	0	42
EOCs	0	0	0	0
PoliceStations	5	3	0	2
FireStations	13	3	0	10

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	71	0	0	71	71
	Bridges	122	12	0	111	119
	Tunnels	0	0	0	0	0
Railways	Segments	110	0	0	110	110
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	1	0	0	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	1	0	0	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	26	6	0	23	26
	Runways	26	0	0	26	26

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	4	2	0	2	4
Waste Water	10	4	0	5	10
Natural Gas	1	0	0	1	1
Oil Systems	0	0	0	0	0
Electrical Power	3	1	0	2	3
Communication	7	2	0	6	7

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	9,559	308	266
Waste Water	5,735	243	211
Natural Gas	3,824	260	225
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	39,541	2,084	1,157	117	0	0
Electric Power		11,371	7,251	3,254	776	15

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 6 ignitions that will burn about 0.06 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 142 people and burn about 8 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 42.00% 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 0 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 (3,683 households to be displaced due to the earthquake. Of these, 927 people (out of a total population of 103,069 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	8	2	0	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	3	1	0	0
	Industrial	12	4	1	1
	Other-Residential	281	72	8	14
	Single Family	344	77	5	8
	Total	**650**	**156**	**14**	**25**
2 PM	Commercial	518	159	26	52
	Commuting	1	1	1	0
	Educational	83	25	4	8
	Hotels	1	0	0	0
	Industrial	92	28	4	9
	Other-Residential	64	17	2	3
	Single Family	79	18	1	2
	Total	**838**	**248**	**39**	**74**
5 PM	Commercial	406	125	21	40
	Commuting	9	11	20	4
	Educational	10	3	1	1
	Hotels	1	0	0	0
	Industrial	58	17	3	5
	Other-Residential	107	28	3	6
	Single Family	138	31	2	3
	Total	**729**	**215**	**49**	**59**

Economic Loss

The total economic loss estimated for the earthquake is 1,700.28 (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 1,315.72 (millions of dollars); 10 % 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 66 % 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	3.04	32.06	1.43	2.72	39.25
	Capital-Related	0.00	1.29	28.26	1.10	1.06	31.71
	Rental	19.36	22.41	15.53	0.59	1.33	59.22
	Relocation	2.12	0.60	0.84	0.06	0.46	4.08
	Subtotal	**21.47**	**27.34**	**76.69**	**3.18**	**5.57**	**134.25**
Capital Stock Loses							
	Structural	101.77	34.82	43.94	10.49	7.52	198.54
	Non_Structural	382.11	164.12	123.22	40.72	32.04	742.22
	Content	96.57	34.58	57.77	26.76	17.12	232.79
	Inventory	0.00	0.00	2.64	5.08	0.20	7.92
	Subtotal	**580.45**	**233.52**	**227.57**	**83.06**	**56.88**	**1,181.47**
	Total	**601.92**	**260.86**	**304.26**	**86.24**	**62.44**	**1,315.72**

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	1,421.20	$12.85	0.90
	Bridges	1,732.06	$116.85	6.75
	Tunnels	0.00	$0.00	0.00
	Subtotal	**3153.30**	**129.70**	
Railways	Segments	209.93	$2.21	1.05
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$1.15	46.70
	Subtotal	**212.40**	**3.40**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	1.23	$0.63	51.16
	Subtotal	**1.20**	**0.60**	
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	160.12	$36.02	22.49
	Runways	913.13	$2.25	0.25
	Subtotal	**1073.30**	**38.30**	
	Total	**4440.10**	**172.00**	

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	150.50	$27.50	18.27
	Distribution Line	191.20	$6.55	3.43
	Subtotal	**341.69**	**$34.05**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	752.60	$112.79	14.99
	Distribution Line	114.70	$5.18	4.52
	Subtotal	**867.29**	**$117.98**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.20	$0.07	5.79
	Distribution Line	76.50	$5.54	7.25
	Subtotal	**77.70**	**$5.61**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	372.90	$54.84	14.71
	Subtotal	**372.90**	**$54.84**	
Communication	Facilities	0.80	$0.11	13.44
	Subtotal	**0.79**	**$0.11**	
	Total	**1,660.38**	**$212.59**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(67)	-7.10
Second Year			
	Employment Impact	0	0.00
	Income Impact	(91)	-9.63
Third Year			
	Employment Impact	0	0.00
	Income Impact	(100)	-10.69
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(100)	-10.69
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(100)	-10.69
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(100)	-10.69

Appendix A: County Listing for the Region

Linn, OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Linn	103,069	4,821	847	5,669
Total State		**103,069**	**4,821**	**847**	**5,669**
Total Region		**103,069**	**4,821**	**847**	**5,669**

HAZUS-MH: Earthquake Event Report

Region Name: ***Linn Cascadia***

Earthquake Scenario: ***Cascadia M9.0***

Print Date: ***March 18, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 2,304.63 square miles and contains 20 census tracts. There are over 39 thousand households in the region and has a total population of 103,069 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 36 thousand buildings in the region with a total building replacement value (excluding contents) of 5,669 (millions of dollars). Approximately 99.00 % of the buildings (and 85.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 4,440 and 1,278 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 36 thousand buildings in the region which have an aggregate total replacement value of 5,669 (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 80% 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 1 hospitals in the region with a total bed capacity of 71 beds. There are 64 schools, 13 fire stations, 5 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 11 dams identified within the region. Of these, 6 of the dams are classified as 'high hazard'. The inventory also includes 69 hazardous material sites, 0 military installations and 0 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 5,718.00 (millions of dollars). This inventory includes over 400 kilometers of highways, 122 bridges, 19,117 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	122	1,732.10
	Segments	71	1,421.20
	Tunnels	0	0.00
		Subtotal	**3,153.30**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	110	209.90
	Tunnels	0	0.00
		Subtotal	**212.40**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	1	1.20
		Subtotal	**1.20**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	26	160.10
	Runways	26	913.10
		Subtotal	**1,073.30**
		Total	**4,440.10**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	191.20
	Facilities	4	150.50
	Pipelines	0	0.00
		Subtotal	**341.70**
Waste Water	Distribution Lines	NA	114.70
	Facilities	10	752.60
	Pipelines	0	0.00
		Subtotal	**867.30**
Natural Gas	Distribution Lines	NA	76.50
	Facilities	1	1.20
	Pipelines	0	0.00
		Subtotal	**77.70**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	3	372.90
		Subtotal	**372.90**
Communication	Facilities	7	0.80
		Subtotal	**0.80**
		Total	**1,660.40**

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	Cascadia M9.0
Type of Earthquake	User-defined
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 10,372 thousand buildings will be at least moderately damaged. This is over 29.00 % of the total number of buildings in the region. There are an estimated 2,470 buildings that will be completely destroyed. 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	0	0.00	0	0.00	0	0.01	0	0.01	0	0.02
Commercial	18	0.10	21	0.26	53	1.00	62	2.40	86	3.47
Education	1	0.00	1	0.01	2	0.04	3	0.11	3	0.13
Government	1	0.01	1	0.01	2	0.03	2	0.07	2	0.09
Industrial	2	0.01	2	0.03	7	0.13	10	0.40	16	0.64
Other Residential	1,161	6.66	1,039	12.41	1,942	36.65	1,950	74.89	1,463	59.20
Religion	1	0.01	1	0.01	1	0.02	1	0.05	2	0.08
Single Family	16,259	93.21	7,304	87.26	3,291	62.12	575	22.07	899	36.37
Total	**17,444**		**8,370**		**5,298**		**2,604**		**2,471**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	7	0.00	0	0.00	1	0.02	2	0.09	4	0.16
MH*	860	4.93	813	9.71	1,779	33.59	1,870	71.80	1,324	53.60
Precast	2	0.01	1	0.02	6	0.11	10	0.38	16	0.64
RM*	1	0.01	1	0.01	3	0.06	5	0.19	6	0.26
Steel	5	0.00	0	0.00	2	0.04	5	0.19	17	0.67
UM*	83	0.47	66	0.78	103	1.95	90	3.45	116	4.71
Wood	16,486	94.50	7471	89.26	3,348	63.20	546	20.97	880	35.63
Total	**17,444**		**8,370**		**5,298**		**2,604**		**2,471**	

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

Essential Facility Damage

Before the earthquake, the region had 71 hospital beds available for use. On the day of the earthquake, the model estimates that only 63 hospital beds (90.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 90.00% of the beds will be back in service. By 30 days, 90.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	0	0	1
Schools	64	0	0	64
EOCs	0	0	0	0
PoliceStations	5	0	0	5
FireStations	13	0	0	13

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	71	0	0	71	71
	Bridges	122	0	0	122	122
	Tunnels	0	0	0	0	0
Railways	Segments	110	0	0	110	110
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	0	0	1	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	0	0	1	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	26	0	0	26	26
	Runways	26	0	0	26	26

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	4	1	0	3	4
Waste Water	10	2	0	2	10
Natural Gas	1	0	0	1	1
Oil Systems	0	0	0	0	0
Electrical Power	3	0	0	2	3
Communication	7	0	0	7	7

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	9,559	451	191
Waste Water	5,735	357	151
Natural Gas	3,824	382	161
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	39,541	777	259	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 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 36.00% 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 0 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 (2,563 households to be displaced due to the earthquake. Of these, 653 people (out of a total population of 103,069 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	9	3	0	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	4	1	0	0
	Industrial	16	5	1	2
	Other-Residential	340	87	9	17
	Single Family	194	43	3	5
	Total	**563**	**139**	**14**	**25**
2 PM	Commercial	619	193	32	63
	Commuting	0	0	0	0
	Educational	96	30	5	10
	Hotels	1	0	0	0
	Industrial	121	37	6	12
	Other-Residential	77	20	2	4
	Single Family	45	10	1	1
	Total	**960**	**290**	**46**	**90**
5 PM	Commercial	494	152	26	49
	Commuting	0	0	0	0
	Educational	10	3	1	1
	Hotels	1	0	0	0
	Industrial	76	23	4	7
	Other-Residential	127	33	4	7
	Single Family	77	17	1	2
	Total	**785**	**229**	**35**	**67**

Economic Loss

The total economic loss estimated for the earthquake is 1,310.63 (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 1,150.68 (millions of dollars); 13 % 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 51 % 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	2.45	43.02	2.09	3.16	50.72
	Capital-Related	0.00	1.04	37.44	1.53	1.16	41.17
	Rental	10.27	20.13	19.59	0.80	1.51	52.29
	Relocation	1.18	0.62	1.09	0.07	0.51	3.47
	Subtotal	**11.45**	**24.23**	**101.14**	**4.49**	**6.34**	**147.65**
Capital Stock Loses							
	Structural	54.39	39.13	57.54	14.03	9.68	174.77
	Non_Structural	209.37	160.93	155.67	51.51	35.46	612.94
	Content	55.41	31.54	68.41	32.40	17.48	205.23
	Inventory	0.00	0.00	3.15	6.65	0.29	10.09
	Subtotal	**319.16**	**231.60**	**284.77**	**104.59**	**62.91**	**1,003.03**
	Total	**330.61**	**255.83**	**385.92**	**109.07**	**69.25**	**1,150.68**

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	1,421.20	$4.44	0.31
	Bridges	1,732.06	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Subtotal	**3153.30**	**4.40**	
Railways	Segments	209.93	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.65	26.32
	Subtotal	**212.40**	**0.60**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	1.23	$0.34	27.99
	Subtotal	**1.20**	**0.30**	
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	160.12	$22.00	13.74
	Runways	913.13	$1.09	0.12
	Subtotal	**1073.30**	**23.10**	
	Total	**4440.10**	**28.50**	

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	150.50	$12.57	8.35
	Distribution Line	191.20	$5.62	2.94
	Subtotal	**341.69**	**$18.19**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	752.60	$83.55	11.10
	Distribution Line	114.70	$4.44	3.87
	Subtotal	**867.29**	**$88.00**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.20	$0.10	8.25
	Distribution Line	76.50	$4.75	6.21
	Subtotal	**77.70**	**$4.85**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	372.90	$20.33	5.45
	Subtotal	**372.90**	**$20.33**	
Communication	Facilities	0.80	$0.07	8.32
	Subtotal	**0.79**	**$0.07**	
	Total	**1,660.38**	**$131.43**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(65)	-6.90
Second Year			
	Employment Impact	0	0.00
	Income Impact	(85)	-9.04
Third Year			
	Employment Impact	0	0.00
	Income Impact	(93)	-9.92
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(93)	-9.92
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(93)	-9.92
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(93)	-9.92

Appendix A: County Listing for the Region

Linn, OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Linn	103,069	4,821	847	5,669
Total State		**103,069**	**4,821**	**847**	**5,669**
Total Region		**103,069**	**4,821**	**847**	**5,669**

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

APPENDIX E: MARION COUNTY

CRUSTAL EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

SUBDUCTION ZONE EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

GEOLOGIC HAZARD MAPS
- Relative Ground-Shaking Amplification Susceptibility Map
- Relative Liquefaction Hazard Susceptibility Map
- Relative Earthquake-induced Landslide Susceptibility Map
- Identified Landslide Areas Map

HAZUS-MH GLOBAL REPORT FOR CRUSTAL SCENARIO
HAZUS-MH GLOBAL REPORT FOR SUBDUCTION ZONE SCENARIO

CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR MARION COUNTY

Crustal Earthquake Scenario: A magnitude 6.9 earthquake on the Mount Angel Fault.

For the magnitude 6.9 earthquake on the Mount Angel Fault scenario, we defined the fault source using the "deterministic seismic source" option within HAZUS-MH (Figure E1) (FEMA, 2003b). The fault and earthquake event were chosen by examination of USGS (2004) data and data in the Geomatrix Consultants, Inc. (1995) *Seismic Design Mapping, State of Oregon* report prepared for the Oregon Department of Transportation. In general, a likely worst-case scenario was selected. Figure E1 has the location of the fault, shown as the dark line, and the census tracts within Marion County. Figure E2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Mount Angel M6.9
Type of Earthquake	Source
Fault Name	Mount Angel Fault
Historical Epicenter ID #	67
Probabilistic Return Period	NA
Longitude of Epicenter	–122.83
Latitude of Epicenter	45.05
Earthquake Magnitude	6.90
Depth (km)	0.00
Rupture Length (km)	30.69
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

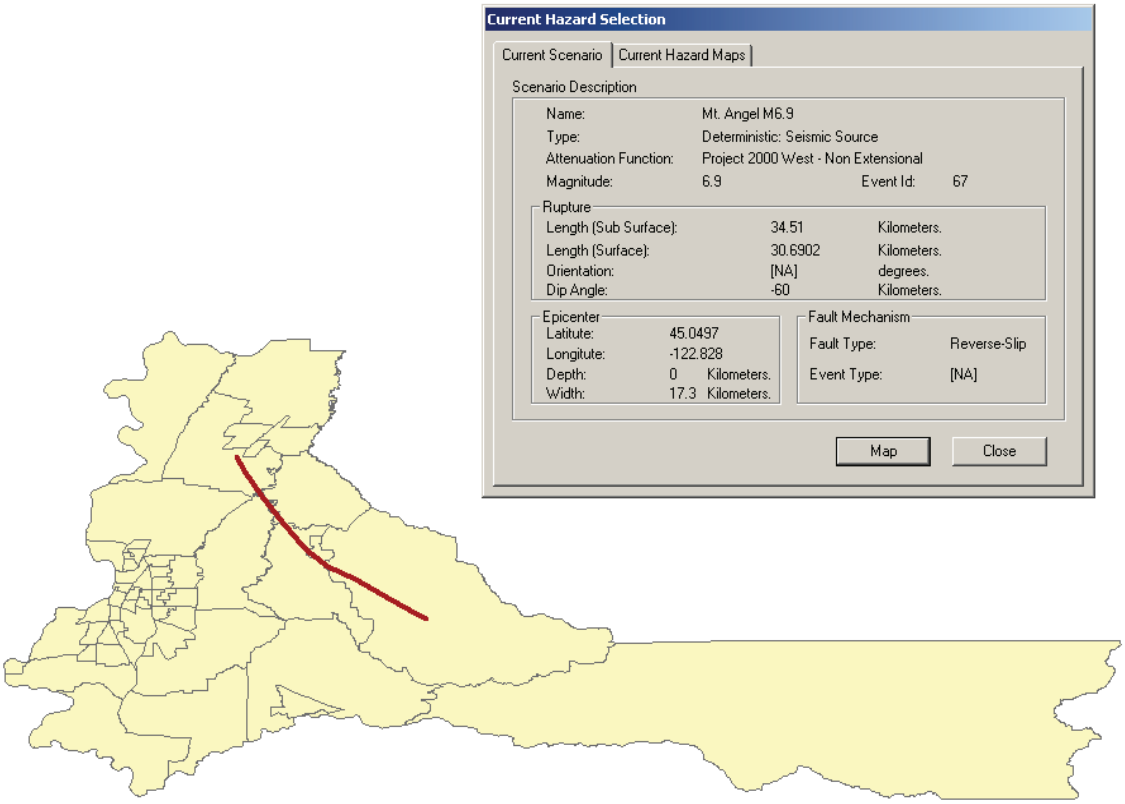

Figure E1. Mount Angel Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dark line.

Crustal Earthquake Scenario Ground Motion Map

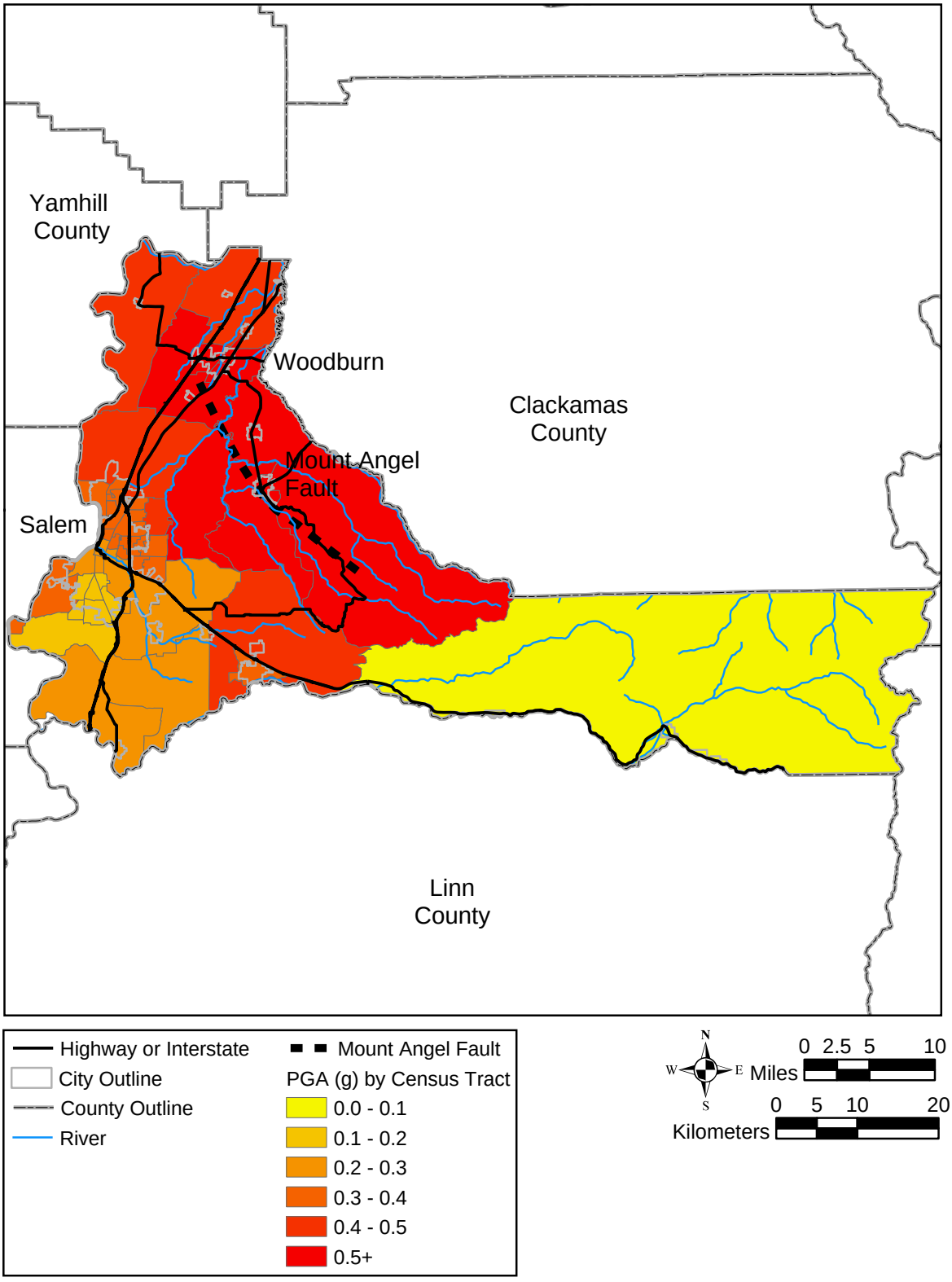

Figure E2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, Marion County, Oregon (FEMA, 2003b)

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR MARION COUNTY

Subduction Zone Scenario: A magnitude 9.0 earthquake on the Cascadia Subduction Zone was selected for the subduction zone earthquake scenario.

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by the Cascadia Region Earthquake Workgroup (CREW, 2003) to model damage and loss from a magnitude 9.0 earthquake (Figure E3). The CREW maps were developed from ground motion data provided by the U.S. Geological Survey. The CREW earthquake scenario required the input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 s and 1.0 s (CREW, 2003). Figure E4 displays the PGA for the subduction zone scenario.

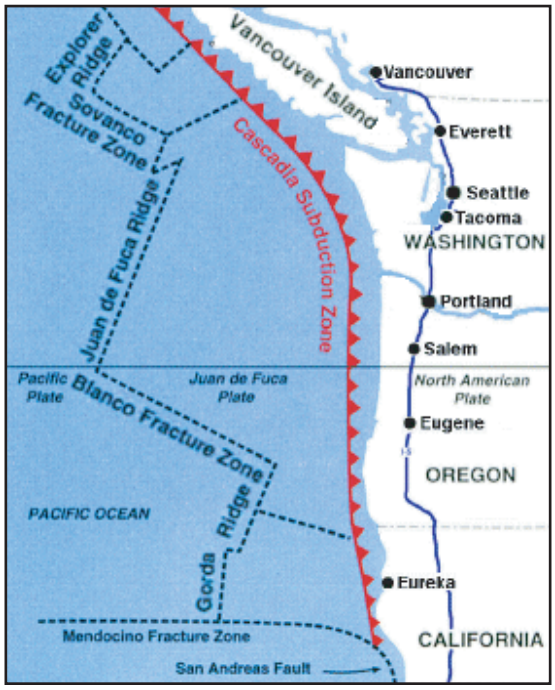

Figure E3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

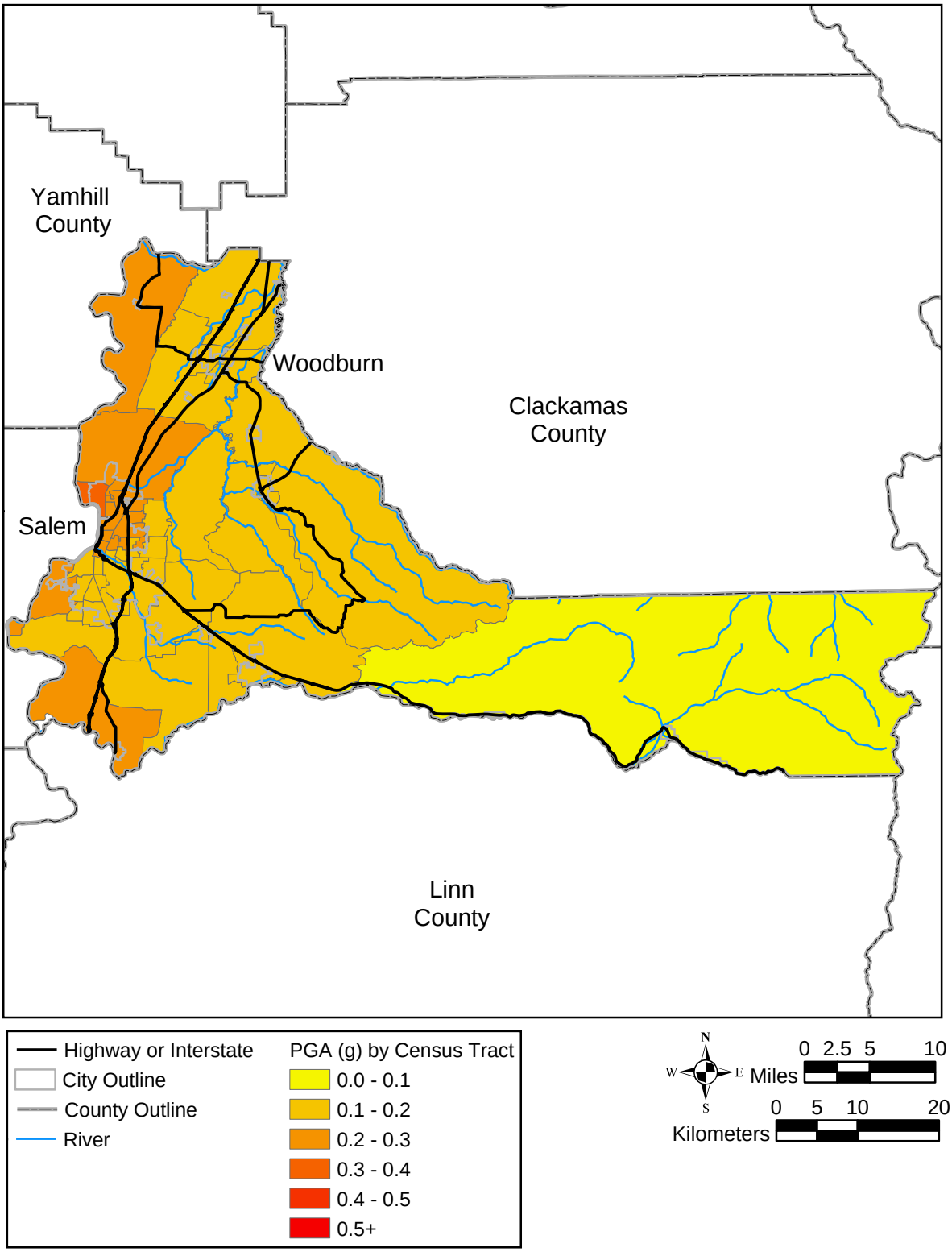

Figure E4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, Marion County, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS

Relative Ground-Shaking Amplification Susceptibility Map

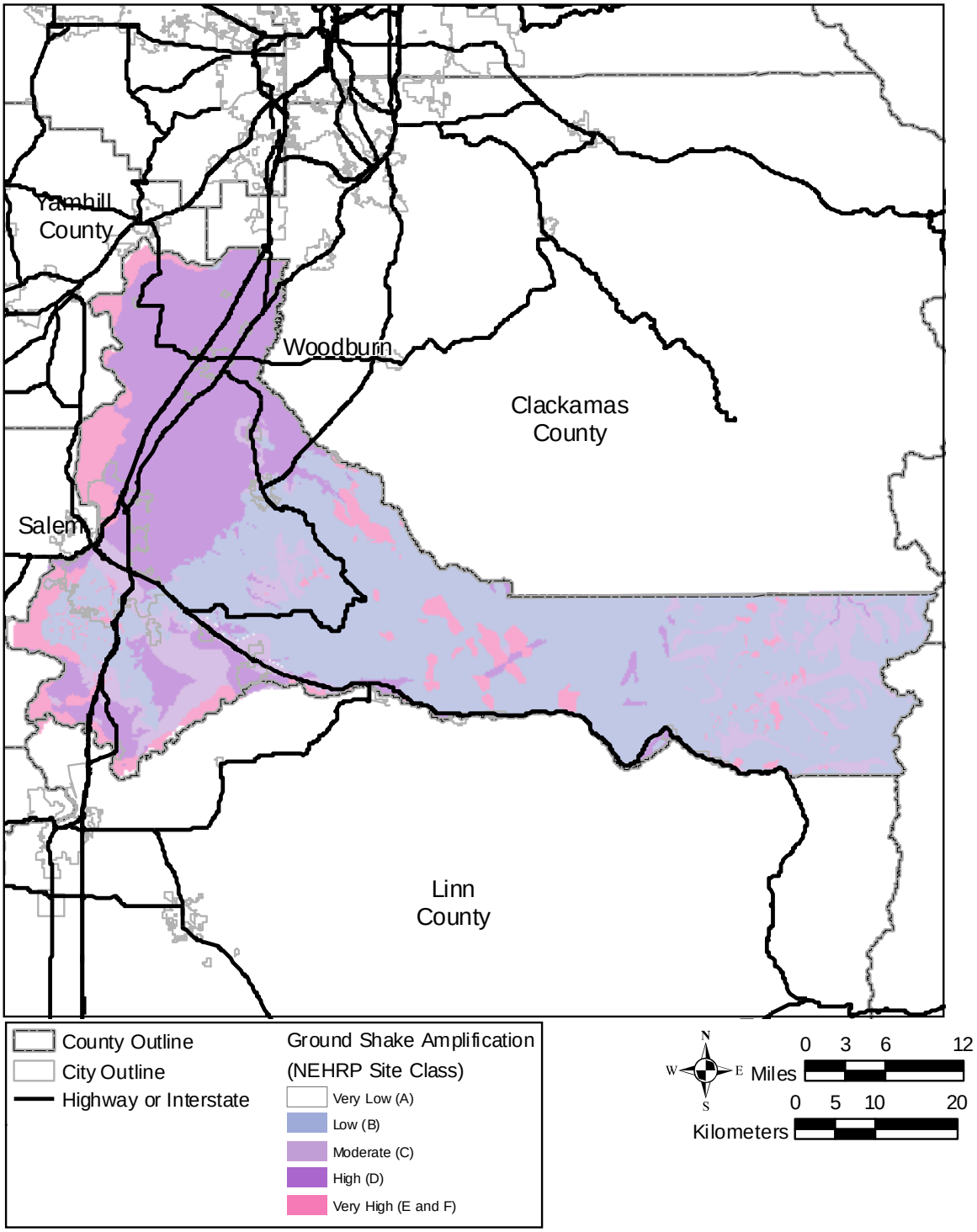

Figure E5. Relative ground-shaking amplification susceptibility map for Marion County, Oregon.

Relative Liquefaction Hazard Susceptibility Map

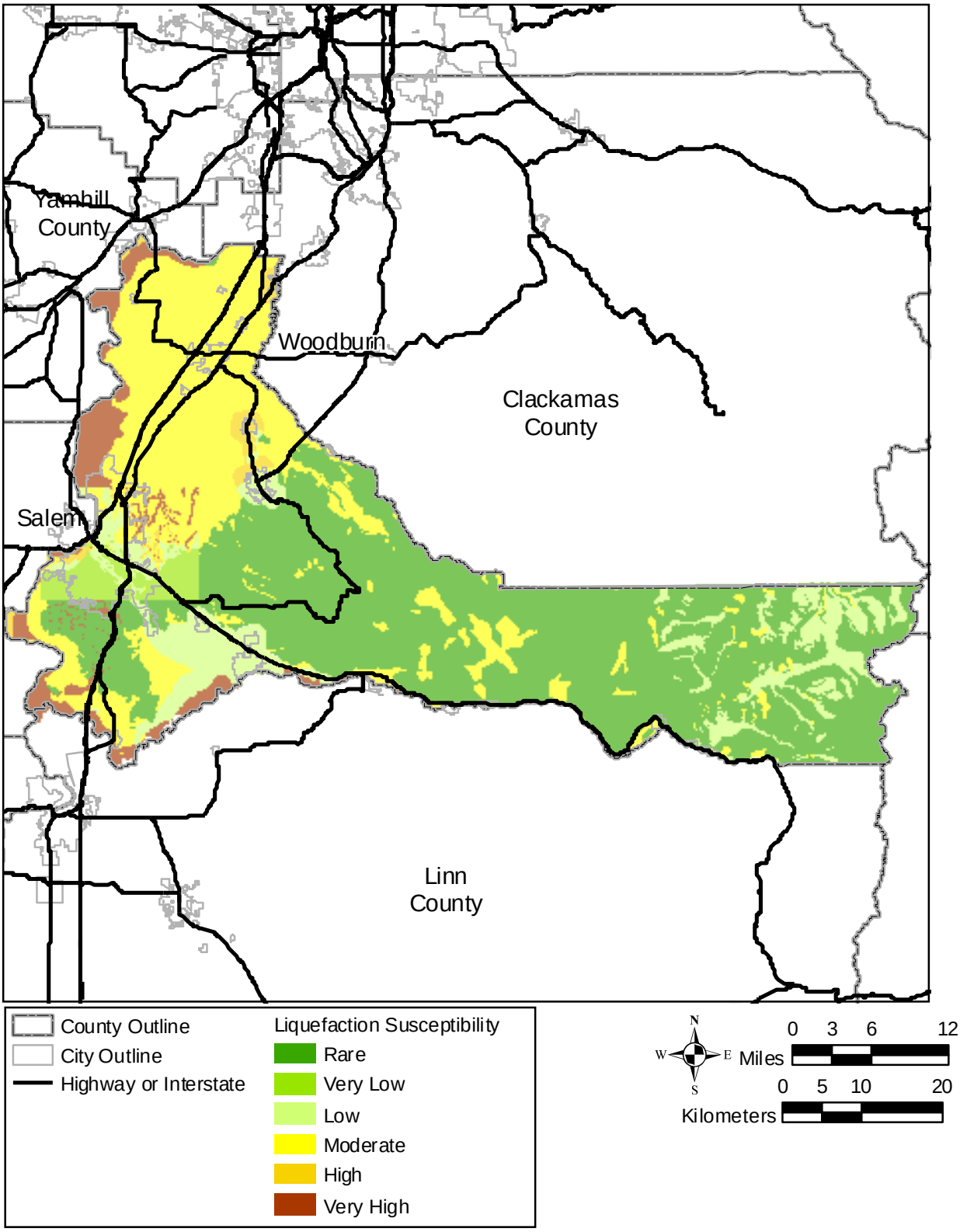

Figure E6. Relative liquefaction susceptibility map for Marion County, Oregon.

Relative Earthquake-induced Landslide Susceptibility Map

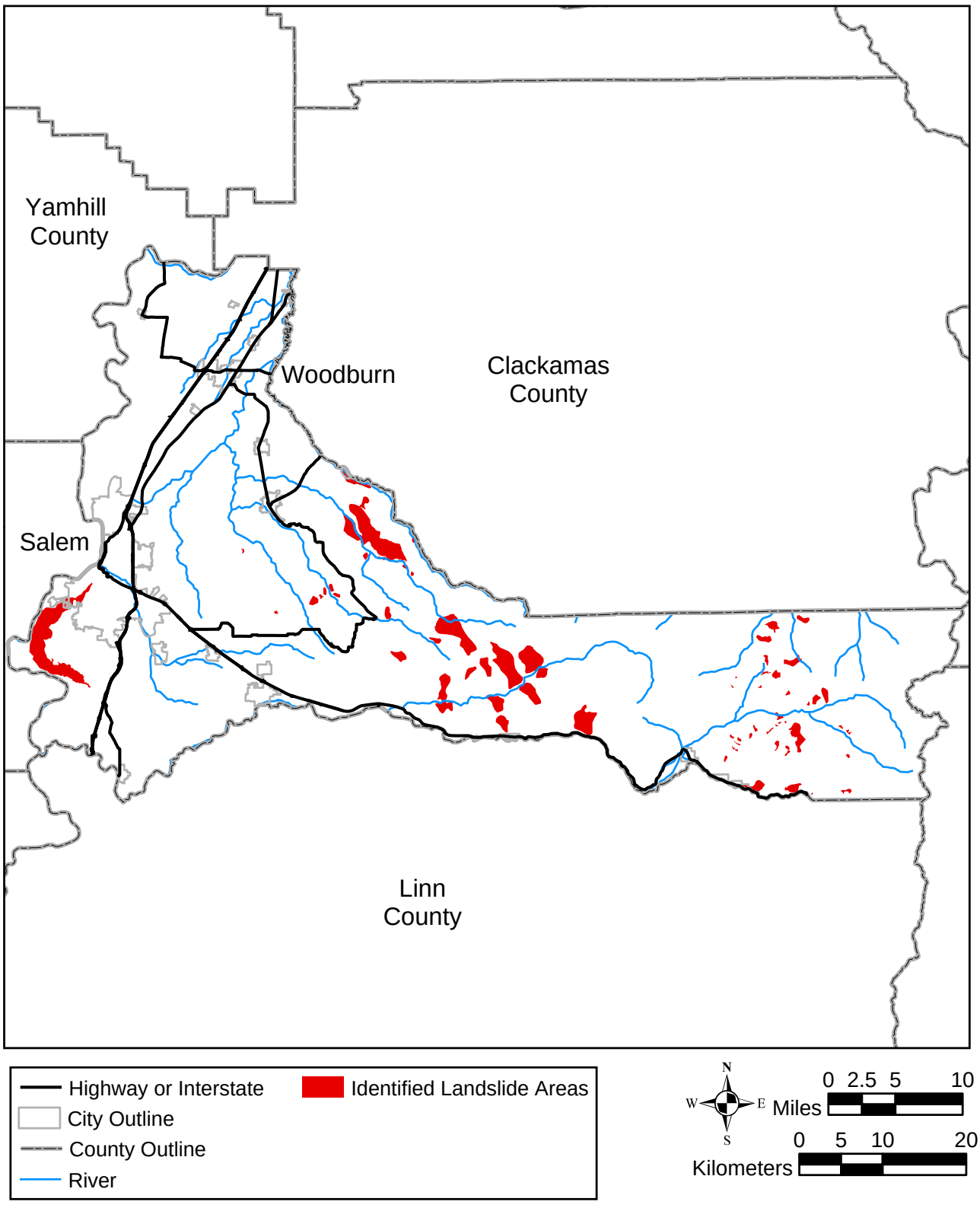

Figure E7. Relative earthquake-induced landslide susceptibility map for Marion County, Oregon.

Identified Landslide Areas Map

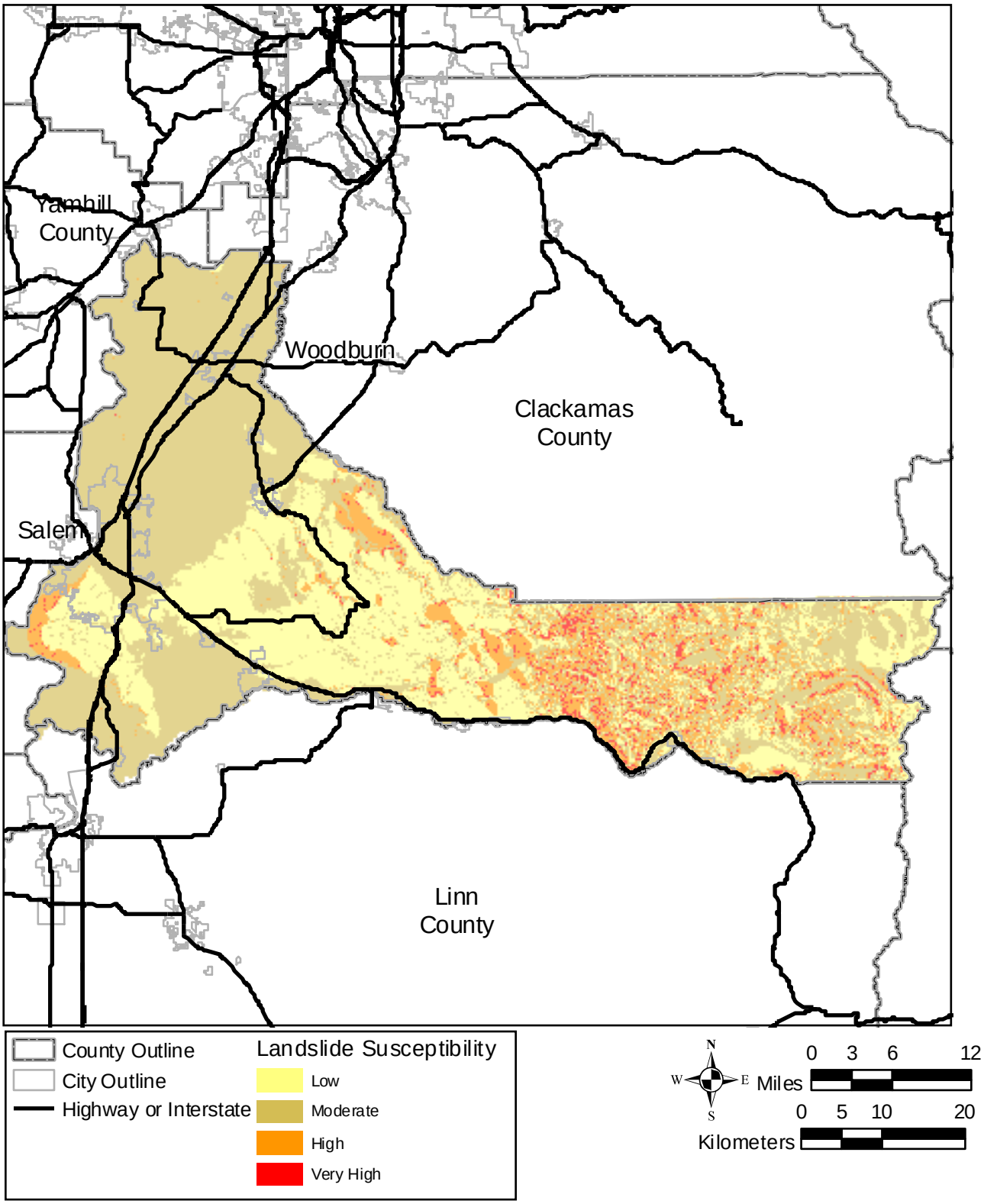

Figure E8. Identified landslide map for Marion County, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Marion Crustal***

Earthquake Scenario: ***Mt. Angel M6.9***

Print Date: ***March 14, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 1,191.16 square miles and contains 51 census tracts. There are over 101 thousand households in the region and has a total population of 284,834 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 87 thousand buildings in the region with a total building replacement value (excluding contents) of 15,860 (millions of dollars). Approximately 99.00 % of the buildings (and 85.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 4,945 and 1,341 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 87 thousand buildings in the region which have an aggregate total replacement value of 15,860 (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 85% 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 5 hospitals in the region with a total bed capacity of 1,078 beds. There are 140 schools, 18 fire stations, 20 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 29 dams identified within the region. Of these, 3 of the dams are classified as 'high hazard'. The inventory also includes 37 hazardous material sites, 0 military installations and 0 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 6,286.00 (millions of dollars). This inventory includes over 347 kilometers of highways, 161 bridges, 11,650 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	161	2,826.40
	Segments	87	1,289.10
	Tunnels	0	0.00
		Subtotal	**4,115.50**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	72	170.10
	Tunnels	0	0.00
		Subtotal	**172.50**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	3	3.70
		Subtotal	**3.70**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	15	92.40
	Runways	16	561.90
		Subtotal	**654.30**
		Total	**4,946.00**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	116.50
	Facilities	3	112.90
	Pipelines	0	0.00
		Subtotal	**229.40**
Waste Water	Distribution Lines	NA	69.90
	Facilities	13	978.40
	Pipelines	0	0.00
		Subtotal	**1,048.30**
Natural Gas	Distribution Lines	NA	46.60
	Facilities	1	1.20
	Pipelines	0	0.00
		Subtotal	**47.80**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	2	248.60
		Subtotal	**248.60**
Communication	Facilities	5	0.60
		Subtotal	**0.60**
		Total	**1,574.70**

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	Mt. Angel M6.9
Type of Earthquake	Source
Fault Name	Mount Angel Fault
Historical Epicenter ID #	67
Probabilistic Return Period	NA
Longitude of Epicenter	-122.83
Latitude of Epicenter	45.05
Earthquake Magnitude	6.90
Depth (Km)	0.00
Rupture Length (Km)	30.69
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 37,487 thousand buildings will be at least moderately damaged. This is over 43.00 % of the total number of buildings in the region. There are an estimated 7,958 buildings that will be completely destroyed. 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	5	0.02	7	0.03	11	0.05	10	0.11	11	0.14
Commercial	119	0.42	104	0.48	196	0.96	173	1.91	173	2.17
Education	0	0.00	0	0.00	1	0.01	1	0.01	1	0.01
Government	14	0.05	11	0.05	17	0.09	11	0.12	6	0.08
Industrial	12	0.04	11	0.05	25	0.12	27	0.29	30	0.37
Other Residential	2,231	7.77	2,009	9.23	3,479	17.00	3,303	36.43	2,872	36.09
Religion	8	0.03	6	0.03	8	0.04	6	0.06	5	0.06
Single Family	26,306	91.67	19,622	90.13	16,724	81.73	5,537	61.07	4,861	61.08
Total	**28,696**		**21,772**		**20,462**		**9,067**		**7,958**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	73	0.02	3	0.01	8	0.04	8	0.08	8	0.10
MH*	1,326	4.62	1276	5.86	2,797	13.67	2,976	32.83	2,552	32.06
Precast	21	0.04	9	0.04	25	0.12	32	0.35	30	0.38
RM*	10	0.03	5	0.02	12	0.06	15	0.16	12	0.14
Steel	60	0.02	5	0.02	15	0.07	22	0.24	31	0.38
UM*	215	0.75	181	0.83	292	1.43	266	2.93	361	4.53
Wood	26,993	93.97	20172	92.65	17,074	83.44	5,537	61.07	4,777	60.03
Total	**28,696**		**21,772**		**20,462**		**9,067**		**7,958**	

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

Essential Facility Damage

Before the earthquake, the region had 1,078 hospital beds available for use. On the day of the earthquake, the model estimates that only 321 hospital beds (30.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 58.00% of the beds will be back in service. By 30 days, 87.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	5	2	0	3
Schools	140	37	0	103
EOCs	2	0	0	2
PoliceStations	20	7	0	13
FireStations	18	7	0	11

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	87	0	0	87	87
	Bridges	161	23	12	138	145
	Tunnels	0	0	0	0	0
Railways	Segments	72	0	0	72	72
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	0	0	1	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	0	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	15	8	0	12	15
	Runways	16	0	0	16	16

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	3	2	0	1	2
Waste Water	13	12	0	0	11
Natural Gas	1	1	0	0	1
Oil Systems	0	0	0	0	0
Electrical Power	2	2	0	0	2
Communication	5	5	0	3	5

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	5,825	1044	801
Waste Water	3,495	826	634
Natural Gas	2,330	883	677
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	101,641	64,244	61,206	54,250	222	0
Electric Power		21,496	14,356	7,030	1,842	28

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 18 ignitions that will burn about 0.17 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 336 people and burn about 14 (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 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 42.00% 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 (10,701 households to be displaced due to the earthquake. Of these, 2,730 people (out of a total population of 284,834 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	20	6	1	2
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	17	5	1	1
	Industrial	40	12	2	4
	Other-Residential	977	252	28	53
	Single Family	1,209	268	18	30
	Total	**2,263**	**544**	**50**	**90**
2 PM	Commercial	1,466	441	72	141
	Commuting	1	1	2	0
	Educational	516	157	26	50
	Hotels	3	1	0	0
	Industrial	292	89	15	29
	Other-Residential	226	59	7	13
	Single Family	279	62	5	7
	Total	**2,784**	**811**	**127**	**240**
5 PM	Commercial	1,290	390	65	123
	Commuting	23	32	52	10
	Educational	47	14	2	4
	Hotels	5	2	0	0
	Industrial	183	56	9	18
	Other-Residential	371	97	11	20
	Single Family	484	108	9	12
	Total	**2,403**	**698**	**148**	**189**

Economic Loss

The total economic loss estimated for the earthquake is 4,728.50 (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 3,979.57 (millions of dollars); 10 % 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 69 % 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	14.74	99.38	4.99	5.28	124.38
	Capital-Related	0.00	6.25	91.43	2.98	1.84	102.51
	Rental	60.72	65.72	45.97	1.84	2.53	176.78
	Relocation	6.67	1.74	2.44	0.13	0.73	11.70
	Subtotal	**67.39**	**88.46**	**239.22**	**9.94**	**10.37**	**415.37**
Capital Stock Loses							
	Structural	321.27	114.03	124.46	27.43	34.73	621.91
	Non_Structural	1,211.44	514.06	342.90	102.87	68.82	2,240.10
	Content	307.69	109.90	157.52	65.56	36.60	677.27
	Inventory	0.00	0.00	6.93	15.33	2.64	24.91
	Subtotal	**1,840.40**	**738.00**	**631.81**	**211.20**	**142.79**	**3,564.19**
	Total	**1,907.78**	**826.45**	**871.03**	**221.14**	**153.17**	**3,979.57**

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	1,289.06	$31.71	2.46
	Bridges	2,826.41	$239.77	8.48
	Tunnels	0.00	$0.00	0.00
	Subtotal	**4115.50**	**271.50**	
Railways	Segments	170.07	$3.74	2.20
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.53	21.54
	Subtotal	**172.50**	**4.30**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.70	$0.76	20.55
	Subtotal	**3.70**	**0.80**	
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	92.38	$31.60	34.21
	Runways	561.93	$6.41	1.14
	Subtotal	**654.30**	**38.00**	
	Total	**4946.00**	**314.50**	

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	112.90	$32.30	28.62
	Distribution Line	116.50	$20.20	17.34
	Subtotal	**229.39**	**$52.50**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	978.40	$285.02	29.13
	Distribution Line	69.90	$15.97	22.85
	Subtotal	**1,048.26**	**$301.00**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.20	$0.36	29.47
	Distribution Line	46.60	$17.08	36.64
	Subtotal	**47.83**	**$17.44**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	248.60	$63.30	25.46
	Subtotal	**248.60**	**$63.30**	
Communication	Facilities	0.60	$0.18	31.06
	Subtotal	**0.57**	**$0.18**	
	Total	**1,574.65**	**$434.41**	

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

	LOSS	Total	%
First Year			
	Employment Impact	1,043	1.61
	Income Impact	(161)	-4.39
Second Year			
	Employment Impact	412	0.64
	Income Impact	(235)	-6.40
Third Year			
	Employment Impact	9	0.01
	Income Impact	(266)	-7.27
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(267)	-7.29
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(267)	-7.29
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(267)	-7.29

Appendix A: County Listing for the Region

Marion,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Marion	284,834	13,461	2,399	15,860
Total State		**284,834**	**13,461**	**2,399**	**15,860**
Total Region		**284,834**	**13,461**	**2,399**	**15,860**

HAZUS-MH: Earthquake Event Report

Region Name: ***Marion Cascadia***

Earthquake Scenario: ***Cascadia M8.5***

Print Date: ***March 14, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 1,191.16 square miles and contains 51 census tracts. There are over 101 thousand households in the region and has a total population of 284,834 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 87 thousand buildings in the region with a total building replacement value (excluding contents) of 15,860 (millions of dollars). Approximately 99.00 % of the buildings (and 85.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 4,945 and 1,341 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 87 thousand buildings in the region which have an aggregate total replacement value of 15,860 (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 85% 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 5 hospitals in the region with a total bed capacity of 1,078 beds. There are 140 schools, 18 fire stations, 20 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 29 dams identified within the region. Of these, 3 of the dams are classified as 'high hazard'. The inventory also includes 37 hazardous material sites, 0 military installations and 0 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 6,286.00 (millions of dollars). This inventory includes over 347 kilometers of highways, 161 bridges, 11,650 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	161	2,826.40
	Segments	87	1,289.10
	Tunnels	0	0.00
		Subtotal	**4,115.50**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	72	170.10
	Tunnels	0	0.00
		Subtotal	**172.50**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	3	3.70
		Subtotal	**3.70**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	15	92.40
	Runways	16	561.90
		Subtotal	**654.30**
		Total	**4,946.00**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	116.50
	Facilities	3	112.90
	Pipelines	0	0.00
		Subtotal	**229.40**
Waste Water	Distribution Lines	NA	69.90
	Facilities	13	978.40
	Pipelines	0	0.00
		Subtotal	**1,048.30**
Natural Gas	Distribution Lines	NA	46.60
	Facilities	1	1.20
	Pipelines	0	0.00
		Subtotal	**47.80**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	2	248.60
		Subtotal	**248.60**
Communication	Facilities	5	0.60
		Subtotal	**0.60**
		Total	**1,574.70**

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	Cascadia M8.5
Type of Earthquake	User-defined
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 21,700 thousand buildings will be at least moderately damaged. This is over 25.00 % of the total number of buildings in the region. There are an estimated 4,629 buildings that will be completely destroyed. 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	12	0.03	7	0.03	8	0.07	8	0.15	8	0.16
Commercial	94	0.21	101	0.48	199	1.68	192	3.66	179	3.87
Education	0	0.00	0	0.00	1	0.01	1	0.02	1	0.02
Government	8	0.02	8	0.04	16	0.14	16	0.31	12	0.26
Industrial	8	0.02	10	0.05	26	0.22	31	0.59	30	0.66
Other Residential	2,197	4.89	2,016	9.46	3,464	29.32	3,583	68.19	2,634	56.90
Religion	8	0.02	5	0.02	7	0.06	7	0.13	6	0.13
Single Family	42,606	94.82	19,173	89.92	8,095	68.51	1,415	26.94	1,759	38.00
Total	**44,933**		**21,322**		**11,817**		**5,254**		**4,629**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	40	0.00	2	0.01	7	0.06	10	0.19	11	0.24
MH*	815	1.81	1318	6.18	3,030	25.64	3,353	63.81	2,411	52.08
Precast	11	0.02	7	0.03	24	0.20	35	0.67	35	0.76
RM*	6	0.01	4	0.02	13	0.11	17	0.33	13	0.28
Steel	24	0.00	2	0.01	12	0.10	23	0.44	39	0.85
UM*	281	0.62	254	1.19	341	2.88	235	4.47	203	4.39
Wood	43,757	97.34	19639	92.11	8,153	69.00	1,318	25.09	1,676	36.21
Total	**44,933**		**21,322**		**11,817**		**5,254**		**4,629**	

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

Essential Facility Damage

Before the earthquake, the region had 1,078 hospital beds available for use. On the day of the earthquake, the model estimates that only 424 hospital beds (39.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 65.00% of the beds will be back in service. By 30 days, 93.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	5	2	0	3
Schools	140	2	0	138
EOCs	2	0	0	2
PoliceStations	20	0	0	20
FireStations	18	0	0	18

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	87	0	0	87	87
	Bridges	161	17	0	144	158
	Tunnels	0	0	0	0	0
Railways	Segments	72	0	0	72	72
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	0	0	1	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	0	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	15	0	0	15	15
	Runways	16	0	0	16	16

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	3	0	0	3	3
Waste Water	13	1	0	9	13
Natural Gas	1	0	0	1	1
Oil Systems	0	0	0	0	0
Electrical Power	2	0	0	2	2
Communication	5	0	0	5	5

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	5,825	435	230
Waste Water	3,495	344	182
Natural Gas	2,330	368	195
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	101,641	11,171	6,093	293	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 12 ignitions that will burn about 0.09 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 155 people and burn about 8 (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 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 33.00% 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 (5,787 households to be displaced due to the earthquake. Of these, 1,470 people (out of a total population of 284,834 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	21	6	1	2
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	11	3	1	1
	Industrial	36	11	2	3
	Other-Residential	787	202	23	44
	Single Family	435	94	6	11
	Total	**1,290**	**317**	**33**	**61**
2 PM	Commercial	1,411	425	71	138
	Commuting	0	0	1	0
	Educational	411	125	21	40
	Hotels	2	1	0	0
	Industrial	264	80	13	25
	Other-Residential	181	47	6	11
	Single Family	97	21	2	3
	Total	**2,367**	**699**	**113**	**218**
5 PM	Commercial	1,164	349	58	112
	Commuting	9	10	19	4
	Educational	46	14	2	5
	Hotels	3	1	0	0
	Industrial	165	50	8	16
	Other-Residential	294	76	9	17
	Single Family	173	38	3	4
	Total	**1,854**	**538**	**100**	**157**

Economic Loss

The total economic loss estimated for the earthquake is 2,868.62 (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 2,604.95 (millions of dollars); 14 % 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 53 % 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	13.45	103.83	5.10	6.10	128.48
	Capital-Related	0.00	5.70	96.51	3.05	1.69	106.94
	Rental	22.73	49.72	48.93	1.93	3.12	126.43
	Relocation	2.67	1.40	2.56	0.15	0.78	7.56
	Subtotal	**25.39**	**70.28**	**251.82**	**10.22**	**11.69**	**369.41**
Capital Stock Loses							
	Structural	122.58	98.02	130.29	28.79	31.78	411.46
	Non_Structural	480.99	386.77	336.66	97.18	65.10	1,366.70
	Content	128.03	75.41	141.95	59.95	30.63	435.97
	Inventory	0.00	0.00	6.16	13.58	1.68	21.42
	Subtotal	**731.60**	**560.21**	**615.06**	**199.49**	**129.19**	**2,235.54**
	Total	**756.99**	**630.49**	**866.88**	**209.71**	**140.88**	**2,604.95**

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	1,289.06	$2.71	0.21
	Bridges	2,826.41	$125.02	4.42
	Tunnels	0.00	$0.00	0.00
	Subtotal	**4115.50**	**127.70**	
Railways	Segments	170.07	$0.38	0.23
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.33	13.27
	Subtotal	**172.50**	**0.70**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.70	$0.52	14.09
	Subtotal	**3.70**	**0.50**	
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	92.38	$12.48	13.51
	Runways	561.93	$0.55	0.10
	Subtotal	**654.30**	**13.00**	
	Total	**4946.00**	**142.00**	

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	112.90	$6.40	5.67
	Distribution Line	116.50	$6.35	5.45
	Subtotal	**229.39**	**$12.74**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	978.40	$80.37	8.21
	Distribution Line	69.90	$5.02	7.18
	Subtotal	**1,048.26**	**$85.39**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.20	$0.07	5.97
	Distribution Line	46.60	$5.36	11.51
	Subtotal	**47.83**	**$5.44**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	248.60	$18.08	7.27
	Subtotal	**248.60**	**$18.08**	
Communication	Facilities	0.60	$0.03	5.95
	Subtotal	**0.57**	**$0.03**	
	Total	**1,574.65**	**$121.68**	

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

	LOSS	Total	%
First Year			
	Employment Impact	544	0.84
	Income Impact	(150)	-4.09
Second Year			
	Employment Impact	225	0.35
	Income Impact	(196)	-5.35
Third Year			
	Employment Impact	6	0.01
	Income Impact	(216)	-5.89
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(216)	-5.90
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(216)	-5.90
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(216)	-5.90

Appendix A: County Listing for the Region

Marion,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Marion	284,834	13,461	2,399	15,860
Total State		**284,834**	**13,461**	**2,399**	**15,860**
Total Region		**284,834**	**13,461**	**2,399**	**15,860**

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

APPENDIX F:
POLK COUNTY

CRUSTAL EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

SUBDUCTION ZONE EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

GEOLOGIC HAZARD MAPS
- Relative Ground-Shaking Amplification Susceptibility Map
- Relative Liquefaction Hazard Susceptibility Map
- Relative Earthquake-induced Landslide Susceptibility Map
- Identified Landslide Areas Map

HAZUS-MH GLOBAL REPORT FOR CRUSTAL SCENARIO
HAZUS-MH GLOBAL REPORT FOR SUBDUCTION ZONE SCENARIO

CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR POLK COUNTY

Crustal Earthquake Scenario: A magnitude 6.7 earthquake on the Mill Creek Fault.

For the magnitude 6.9 earthquake on the Mill Creek Fault scenario, we defined the fault source using the "deterministic seismic source" option within HAZUS-MH (Figure F1) (FEMA, 2003b) The fault and earthquake event were chosen by examination of USGS (2004) data and data in the Geomatrix Consultants, Inc. (1995) *Seismic Design Mapping, State of Oregon* report prepared for the Oregon Department of Transportation. In general, a likely worst-case scenario was selected. Figure F1 has the location of the fault, shown as the dark line, and the census tracts within Polk County. Figure F2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Mill Creek M6.7
Type of Earthquake	Source
Fault Name	Mill Creek Fault
Historical Epicenter ID #	70
Probabilistic Return Period	NA
Longitude of Epicenter	–123.015
Latitude of Epicenter	44.7428
Earthquake Magnitude	6.7
Depth (Km)	0.00
Rupture Length (Km)	27.11
Rupture Orientation (degrees)	0.00
Attenuation Function	Reverse-Slip

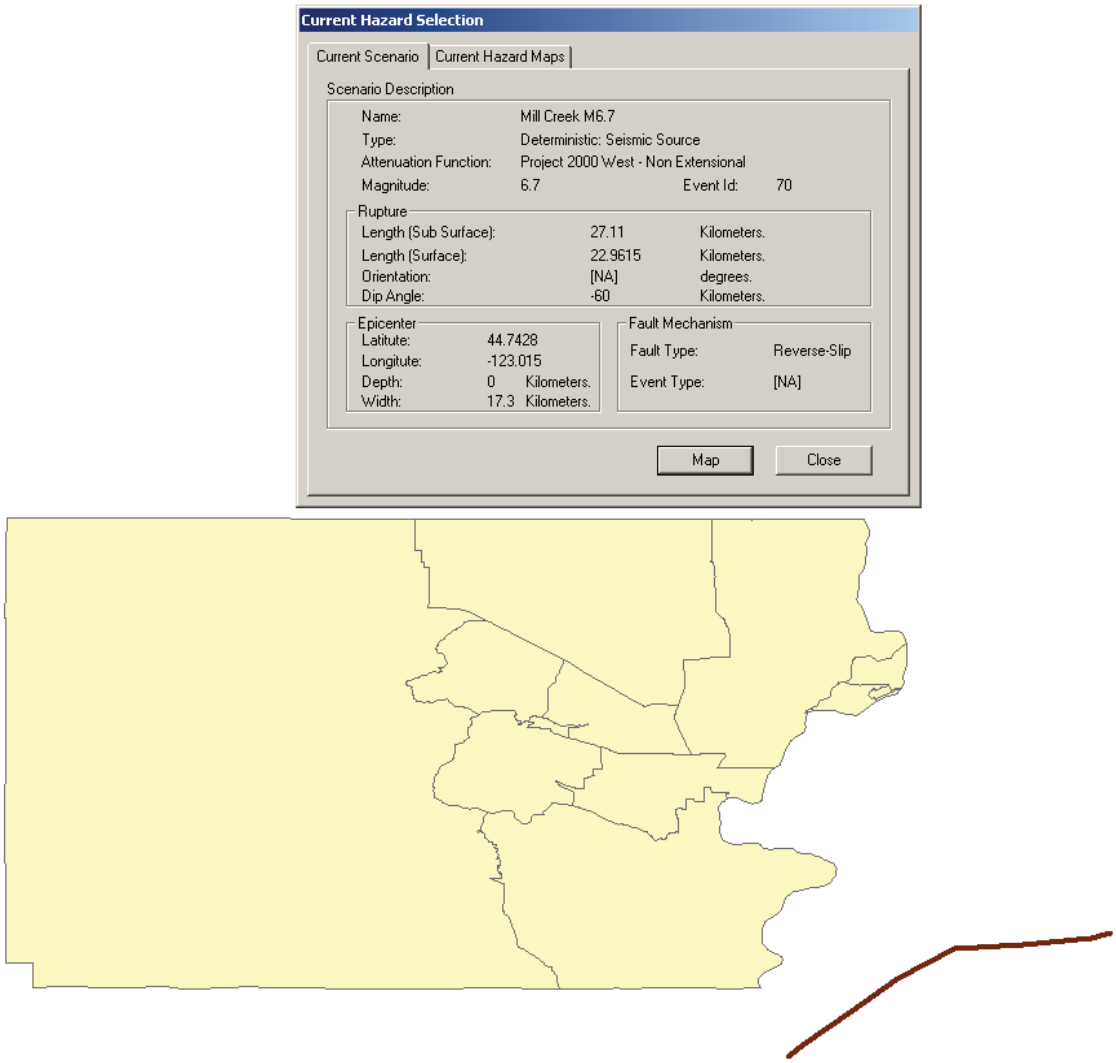

Figure F1. Mill Creek Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dark line.

Crustal Earthquake Scenario Ground Motion Map

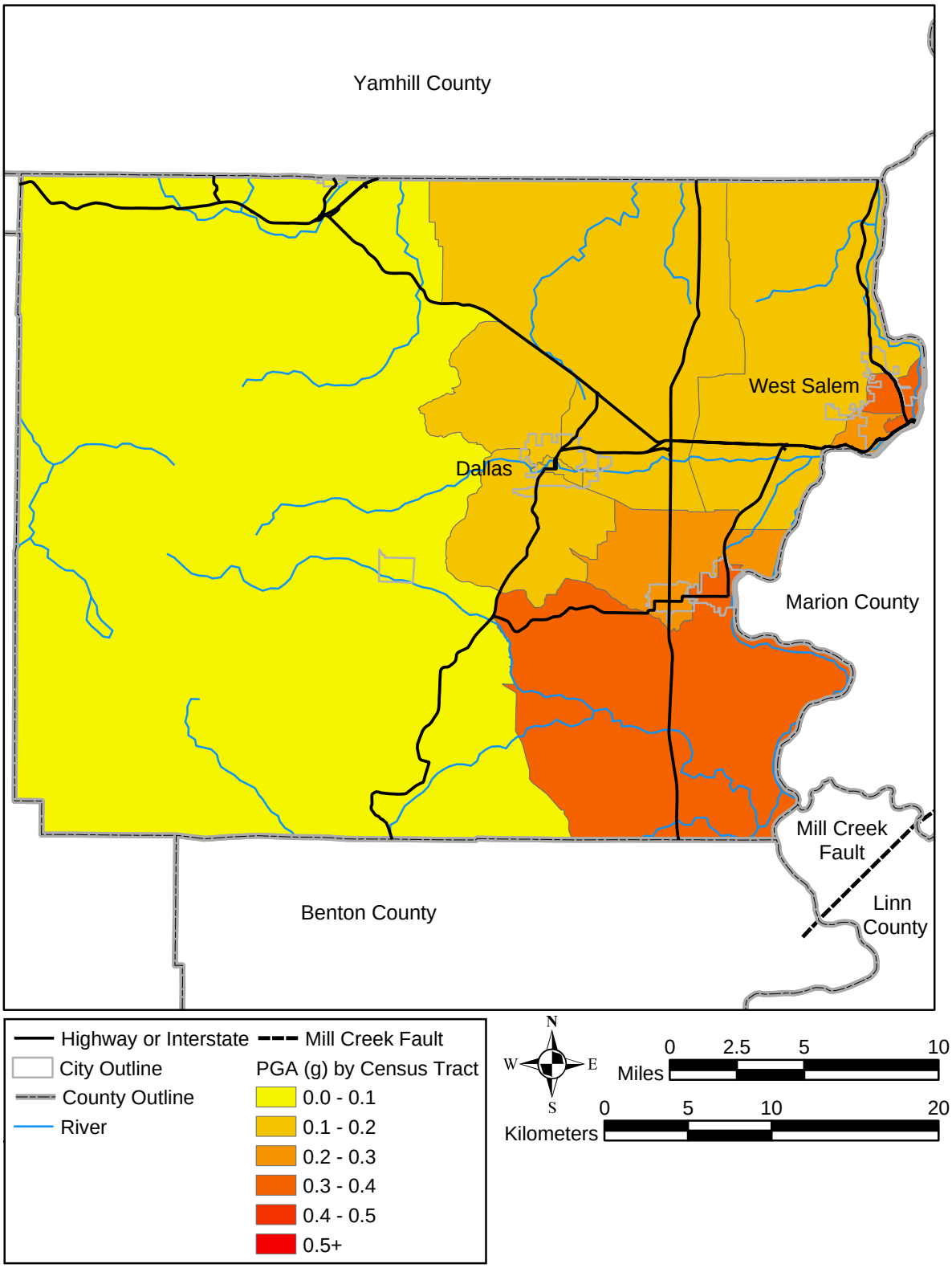

Figure F2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, Polk County, Oregon (FEMA, 2003b).

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR POLK COUNTY

Subduction Zone Scenario: A magnitude 9.0 earthquake on the Cascadia Subduction Zone was selected for the subduction zone earthquake scenario.

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by the Cascadia Region Earthquake Workgroup (CREW, 2003) to model damage and loss from a magnitude 9.0 earthquake (Figure F3). The CREW maps were developed from ground motion data provided by the U.S. Geological Survey. The CREW earthquake scenario required the input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 s and 1.0 s (CREW, 2003). Figure F4 displays the PGA for the subduction zone scenario.

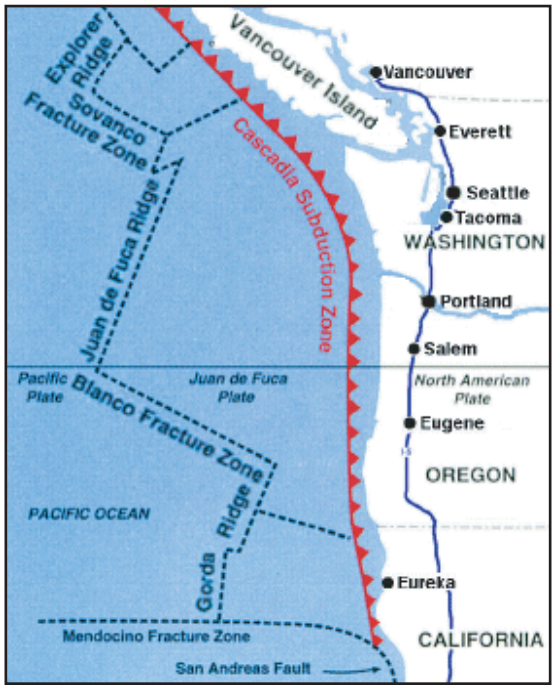

Figure F3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

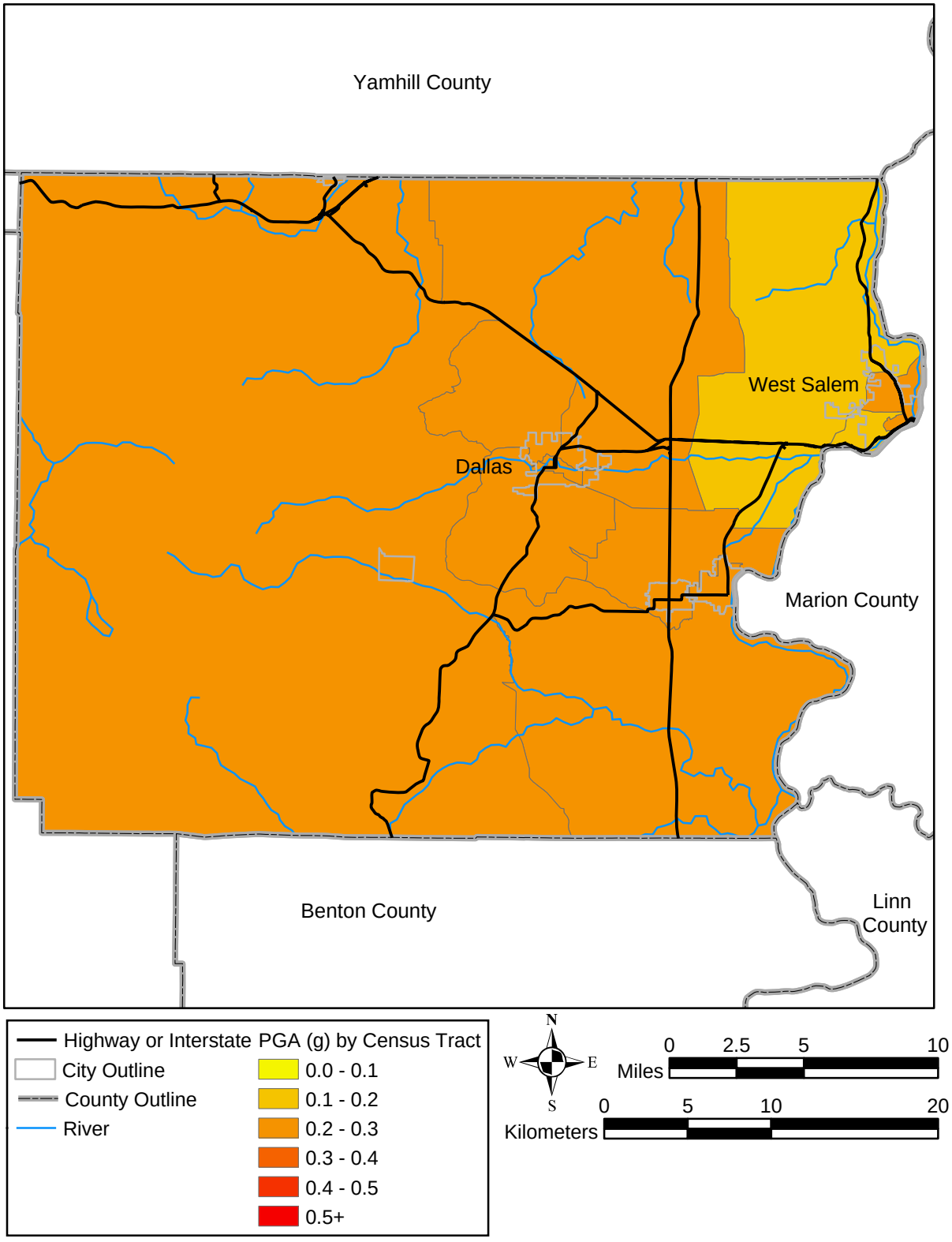

Figure F4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, Polk County, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS

Relative Ground-Shaking Amplification Susceptibility Map

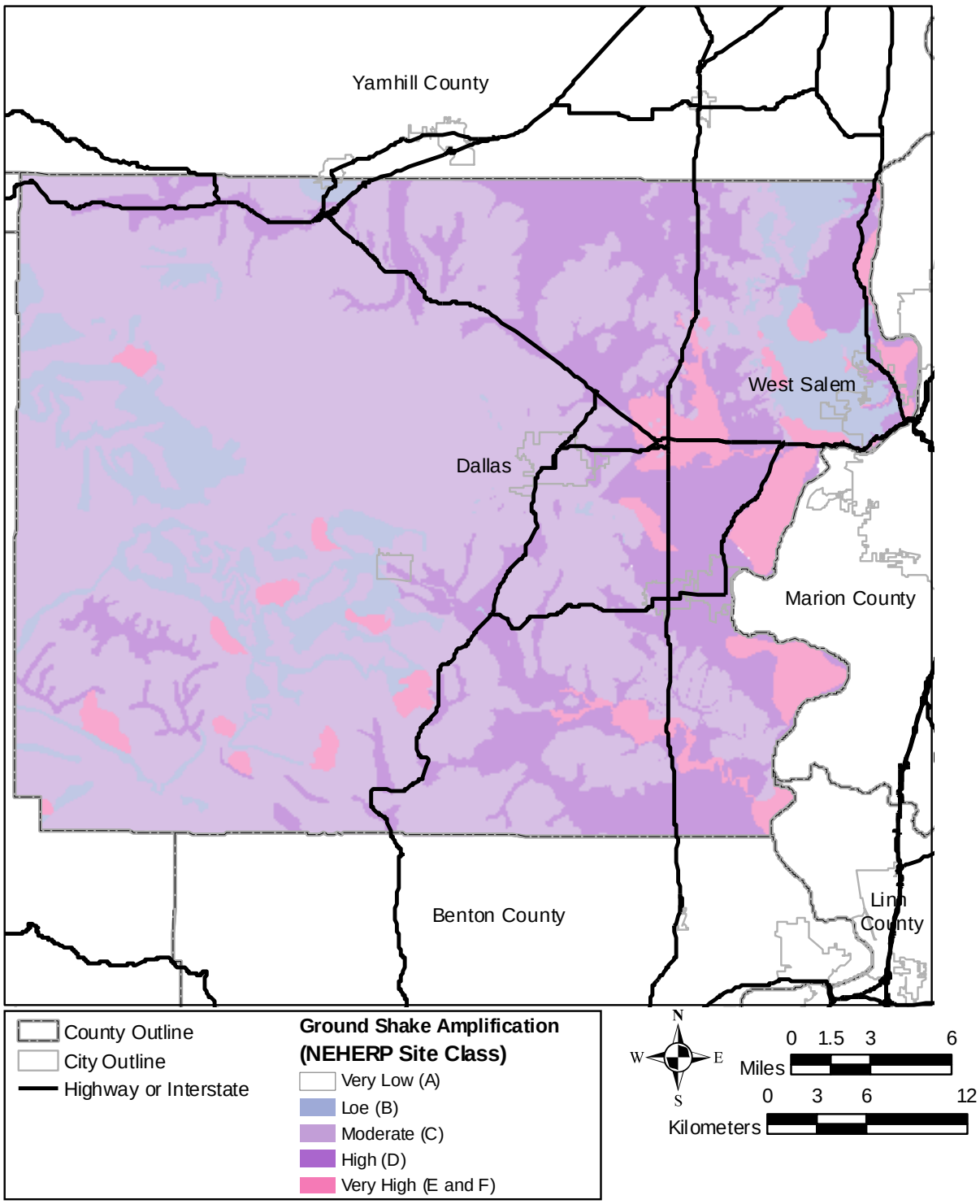

Figure F5. Relative ground-shaking amplification susceptibility map for Polk County, Oregon.

Relative Liquefaction Hazard Susceptibility Map

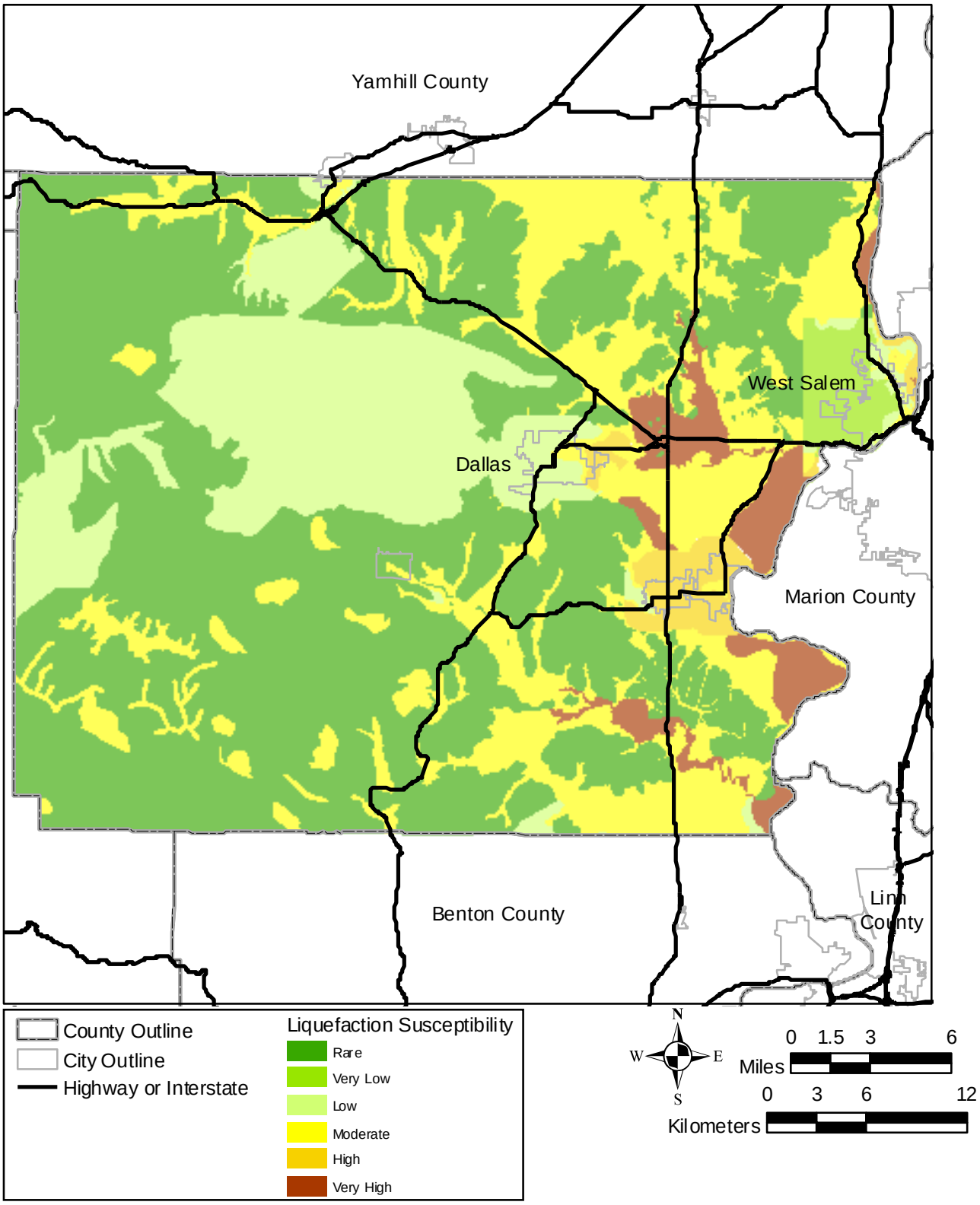

Figure F6. Relative liquefaction susceptibility map for Polk County, Oregon.

Relative Earthquake-induced Landslide Susceptibility Map

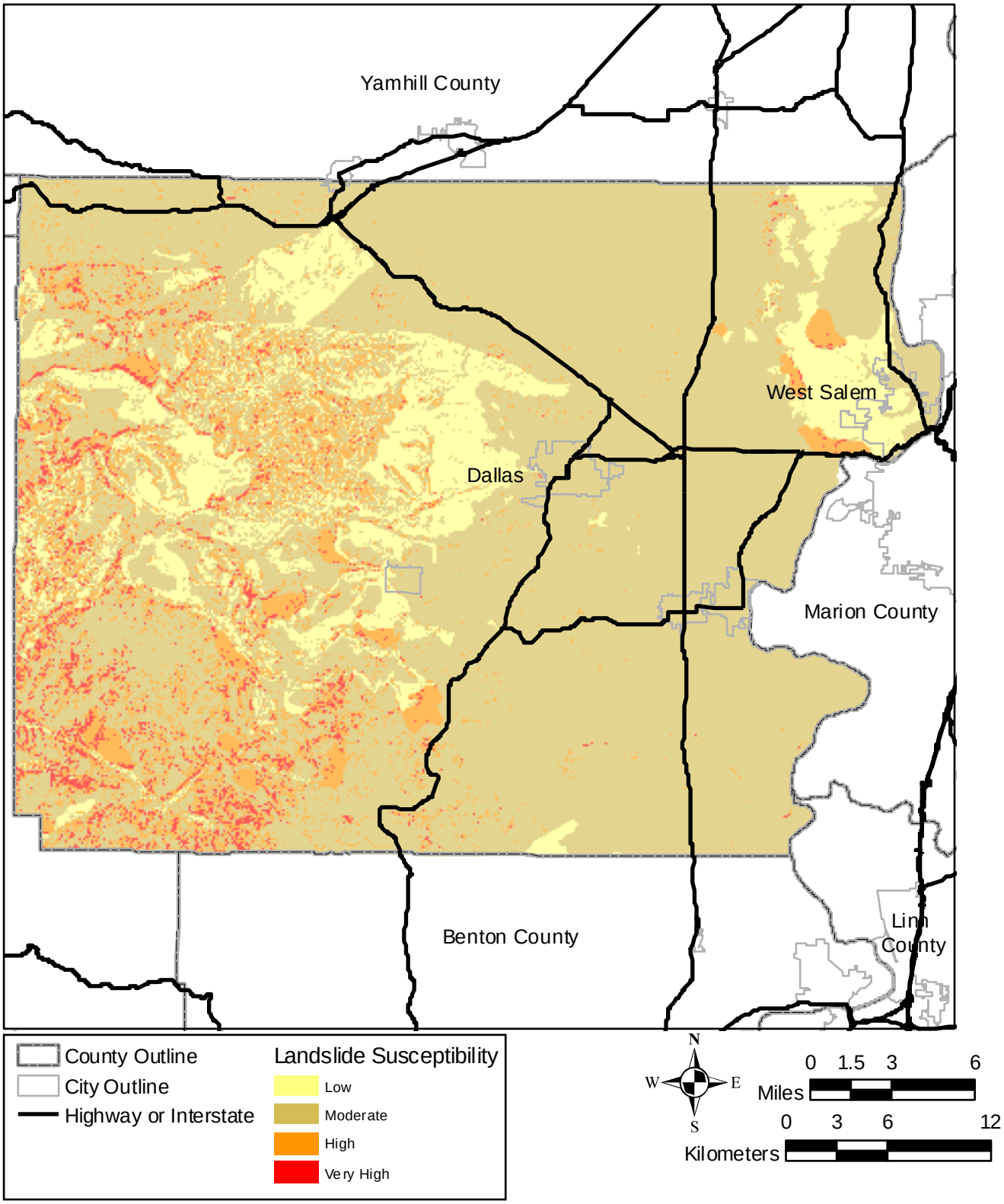

Figure F7. Relative earthquake-induced landslide susceptibility map for Polk County, Oregon.

Identified Landslide Areas Map

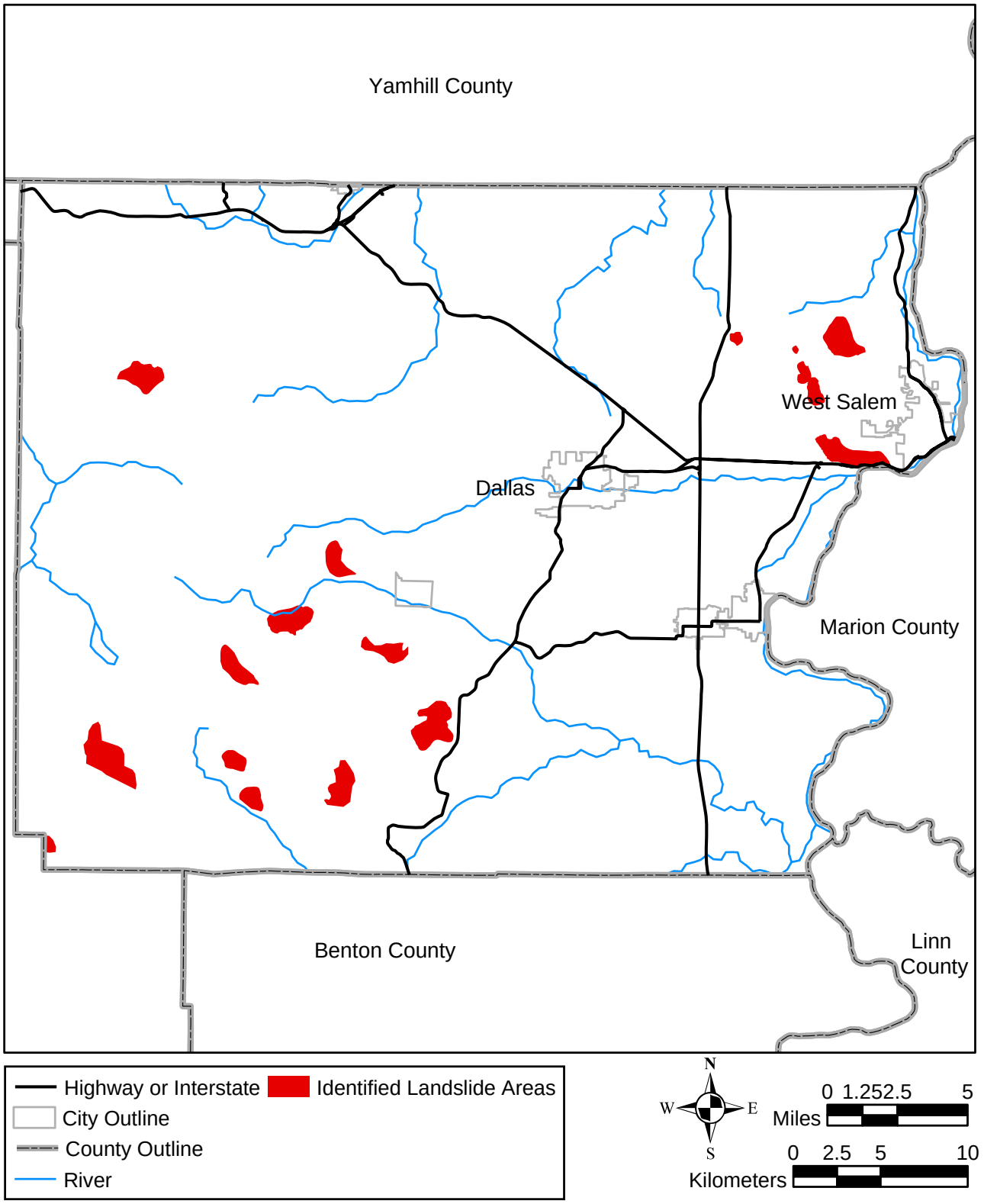

Figure F8. Identified landslide map for Polk County, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Polk Crustal***

Earthquake Scenario: ***Mill Creek M6.7***

Print Date: ***March 14, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 742.30 square miles and contains 12 census tracts. There are over 23 thousand households in the region and has a total population of 62,380 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 21 thousand buildings in the region with a total building replacement value (excluding contents) of 3,467 (millions of dollars). Approximately 100.00 % of the buildings (and 92.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,555 and 538 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 21 thousand buildings in the region which have an aggregate total replacement value of 3,467 (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 86% 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 1 hospitals in the region with a total bed capacity of 44 beds. There are 29 schools, 3 fire stations, 4 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 28 dams identified within the region. Of these, 1 of the dams are classified as 'high hazard'. The inventory also includes 12 hazardous material sites, 0 military installations and 0 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 2,093.00 (millions of dollars). This inventory includes over 185 kilometers of highways, 107 bridges, 6,868 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	107	632.30
	Segments	37	573.30
	Tunnels	0	0.00
		Subtotal	**1,205.60**
Railways	Bridges	0	0.00
	Facilities	0	0.00
	Segments	32	60.60
	Tunnels	0	0.00
		Subtotal	**60.60**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	0	0.00
		Subtotal	**0.00**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	7	43.10
	Runways	7	245.80
		Subtotal	**289.00**
		Total	**1,555.20**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	68.70
	Facilities	1	37.60
	Pipelines	0	0.00
		Subtotal	**106.30**
Waste Water	Distribution Lines	NA	41.20
	Facilities	5	376.30
	Pipelines	0	0.00
		Subtotal	**417.50**
Natural Gas	Distribution Lines	NA	27.50
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**27.50**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	4	0.50
		Subtotal	**0.50**
		Total	**676.00**

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	Mill Creek M6.7
Type of Earthquake	Source
Fault Name	Mill Creek Fault
Historical Epicenter ID #	70
Probabilistic Return Period	NA
Longitude of Epicenter	-123.01
Latitude of Epicenter	44.74
Earthquake Magnitude	6.70
Depth (Km)	0.00
Rupture Length (Km)	22.96
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 4,197 thousand buildings will be at least moderately damaged. This is over 20.00 % of the total number of buildings in the region. There are an estimated 940 buildings that will be completely destroyed. 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	1	0.01	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	26	0.21	14	0.31	18	0.71	11	1.58	9	0.95
Education	0	0.00	0	0.00	0	0.01	0	0.02	0	0.03
Government	5	0.04	2	0.05	2	0.09	1	0.13	1	0.06
Industrial	3	0.02	2	0.04	3	0.10	2	0.25	1	0.15
Other Residential	1,283	10.13	597	13.60	668	26.07	299	42.98	216	23.01
Religion	2	0.02	1	0.01	0	0.02	0	0.02	0	0.00
Single Family	11,341	89.58	3,776	85.99	1,870	73.00	383	55.01	713	75.81
Total	**12,661**		**4,392**		**2,562**		**695**		**940**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	24	0.01	1	0.01	1	0.04	1	0.08	1	0.05
MH*	1,015	8.02	465	10.60	575	22.46	263	37.76	168	17.86
Precast	5	0.02	1	0.02	2	0.07	2	0.25	1	0.11
RM*	3	0.02	1	0.02	2	0.07	2	0.23	1	0.10
Steel	18	0.02	1	0.03	3	0.13	4	0.52	3	0.28
UM*	100	0.79	48	1.10	54	2.10	34	4.89	35	3.76
Wood	11,496	90.76	3851	87.70	1,892	73.85	372	53.50	718	76.31
Total	**12,661**		**4,392**		**2,562**		**695**		**940**	

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

Essential Facility Damage

Before the earthquake, the region had 44 hospital beds available for use. On the day of the earthquake, the model estimates that only 30 hospital beds (70.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 93.00% of the beds will be back in service. By 30 days, 100.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	0	0	1
Schools	29	0	0	29
EOCs	0	0	0	0
PoliceStations	4	0	0	4
FireStations	3	0	0	3

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	37	0	0	37	37
	Bridges	107	10	2	99	104
	Tunnels	0	0	0	0	0
Railways	Segments	32	0	0	32	32
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	7	2	0	7	7
	Runways	7	0	0	7	7

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	1	0	0	1	1
Waste Water	5	2	0	2	5
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	1	0	0	1
Communication	4	1	0	4	4

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,434	93	93
Waste Water	2,061	73	74
Natural Gas	1,374	79	79
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	23,058	666	9	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 3 ignitions that will burn about 0.03 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 12 people and burn about 0 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 46.00% 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 0 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 (1,412 households to be displaced due to the earthquake. Of these, 361 people (out of a total population of 62,380 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	1	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	2	1	0	0
	Other-Residential	100	26	3	5
	Single Family	149	35	2	4
	Total	**253**	**61**	**5**	**10**
2 PM	Commercial	91	27	4	8
	Commuting	0	0	0	0
	Educational	64	19	3	6
	Hotels	0	0	0	0
	Industrial	16	4	1	1
	Other-Residential	15	4	0	1
	Single Family	24	6	0	1
	Total	**211**	**60**	**9**	**17**
5 PM	Commercial	101	30	5	9
	Commuting	5	7	12	2
	Educational	17	5	1	2
	Hotels	0	0	0	0
	Industrial	10	3	0	1
	Other-Residential	38	10	1	2
	Single Family	60	14	1	2
	Total	**232**	**69**	**20**	**18**

Economic Loss

The total economic loss estimated for the earthquake is 519.40 (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 409.43 (millions of dollars); 9 % 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 82 % 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	1.18	6.74	0.30	0.54	8.76
	Capital-Related	0.00	0.50	6.10	0.18	0.15	6.93
	Rental	7.14	8.09	2.66	0.09	0.23	18.22
	Relocation	0.80	0.22	0.14	0.01	0.07	1.24
	Subtotal	**7.94**	**9.99**	**15.65**	**0.59**	**0.99**	**35.15**
Capital Stock Loses							
	Structural	39.10	13.75	6.39	1.87	1.78	62.88
	Non_Structural	148.88	62.99	18.14	6.21	5.20	241.42
	Content	39.85	13.76	8.36	3.84	2.85	68.67
	Inventory	0.00	0.00	0.32	0.91	0.09	1.31
	Subtotal	**227.83**	**90.50**	**33.20**	**12.83**	**9.92**	**374.28**
	Total	**235.77**	**100.49**	**48.85**	**13.42**	**10.90**	**409.43**

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	573.33	$4.74	0.83
	Bridges	632.28	$30.99	4.90
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1205.60**	**35.70**	
Railways	Segments	60.59	$0.18	0.30
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**60.60**	**0.20**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
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	43.11	$9.18	21.30
	Runways	245.84	$1.83	0.74
	Subtotal	**289.00**	**11.00**	
	Total	**1555.20**	**46.90**	

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	37.60	$1.21	3.21
	Distribution Line	68.70	$2.24	3.26
	Subtotal	**106.32**	**$3.45**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	376.30	$35.38	9.40
	Distribution Line	41.20	$1.77	4.30
	Subtotal	**417.50**	**$37.15**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	27.50	$1.89	6.89
	Subtotal	**27.47**	**$1.89**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$20.52	16.51
	Subtotal	**124.30**	**$20.52**	
Communication	Facilities	0.50	$0.05	10.69
	Subtotal	**0.45**	**$0.05**	
	Total	**676.04**	**$63.05**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(25)	-4.55
Second Year			
	Employment Impact	0	0.00
	Income Impact	(33)	-5.96
Third Year			
	Employment Impact	0	0.00
	Income Impact	(36)	-6.55
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(36)	-6.55
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(36)	-6.55
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(36)	-6.55

Appendix A: County Listing for the Region

Polk, OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Polk	62,380	3,187	280	3,467
Total State		**62,380**	**3,187**	**280**	**3,467**
Total Region		**62,380**	**3,187**	**280**	**3,467**

HAZUS-MH: Earthquake Event Report

Region Name: ***Polk Cascadia***

Earthquake Scenario: ***Cascadia M8.5***

Print Date: ***March 14, 2005***

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.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 742.30 square miles and contains 12 census tracts. There are over 23 thousand households in the region and has a total population of 62,380 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 21 thousand buildings in the region with a total building replacement value (excluding contents) of 3,467 (millions of dollars). Approximately 100.00 % of the buildings (and 92.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,555 and 538 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 21 thousand buildings in the region which have an aggregate total replacement value of 3,467 (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 86% 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 1 hospitals in the region with a total bed capacity of 44 beds. There are 29 schools, 3 fire stations, 4 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 28 dams identified within the region. Of these, 1 of the dams are classified as 'high hazard'. The inventory also includes 12 hazardous material sites, 0 military installations and 0 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 2,093.00 (millions of dollars). This inventory includes over 185 kilometers of highways, 107 bridges, 6,868 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	107	632.30
	Segments	37	573.30
	Tunnels	0	0.00
		Subtotal	**1,205.60**
Railways	Bridges	0	0.00
	Facilities	0	0.00
	Segments	32	60.60
	Tunnels	0	0.00
		Subtotal	**60.60**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	0	0.00
		Subtotal	**0.00**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	7	43.10
	Runways	7	245.80
		Subtotal	**289.00**
		Total	**1,555.20**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	68.70
	Facilities	1	37.60
	Pipelines	0	0.00
		Subtotal	**106.30**
Waste Water	Distribution Lines	NA	41.20
	Facilities	5	376.30
	Pipelines	0	0.00
		Subtotal	**417.50**
Natural Gas	Distribution Lines	NA	27.50
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**27.50**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	4	0.50
		Subtotal	**0.50**
		Total	**676.00**

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	Cascadia M8.5
Type of Earthquake	User-defined
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 6,195 thousand buildings will be at least moderately damaged. This is over 29.00 % of the total number of buildings in the region. There are an estimated 1,510 buildings that will be completely destroyed. 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	0	0.00	0	0.00	0	0.01	0	0.01	0	0.01
Commercial	4	0.05	7	0.12	18	0.54	22	1.66	27	1.78
Education	0	0.00	0	0.00	0	0.00	0	0.02	1	0.03
Government	1	0.01	1	0.01	2	0.07	3	0.24	4	0.26
Industrial	0	0.01	1	0.01	2	0.07	3	0.22	4	0.23
Other Residential	307	3.39	389	6.47	733	21.71	842	64.27	792	52.44
Religion	1	0.01	0	0.01	1	0.02	1	0.05	1	0.05
Single Family	8,736	96.54	5,607	93.37	2,618	77.58	439	33.53	683	45.19
Total	**9,049**		**6,005**		**3,374**		**1,311**		**1,511**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	3	0.00	0	0.00	1	0.02	1	0.10	2	0.12
MH*	112	1.24	244	4.05	636	18.85	791	60.35	704	46.58
Precast	0	0.00	0	0.01	2	0.05	3	0.20	3	0.23
RM*	0	0.01	0	0.01	2	0.05	3	0.21	3	0.21
Steel	1	0.00	0	0.00	1	0.03	3	0.22	9	0.59
UM*	25	0.27	35	0.59	65	1.92	62	4.76	84	5.59
Wood	8,907	98.42	5717	95.19	2,640	78.24	408	31.10	653	43.25
Total	**9,049**		**6,005**		**3,374**		**1,311**		**1,511**	

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

Essential Facility Damage

Before the earthquake, the region had 44 hospital beds available for use. On the day of the earthquake, the model estimates that only 3 hospital beds (7.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 28.00% of the beds will be back in service. By 30 days, 76.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	1	0	0
Schools	29	0	0	29
EOCs	0	0	0	0
PoliceStations	4	0	0	4
FireStations	3	0	0	3

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	37	0	0	37	37
	Bridges	107	19	0	88	95
	Tunnels	0	0	0	0	0
Railways	Segments	32	0	0	32	32
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	7	0	0	7	7
	Runways	7	0	0	7	7

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	1	0	0	1	1
Waste Water	5	0	0	0	5
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	0	0	1	1
Communication	4	0	0	4	4

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,434	273	141
Waste Water	2,061	216	112
Natural Gas	1,374	231	120
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	23,058	2,346	617	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 3 ignitions that will burn about 0.03 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 12 people and burn about 0 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 39.00% 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 0 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 (1,822 households to be displaced due to the earthquake. Of these, 464 people (out of a total population of 62,380 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	3	1	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	1	0	0	0
	Industrial	7	2	0	1
	Other-Residential	224	60	7	13
	Single Family	154	35	2	4
	Total	**389**	**98**	**10**	**19**
2 PM	Commercial	263	80	13	26
	Commuting	0	0	1	0
	Educational	153	48	8	16
	Hotels	0	0	0	0
	Industrial	50	15	2	5
	Other-Residential	40	11	1	2
	Single Family	27	6	1	1
	Total	**534**	**160**	**26**	**49**
5 PM	Commercial	273	83	14	26
	Commuting	7	10	16	3
	Educational	34	11	2	4
	Hotels	0	0	0	0
	Industrial	31	9	2	3
	Other-Residential	85	23	3	5
	Single Family	61	14	1	2
	Total	**491**	**150**	**37**	**43**

Economic Loss

The total economic loss estimated for the earthquake is 767.37 (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 624.43 (millions of dollars); 11 % 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 71 % 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	2.64	15.55	0.72	1.31	20.22
	Capital-Related	0.00	1.12	14.12	0.43	0.35	16.02
	Rental	7.91	13.80	6.27	0.20	0.70	28.88
	Relocation	0.91	0.37	0.32	0.02	0.17	1.79
	Subtotal	**8.82**	**17.94**	**36.26**	**1.36**	**2.53**	**66.91**
Capital Stock Loses							
	Structural	42.32	28.69	16.70	4.16	5.06	96.92
	Non_Structural	162.29	117.55	47.24	14.38	14.00	355.46
	Content	42.54	23.75	20.36	8.57	6.81	102.02
	Inventory	0.00	0.00	0.82	2.09	0.21	3.12
	Subtotal	**247.14**	**169.99**	**85.11**	**29.19**	**26.08**	**557.52**
	Total	**255.96**	**187.93**	**121.38**	**30.56**	**28.60**	**624.43**

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	573.33	$9.49	1.66
	Bridges	632.28	$49.88	7.89
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1205.60**	**59.40**	
Railways	Segments	60.59	$0.40	0.66
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**60.60**	**0.40**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
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	43.11	$9.94	23.06
	Runways	245.84	$4.03	1.64
	Subtotal	**289.00**	**14.00**	
	Total	**1555.20**	**73.70**	

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	37.60	$3.04	8.07
	Distribution Line	68.70	$3.92	5.71
	Subtotal	**106.32**	**$6.96**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	376.30	$47.51	12.63
	Distribution Line	41.20	$3.10	7.53
	Subtotal	**417.50**	**$50.61**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	27.50	$3.32	12.07
	Subtotal	**27.47**	**$3.32**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$8.26	6.65
	Subtotal	**124.30**	**$8.26**	
Communication	Facilities	0.50	$0.05	11.19
	Subtotal	**0.45**	**$0.05**	
	Total	**676.04**	**$69.19**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(27)	-4.87
Second Year			
	Employment Impact	0	0.00
	Income Impact	(38)	-6.95
Third Year			
	Employment Impact	0	0.00
	Income Impact	(43)	-7.82
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(43)	-7.82
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(43)	-7.82
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(43)	-7.82

Appendix A: County Listing for the Region

Polk, OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Polk	62,380	3,187	280	3,467
Total State		**62,380**	**3,187**	**280**	**3,467**
Total Region		**62,380**	**3,187**	**280**	**3,467**

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

APPENDIX G: YAMHILL COUNTY

CRUSTAL EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

SUBDUCTION ZONE EARTHQUAKE SCENARIO
- Scenario Details
- Ground Motion Map

GEOLOGIC HAZARD MAPS
- Relative Ground-Shaking Amplification Susceptibility Map
- Relative Liquefaction Hazard Susceptibility Map
- Relative Earthquake-induced Landslide Susceptibility Map
- Identified Landslide Areas Map

HAZUS-MH GLOBAL REPORT FOR CRUSTAL SCENARIO
HAZUS-MH GLOBAL REPORT FOR SUBDUCTION ZONE SCENARIO

CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR YAMHILL COUNTY

Crustal Scenario: A magnitude 6.8 earthquake on the Newberg Fault.

For the magnitude 6.8 Newberg Fault earthquake scenario, we defined the fault source using the "Deterministic Seismic Source" option within HAZUS-MH (Figure G1) (FEMA, 2003b). The fault and earthquake event were chosen by examination of USGS (2004) data and data in the Geomatrix Consultants, Inc. (1995) *Seismic Design Mapping, State of Oregon* report prepared for the Oregon Department of Transportation. In general, a likely worst-case scenario was selected. Figure G1 has the location of the fault, shown as the dark line, and the census tracts within Yamhill County. Figure G2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Newberg Fault M6.8
Type of Earthquake	Source
Fault Name	Newberg Fault
Historical Epicenter ID #	68
Probabilistic Return Period	NA
Longitude of Epicenter	–123.04
Latitude of Epicenter	45.32
Earthquake Magnitude	6.8
Depth (Km)	0.00
Rupture Length (Km)	26.55
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

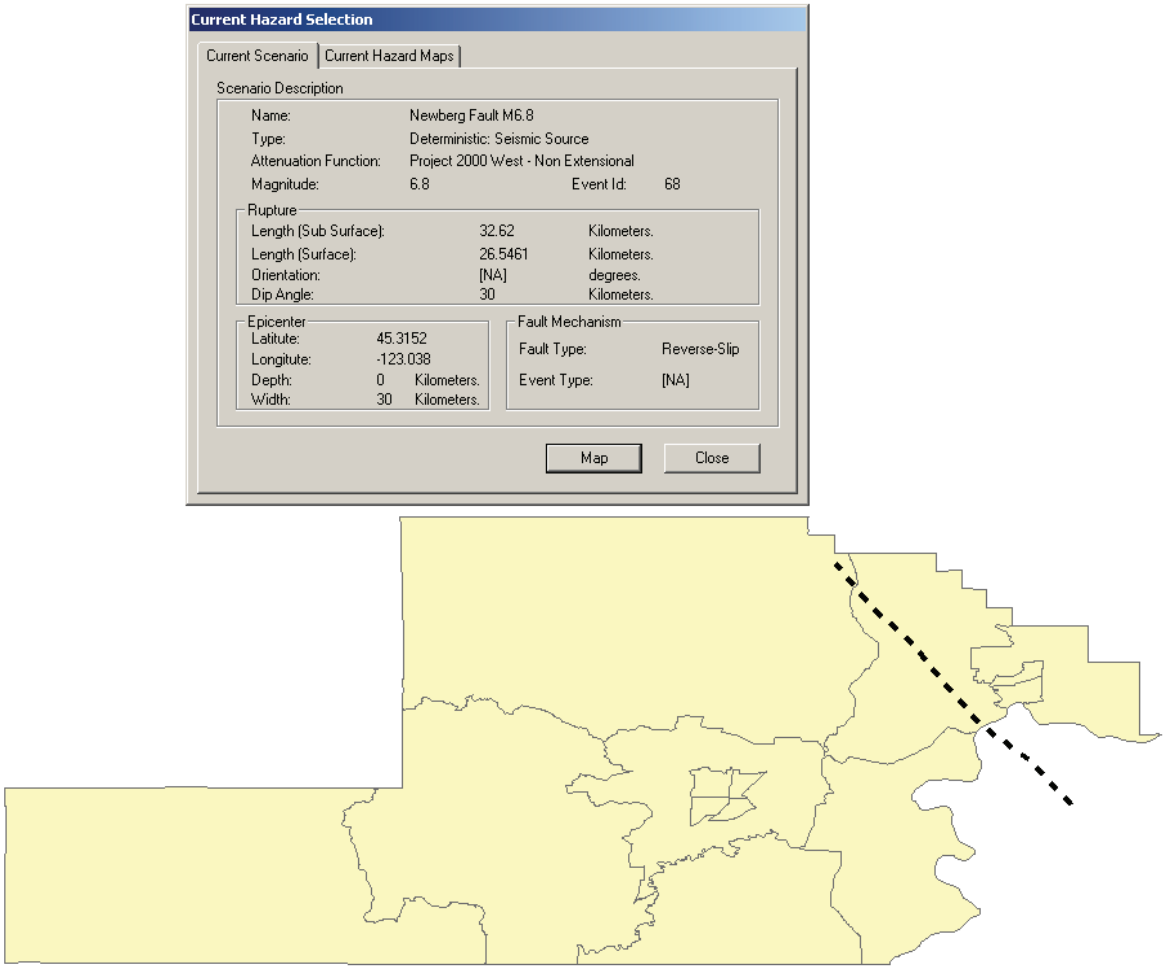

Figure G1. Newberg Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dashed line.

Crustal Earthquake Scenario Ground Motion Map

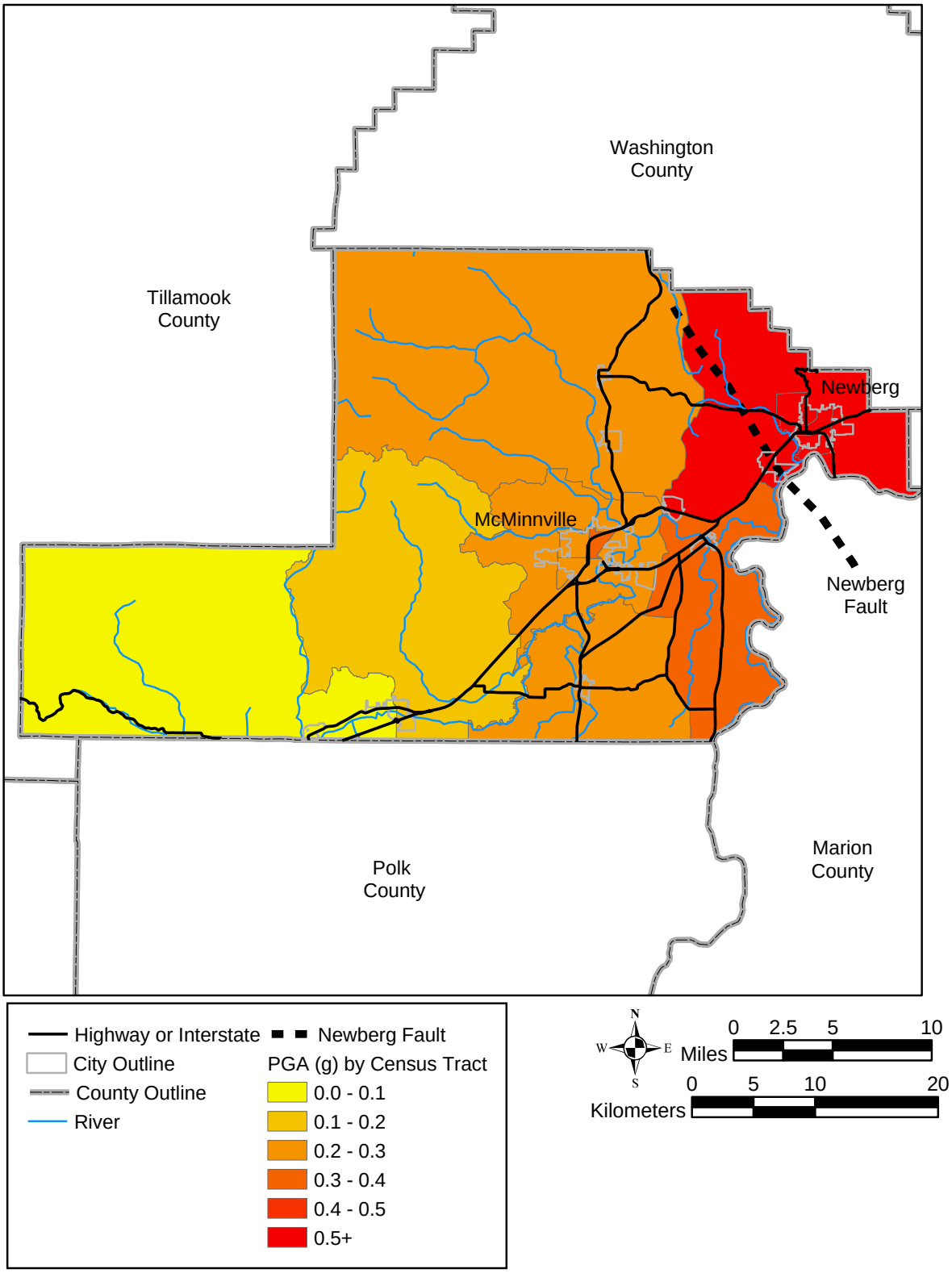

Figure G2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, Yamhill County, Oregon (FEMA, 2003b).

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR YAMHILL COUNTY

Subduction Zone Scenario: A magnitude 9.0 earthquake on the Cascadia Subduction Zone was selected for the subduction zone earthquake scenario.

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by the Cascadia Region Earthquake Workgroup (CREW, 2003) to model damage and loss from a magnitude 9.0 earthquake (Figure G3). The CREW maps were developed from ground motion data provided by the U.S. Geological Survey. The CREW earthquake scenario required the input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 s and 1.0 s (CREW, 2003). Figure G4 displays the PGA for the subduction zone scenario.

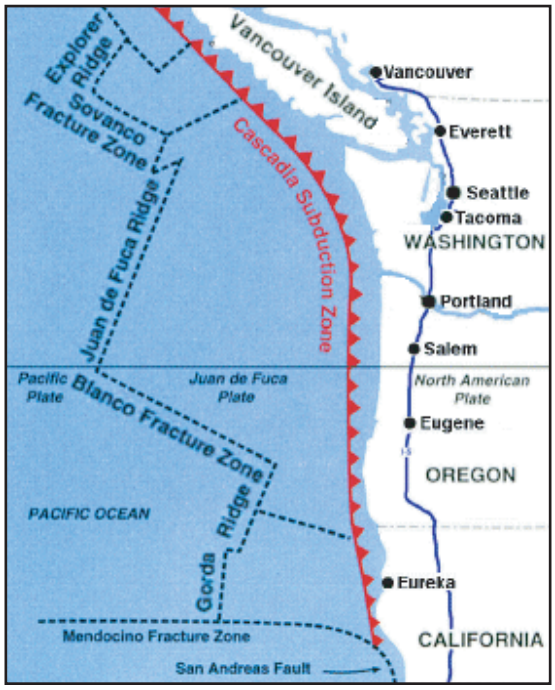

Figure G3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

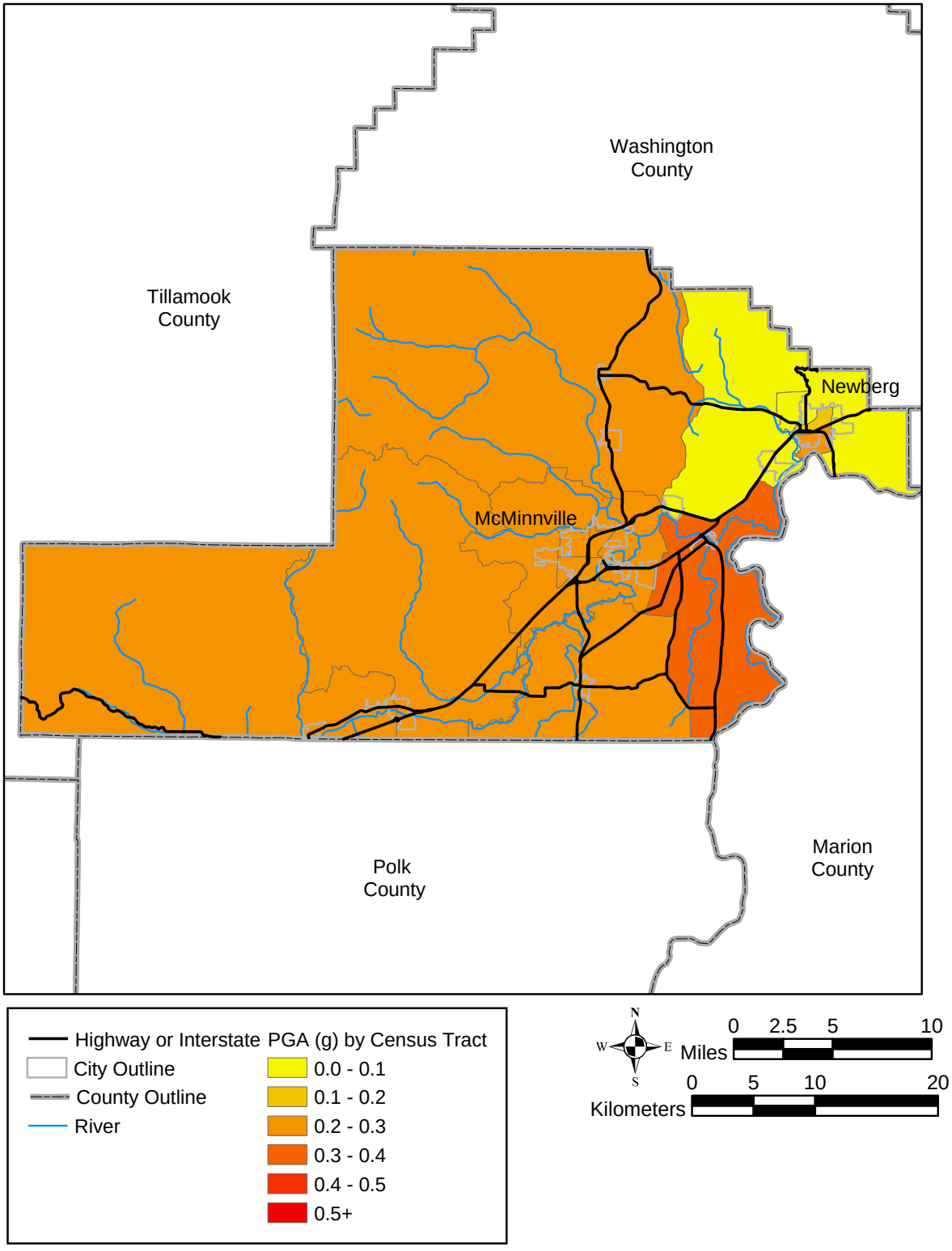

Figure G4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, Yamhill County, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS

Relative Ground-Shaking Amplification Susceptibility Map

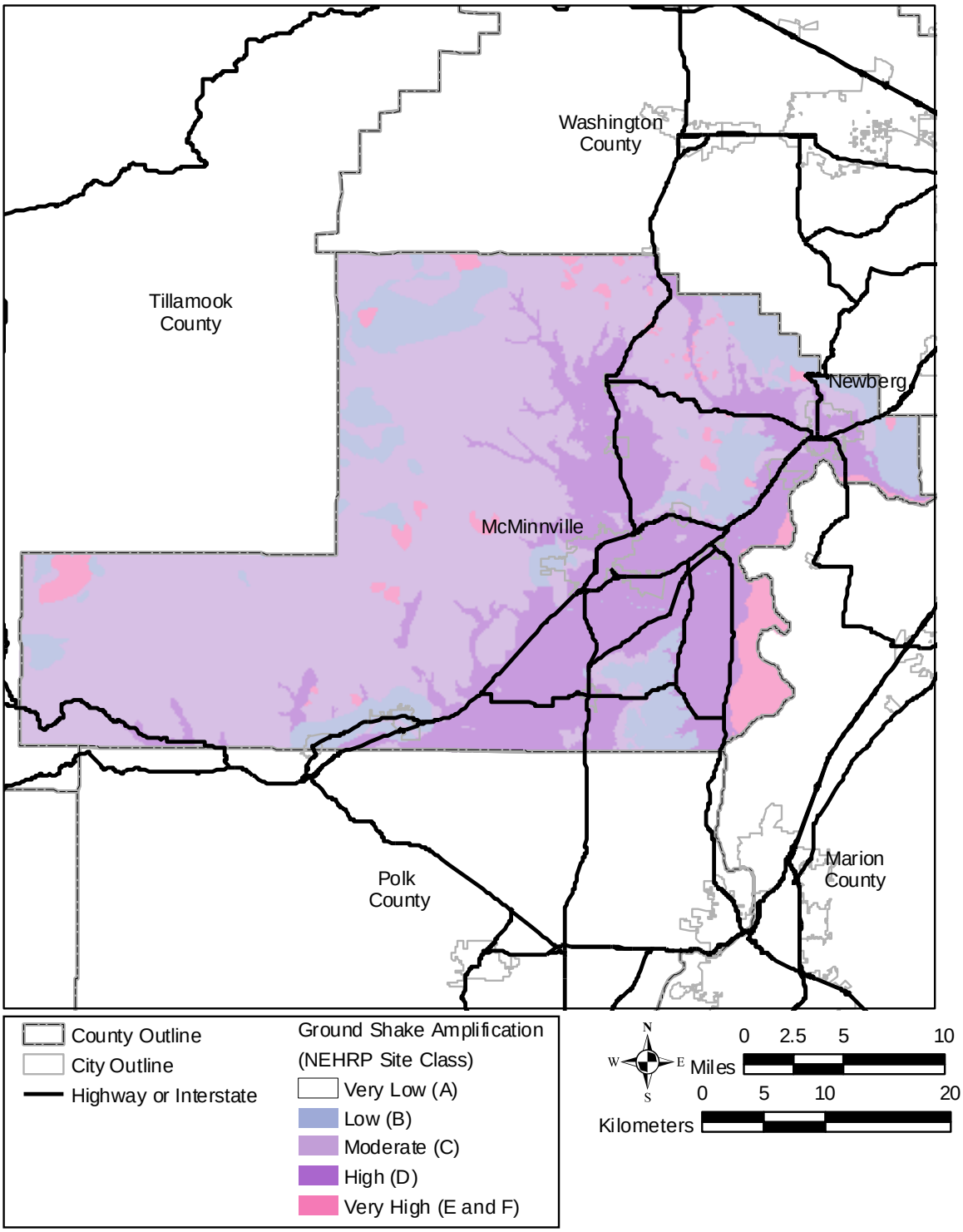

Figure G5. Relative ground-shaking amplification susceptibility map for Yamhill County, Oregon.

Relative Liquefaction Hazard Susceptibility Map

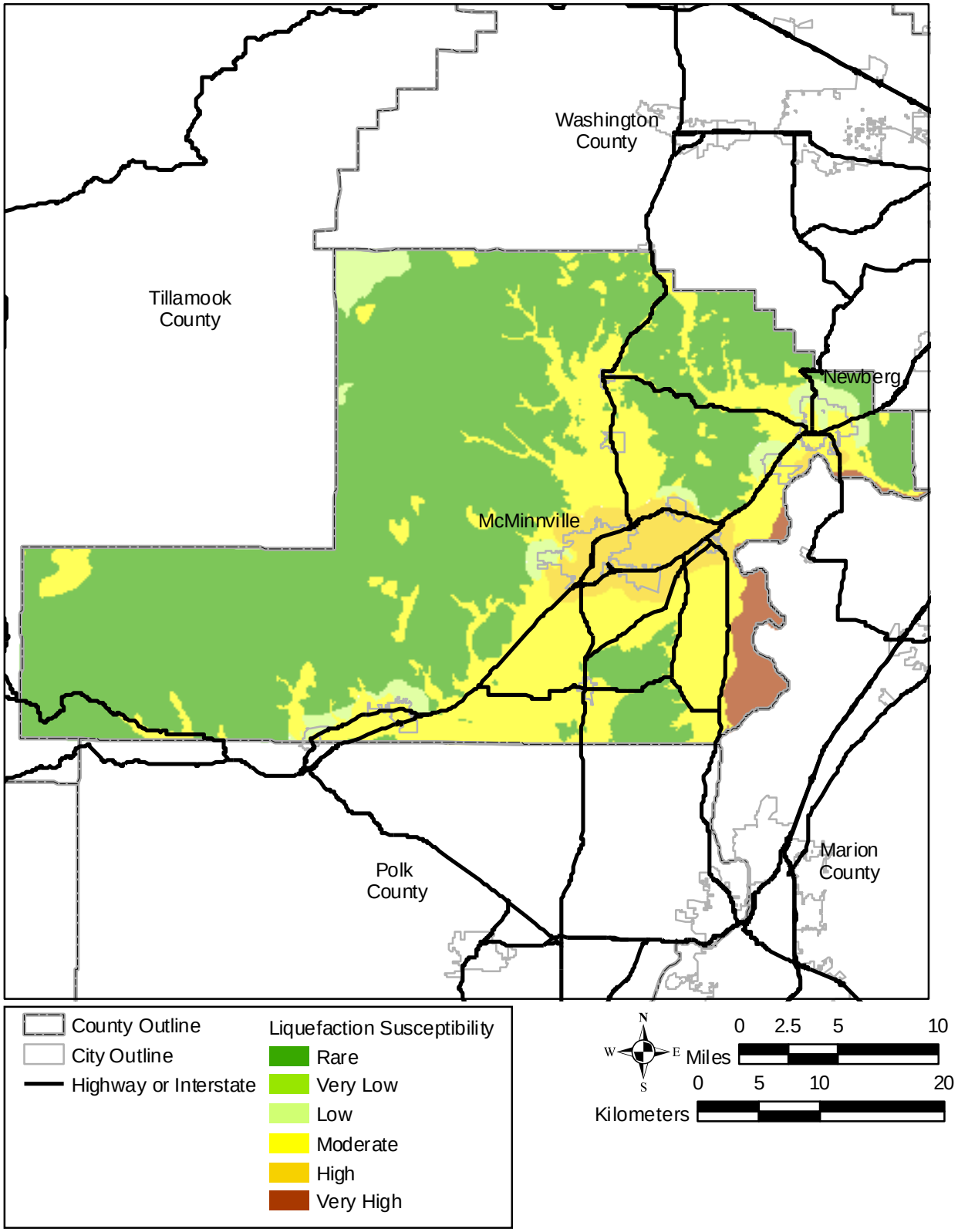

Figure G6. Relative liquefaction susceptibility map for Yamhill County, Oregon.

Relative Earthquake-induced Landslide Susceptibility Map

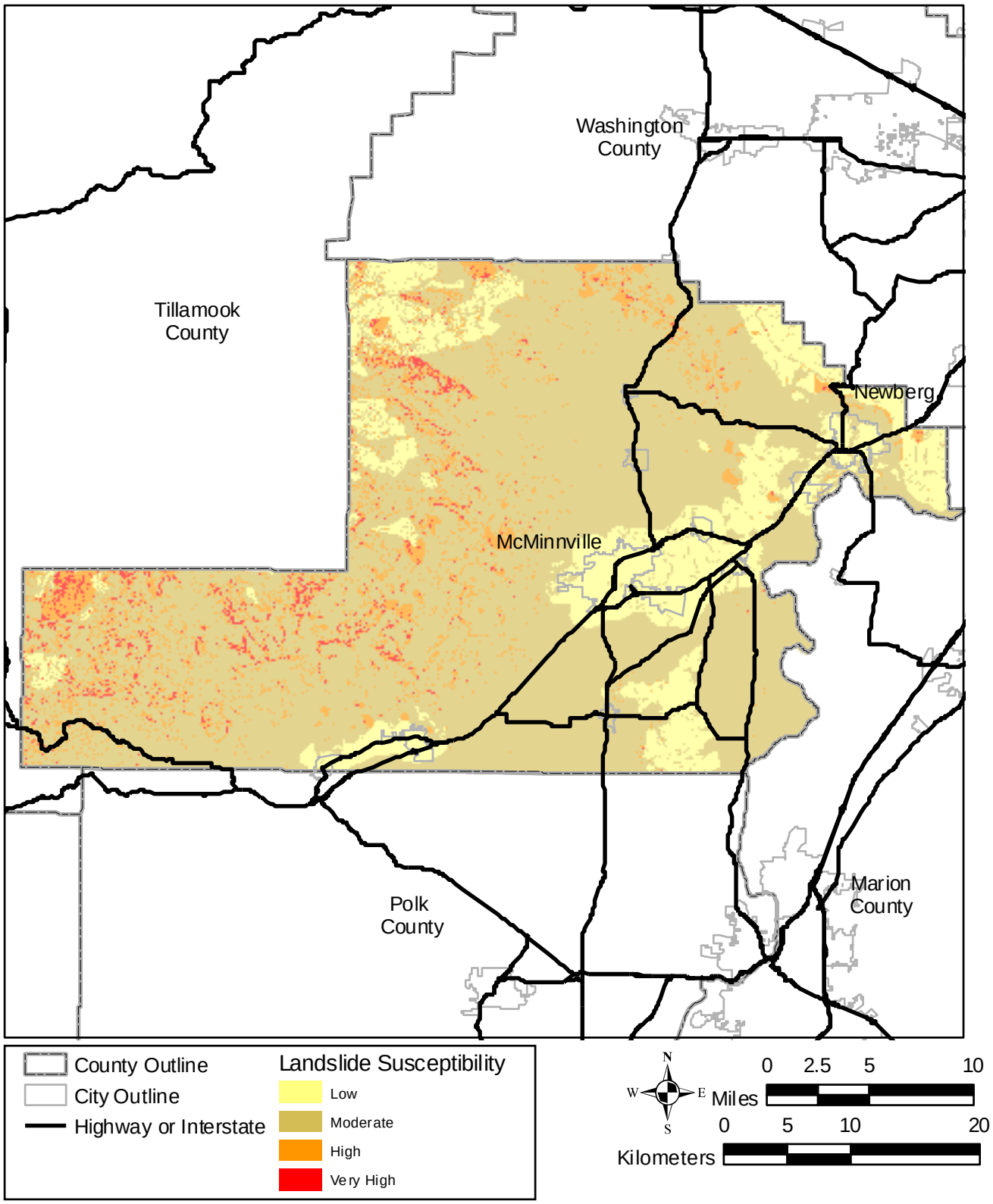

Figure G7. Relative earthquake-induced landslide susceptibility map for Yamhill County, Oregon.

Identified Landslide Areas Map

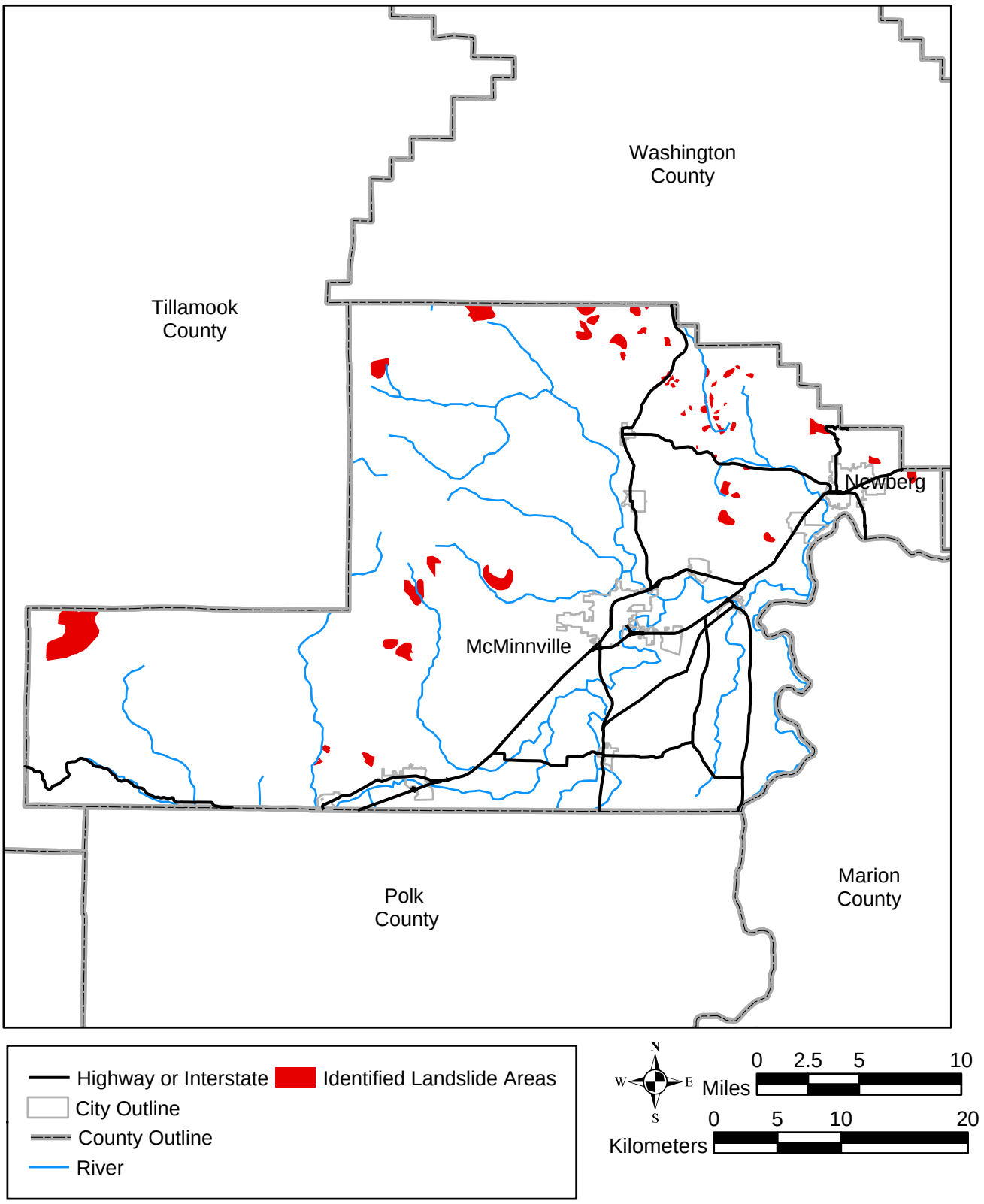

Figure G8. Identified landslide map for Yamhill County, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Yamhill Crustal***

Earthquake Scenario: ***Newberg Fault M6.8***

Print Date: ***March 14, 2005***

Disclaimer:
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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 county(ies) from the following state(s):

Oregon

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

The geographical size of the region is 716.52 square miles and contains 14 census tracts. There are over 28 thousand households in the region and has a total population of 84,992 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 27 thousand buildings in the region with a total building replacement value (excluding contents) of 4,597 (millions of dollars). Approximately 99.00 % of the buildings (and 86.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,810 and 828 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 27 thousand buildings in the region which have an aggregate total replacement value of 4,597 (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 83% 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 2 hospitals in the region with a total bed capacity of 102 beds. There are 47 schools, 10 fire stations, 11 police stations and 1 emergency operation facilities. With respect to HPL facilities, there are 31 dams identified within the region. Of these, 1 of the dams are classified as 'high hazard'. The inventory also includes 18 hazardous material sites, 0 military installations and 0 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 2,638.00 (millions of dollars). This inventory includes over 210 kilometers of highways, 46 bridges, 7,382 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	46	481.00
	Segments	68	649.90
	Tunnels	0	0.00
	Subtotal		**1,130.90**
Railways	Bridges	0	0.00
	Facilities	0	0.00
	Segments	46	65.30
	Tunnels	0	0.00
	Subtotal		**65.30**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
	Subtotal		**0.00**
Bus	Facilities	1	1.20
	Subtotal		**1.20**
Ferry	Facilities	0	0.00
	Subtotal		**0.00**
Port	Facilities	0	0.00
	Subtotal		**0.00**
Airport	Facilities	14	86.20
	Runways	15	526.80
	Subtotal		**613.00**
	Total		**1,810.40**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	73.80
	Facilities	4	150.50
	Pipelines	0	0.00
		Subtotal	**224.30**
Waste Water	Distribution Lines	NA	44.30
	Facilities	9	677.30
	Pipelines	0	0.00
		Subtotal	**721.60**
Natural Gas	Distribution Lines	NA	29.50
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**29.50**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	0	0.00
		Subtotal	**0.00**
Communication	Facilities	3	0.30
		Subtotal	**0.30**
		Total	**975.80**

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	Newberg Fault M6.8
Type of Earthquake	Source
Fault Name	Newberg Fault
Historical Epicenter ID #	68
Probabilistic Return Period	NA
Longitude of Epicenter	-123.04
Latitude of Epicenter	45.32
Earthquake Magnitude	6.80
Depth (Km)	0.00
Rupture Length (Km)	26.55
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 13,647 thousand buildings will be at least moderately damaged. This is over 50.00 % of the total number of buildings in the region. There are an estimated 3,627 buildings that will be completely destroyed. 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	2	0.03	1	0.02	1	0.02	1	0.02	1	0.02
Commercial	24	0.32	20	0.33	40	0.61	38	1.12	59	1.63
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.01
Government	1	0.01	1	0.01	1	0.02	1	0.02	1	0.02
Industrial	4	0.05	2	0.04	6	0.08	6	0.18	9	0.26
Other Residential	531	7.04	597	9.91	1,246	18.88	1,143	33.43	1,149	31.68
Religion	3	0.04	3	0.05	5	0.08	5	0.15	6	0.17
Single Family	6,987	92.52	5,398	89.63	5,300	80.30	2,225	65.08	2,402	66.21
Total	**7,552**		**6,022**		**6,601**		**3,419**		**3,628**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	12	0.01	1	0.01	2	0.03	2	0.06	3	0.09
MH*	417	5.52	504	8.37	1,108	16.79	1,051	30.73	1,015	27.98
Precast	4	0.04	2	0.03	5	0.08	6	0.19	8	0.23
RM*	2	0.02	1	0.01	2	0.03	3	0.08	4	0.11
Steel	10	0.01	1	0.01	2	0.04	4	0.10	8	0.21
UM*	51	0.68	44	0.73	72	1.09	67	1.97	119	3.28
Wood	7,056	93.37	5449	90.48	5,363	81.25	2,240	65.52	2,400	66.15
Total	**7,552**		**6,022**		**6,601**		**3,419**		**3,628**	

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

Essential Facility Damage

Before the earthquake, the region had 102 hospital beds available for use. On the day of the earthquake, the model estimates that only 8 hospital beds (9.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 26.00% of the beds will be back in service. By 30 days, 60.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	2	2	0	0
Schools	47	15	0	32
EOCs	1	0	0	1
PoliceStations	11	4	0	7
FireStations	10	5	0	5

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	68	0	0	68	68
	Bridges	46	5	1	41	42
	Tunnels	0	0	0	0	0
Railways	Segments	46	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	0	0	1	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	14	8	0	8	13
	Runways	15	0	0	15	15

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	4	2	0	2	4
Waste Water	9	6	0	2	7
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	3	2	0	2	3

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,691	491	270
Waste Water	2,215	388	213
Natural Gas	1,477	415	228
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	28,732	9,035	6,494	1,578	0	0
Electric Power		9,054	6,826	3,842	1,066	11

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 5 ignitions that will burn about 0.07 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 105 people and burn about 5 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 44.00% 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 0 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 (4,256 households to be displaced due to the earthquake. Of these, 1,008 people (out of a total population of 84,992 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	7	2	0	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	8	2	0	1
	Industrial	12	4	1	1
	Other-Residential	376	100	11	21
	Single Family	519	119	8	13
	Total	**921**	**228**	**20**	**36**
2 PM	Commercial	462	143	24	46
	Commuting	0	1	1	0
	Educational	212	66	11	21
	Hotels	1	0	0	0
	Industrial	89	28	5	9
	Other-Residential	67	18	2	4
	Single Family	105	24	2	3
	Total	**937**	**280**	**44**	**83**
5 PM	Commercial	426	132	22	42
	Commuting	7	13	18	4
	Educational	25	8	1	3
	Hotels	2	1	0	0
	Industrial	55	17	3	6
	Other-Residential	143	38	5	8
	Single Family	208	48	4	5
	Total	**868**	**257**	**53**	**67**

Economic Loss

The total economic loss estimated for the earthquake is 1,881.50 (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 1,525.35 (millions of dollars); 9 % 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 74 % 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	2.23	32.36	1.37	1.52	37.49
	Capital-Related	0.00	0.95	27.64	0.86	0.57	30.02
	Rental	25.47	22.48	12.73	0.50	0.79	61.97
	Relocation	2.74	0.56	0.66	0.05	0.29	4.30
	Subtotal	**28.20**	**26.23**	**73.39**	**2.78**	**3.17**	**133.78**
Capital Stock Loses							
	Structural	140.63	43.54	35.20	8.72	9.64	237.73
	Non_Structural	522.97	193.31	107.54	35.39	25.02	884.22
	Content	133.74	41.89	51.40	22.68	12.48	262.19
	Inventory	0.00	0.00	2.10	4.89	0.45	7.43
	Subtotal	**797.33**	**278.75**	**196.24**	**71.67**	**47.58**	**1,391.57**
	Total	**825.54**	**304.98**	**269.64**	**74.45**	**50.75**	**1,525.35**

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	649.91	$26.39	4.06
	Bridges	480.95	$44.94	9.34
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1130.90**	**71.30**	
Railways	Segments	65.28	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**65.30**	**0.00**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	1.23	$0.33	26.41
	Subtotal	**1.20**	**0.30**	
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	86.22	$32.89	38.15
	Runways	526.81	$11.03	2.09
	Subtotal	**613.00**	**43.90**	
	Total	**1810.40**	**115.60**	

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	150.50	$33.72	22.40
	Distribution Line	73.80	$7.36	9.97
	Subtotal	**224.34**	**$41.08**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	677.30	$187.34	27.66
	Distribution Line	44.30	$5.82	13.14
	Subtotal	**721.62**	**$193.16**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	29.50	$6.22	21.07
	Subtotal	**29.53**	**$6.22**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Communication	Facilities	0.30	$0.10	29.65
	Subtotal	**0.34**	**$0.10**	
	Total	**975.83**	**$240.56**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(28)	-3.14
Second Year			
	Employment Impact	0	0.00
	Income Impact	(55)	-6.29
Third Year			
	Employment Impact	0	0.00
	Income Impact	(67)	-7.63
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(67)	-7.63
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(67)	-7.63
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(67)	-7.63

Appendix A: County Listing for the Region

Yamhill,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Yamhill	84,992	3,974	622	4,597
Total State		**84,992**	**3,974**	**622**	**4,597**
Total Region		**84,992**	**3,974**	**622**	**4,597**

HAZUS-MH: Earthquake Event Report

Region Name: ***Yamhill Cascadia***

Earthquake Scenario: ***Cascadia M8.5***

Print Date: ***March 14, 2005***

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General Description of the Region

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The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

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Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 27 thousand buildings in the region which have an aggregate total replacement value of 4,597 (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 83% 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 2 hospitals in the region with a total bed capacity of 102 beds. There are 47 schools, 10 fire stations, 11 police stations and 1 emergency operation facilities. With respect to HPL facilities, there are 31 dams identified within the region. Of these, 1 of the dams are classified as 'high hazard'. The inventory also includes 18 hazardous material sites, 0 military installations and 0 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 2,638.00 (millions of dollars). This inventory includes over 210 kilometers of highways, 46 bridges, 7,382 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	46	481.00
	Segments	68	649.90
	Tunnels	0	0.00
		Subtotal	**1,130.90**
Railways	Bridges	0	0.00
	Facilities	0	0.00
	Segments	46	65.30
	Tunnels	0	0.00
		Subtotal	**65.30**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	1	1.20
		Subtotal	**1.20**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	14	86.20
	Runways	15	526.80
		Subtotal	**613.00**
		Total	**1,810.40**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	73.80
	Facilities	4	150.50
	Pipelines	0	0.00
		Subtotal	**224.30**
Waste Water	Distribution Lines	NA	44.30
	Facilities	9	677.30
	Pipelines	0	0.00
		Subtotal	**721.60**
Natural Gas	Distribution Lines	NA	29.50
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**29.50**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	0	0.00
		Subtotal	**0.00**
Communication	Facilities	3	0.30
		Subtotal	**0.30**
		Total	**975.80**

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	Cascadia M8.5
Type of Earthquake	User-defined
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 9,517 thousand buildings will be at least moderately damaged. This is over 35.00 % of the total number of buildings in the region. There are an estimated 3,106 buildings that will be completely destroyed. 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	1	0.01	1	0.01	1	0.02	1	0.05	2	0.06
Commercial	10	0.09	16	0.23	39	0.90	47	2.28	71	2.27
Education	0	0.00	0	0.00	0	0.00	0	0.01	1	0.02
Government	0	0.00	0	0.00	1	0.02	1	0.05	2	0.06
Industrial	1	0.01	2	0.03	5	0.12	8	0.37	11	0.36
Other Residential	349	3.23	498	7.21	1,077	24.64	1,354	66.32	1,389	44.72
Religion	2	0.02	2	0.03	4	0.09	5	0.22	10	0.33
Single Family	10,430	96.63	6,392	92.49	3,242	74.21	627	30.69	1,621	52.18
Total	**10,794**		**6,911**		**4,369**		**2,042**		**3,106**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	4	0.00	0	0.00	1	0.03	3	0.12	4	0.13
MH*	159	1.47	366	5.30	987	22.58	1,303	63.82	1,280	41.22
Precast	1	0.01	1	0.01	4	0.10	7	0.35	12	0.38
RM*	1	0.01	1	0.01	2	0.05	3	0.17	5	0.15
Steel	2	0.00	0	0.00	1	0.03	3	0.16	10	0.33
UM*	37	0.34	45	0.65	78	1.79	74	3.64	120	3.85
Wood	10,591	98.10	6485	93.84	3,253	74.45	589	28.85	1,588	51.12
Total	**10,794**		**6,911**		**4,369**		**2,042**		**3,106**	

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

Essential Facility Damage

Before the earthquake, the region had 102 hospital beds available for use. On the day of the earthquake, the model estimates that only 7 hospital beds (8.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 28.00% of the beds will be back in service. By 30 days, 70.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	2	2	0	0
Schools	47	1	0	46
EOCs	1	0	0	1
PoliceStations	11	0	0	11
FireStations	10	0	0	10

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	68	0	0	68	68
	Bridges	46	7	0	39	41
	Tunnels	0	0	0	0	0
Railways	Segments	46	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	0	0	1	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	14	0	0	14	14
	Runways	15	0	0	15	15

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	4	0	0	4	4
Waste Water	9	1	0	0	9
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	3	0	0	3	3

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,691	517	322
Waste Water	2,215	409	255
Natural Gas	1,477	437	272
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	28,732	11,466	9,144	4,006	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 4 ignitions that will burn about 0.03 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 21 people and burn about 1 (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 0 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 37.00% 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 0 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 (3,082 households to be displaced due to the earthquake. Of these, 750 people (out of a total population of 84,992 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	8	2	0	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	8	2	0	1
	Industrial	14	4	1	1
	Other-Residential	389	104	12	22
	Single Family	339	81	6	9
	Total	**758**	**194**	**19**	**34**
2 PM	Commercial	554	173	29	57
	Commuting	0	0	0	0
	Educational	206	64	11	21
	Hotels	1	0	0	0
	Industrial	105	33	6	11
	Other-Residential	78	21	2	4
	Single Family	78	19	2	2
	Total	**1,023**	**311**	**50**	**95**
5 PM	Commercial	498	155	26	50
	Commuting	7	8	15	3
	Educational	18	6	1	2
	Hotels	2	1	0	0
	Industrial	66	21	3	7
	Other-Residential	147	40	5	8
	Single Family	136	33	3	4
	Total	**874**	**263**	**53**	**74**

Economic Loss

The total economic loss estimated for the earthquake is 1,399.50 (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 1,198.48 (millions of dollars); 11 % 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 62 % 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	2.27	36.67	1.62	2.23	42.80
	Capital-Related	0.00	0.97	32.31	1.01	0.82	35.12
	Rental	14.45	19.60	15.11	0.61	1.13	50.91
	Relocation	1.60	0.53	0.77	0.05	0.41	3.36
	Subtotal	**16.04**	**23.37**	**84.87**	**3.30**	**4.60**	**132.18**
Capital Stock Loses							
	Structural	79.36	43.83	42.71	10.28	13.62	189.80
	Non_Structural	288.88	177.39	122.43	38.80	36.14	663.64
	Content	73.14	36.11	54.05	24.27	17.13	204.70
	Inventory	0.00	0.00	2.34	5.25	0.56	8.16
	Subtotal	**441.38**	**257.33**	**221.53**	**78.61**	**67.45**	**1,066.30**
	Total	**457.42**	**280.71**	**306.40**	**81.91**	**72.05**	**1,198.48**

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	649.91	$17.70	2.72
	Bridges	480.95	$42.51	8.84
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1130.90**	**60.20**	
Railways	Segments	65.28	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**65.30**	**0.00**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	1.23	$0.25	20.69
	Subtotal	**1.20**	**0.30**	
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	86.22	$15.89	18.43
	Runways	526.81	$5.48	1.04
	Subtotal	**613.00**	**21.40**	
	Total	**1810.40**	**81.80**	

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	150.50	$17.44	11.59
	Distribution Line	73.80	$8.51	11.53
	Subtotal	**224.34**	**$25.95**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	677.30	$79.27	11.70
	Distribution Line	44.30	$6.73	15.19
	Subtotal	**721.62**	**$86.00**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	29.50	$7.19	24.36
	Subtotal	**29.53**	**$7.19**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Communication	Facilities	0.30	$0.03	10.24
	Subtotal	**0.34**	**$0.03**	
	Total	**975.83**	**$119.18**	

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

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(24)	-2.77
Second Year			
	Employment Impact	0	0.00
	Income Impact	(46)	-5.17
Third Year			
	Employment Impact	0	0.00
	Income Impact	(54)	-6.19
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(55)	-6.19
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(55)	-6.19
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(55)	-6.19

Appendix A: County Listing for the Region

Yamhill,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Yamhill	84,992	3,974	622	4,597
Total State		**84,992**	**3,974**	**622**	**4,597**
Total Region		**84,992**	**3,974**	**622**	**4,597**

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

APPENDIX H:
PROCEDURE USED TO DEVELOP
RELATIVE GROUND-SHAKING AMPLIFICATION SUSCEPTIBILITY MAP,
RELATIVE LIQUEFACTION HAZARD SUSCEPTIBILITY MAP,
RELATIVE EARTHQUAKE-INDUCED LANDSLIDE SUSCEPTIBILITY MAP,
IDENTIFIED LANDSLIDE AREAS MAP,
AND REFERENCE MAP

SURFACE GEOLOGIC COMPILATION

The following steps were used to develop the relative ground-shaking amplification, liquefaction, and earthquake-induced landslide susceptibility hazard layers for Yamhill, Marion, Polk, Linn, and Lane Counties, and the City of Albany.

We combined available digital GIS data from previous surface geology studies. The base geologic layer consisted of the USGS Willamette Valley Compilation (O'Connor and others, 2001) and the USGS digital, 1:500,000 scale geologic map or the State of Oregon (Walker and others, 2002).

To improve the base geologic map, we digitized numerous geologic maps and/or incorporated existing GIS data into the base map through "heads-up" digitization. A geographic reference to these previous studies is included in this appendix (Figures H1–H4), and the maps used are listed as full references (Table H1).

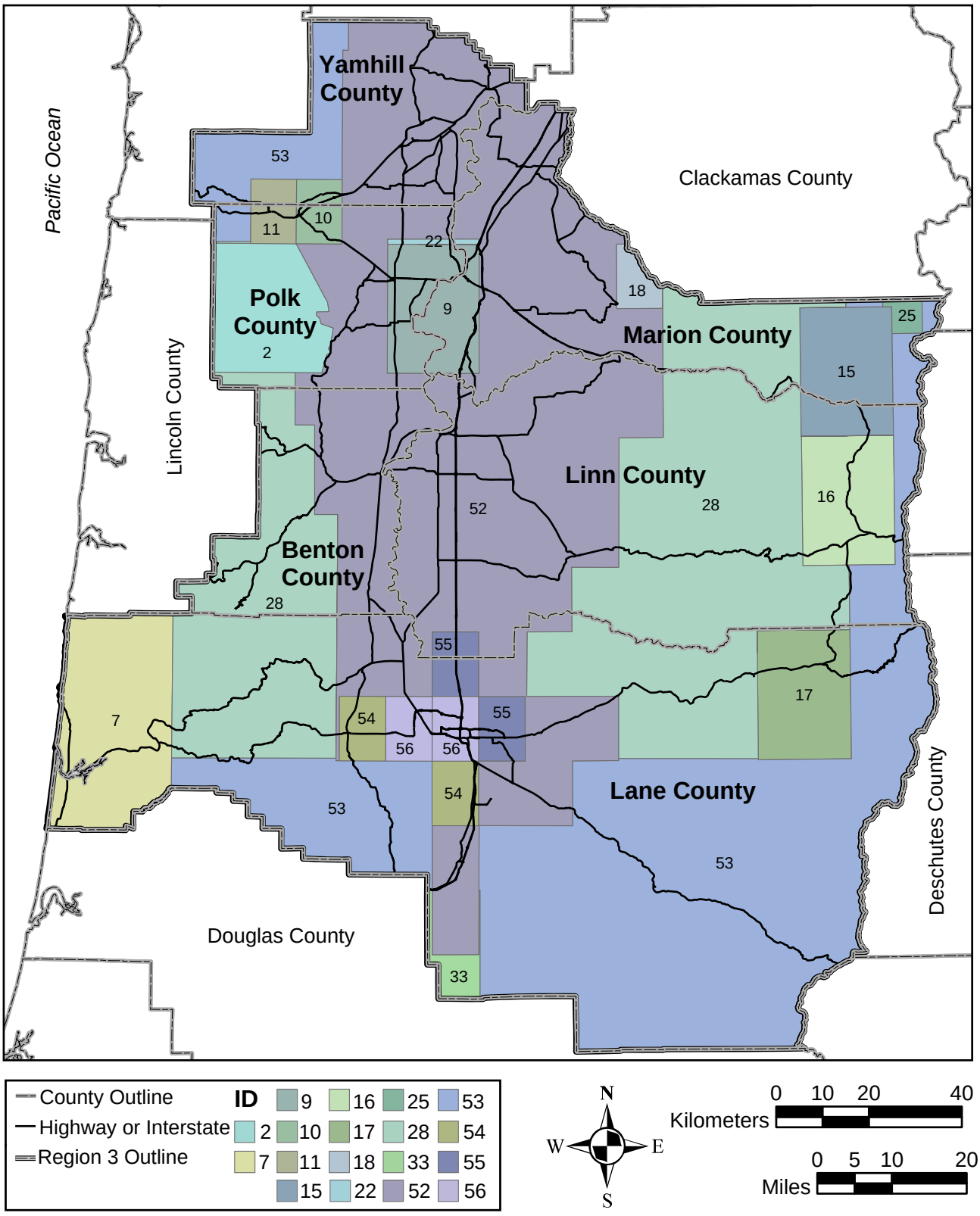

Figure H1. Map of references and extent of references used to compile the base geologic map. Number (reference ID) corresponds to the map reference in Table H1.

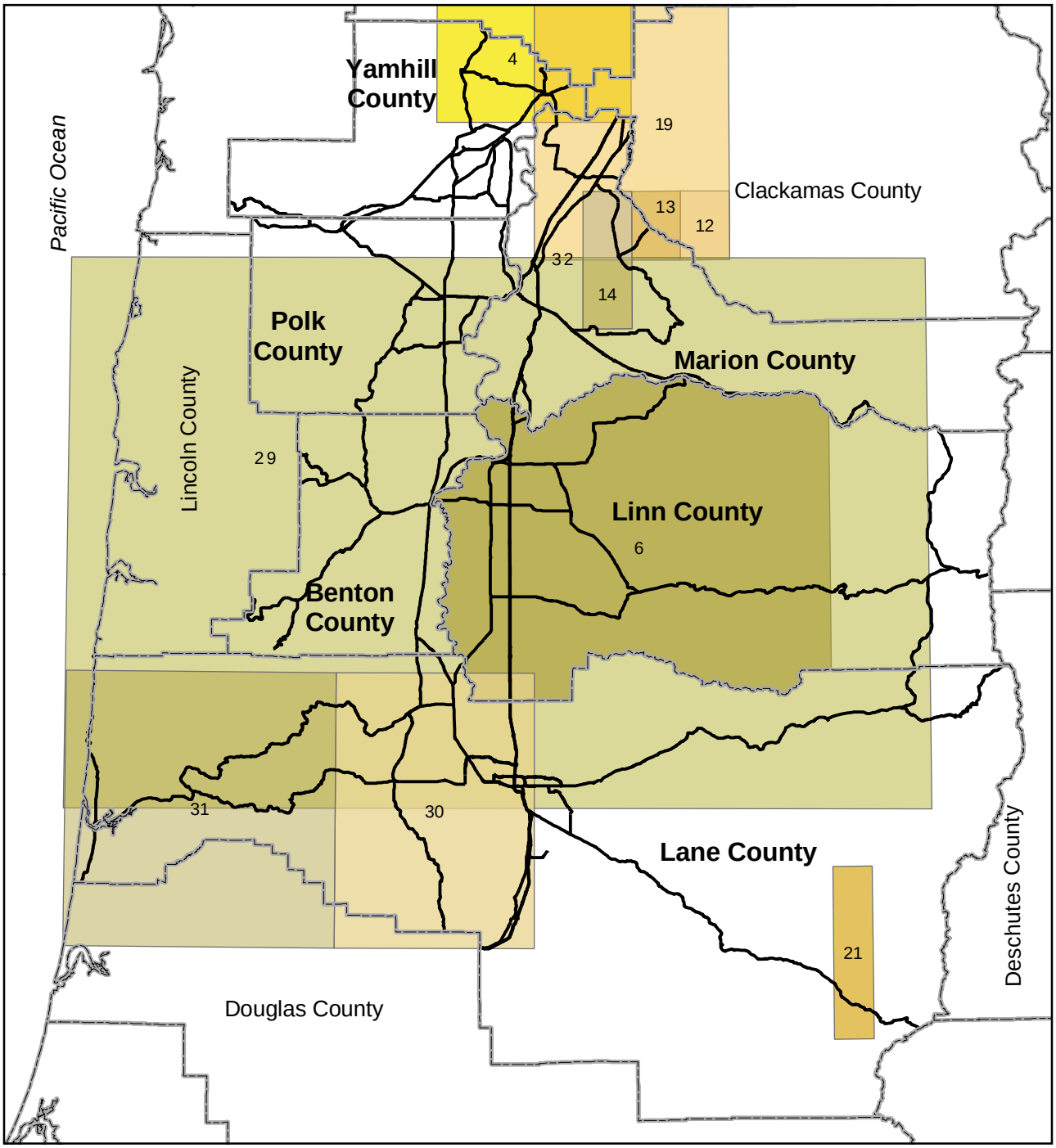

Figure H2. Map of references partially used to compile the base geologic map. Most of these maps were used only to improve the base Quaternary alluvium and landslide deposits. Number (reference ID) corresponds to the map reference in Table H1.

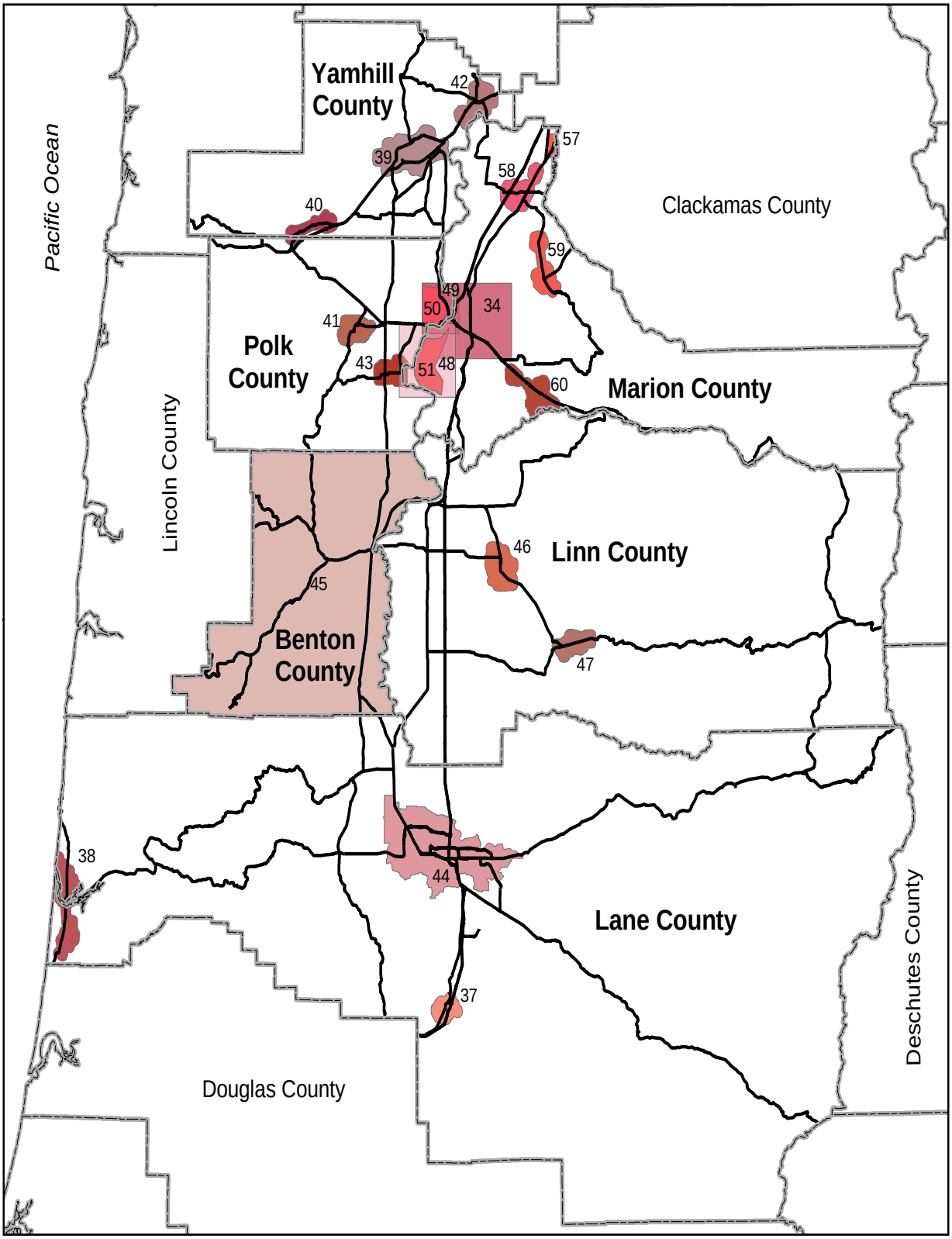

Figure H3. Map of existing hazards studies used it to supersede the countywide data at all locations. Number (reference ID) corresponds to the map reference in Table H1.

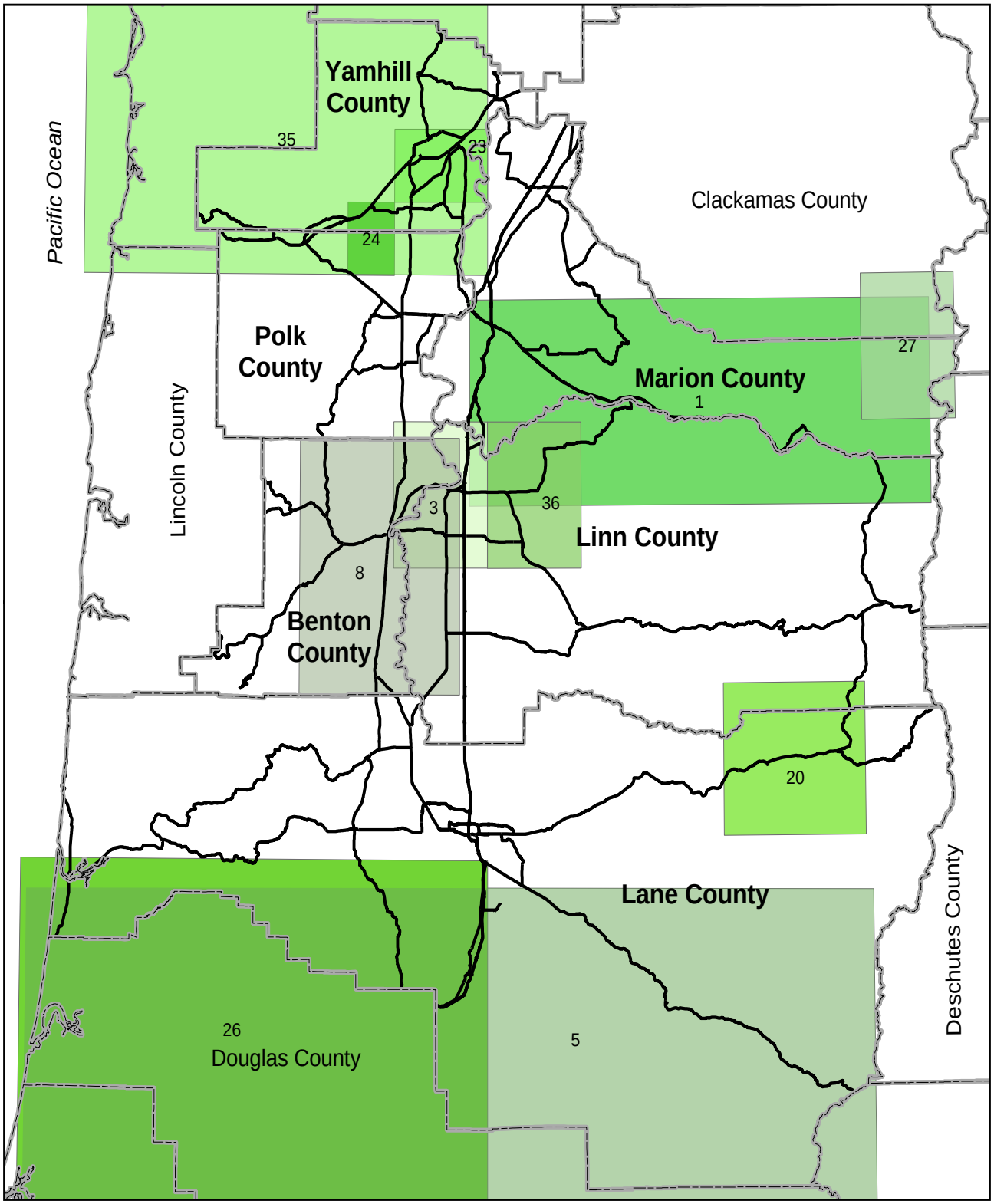

Figure H4. Map of references used only as references to compile the base geologic map. Number (reference ID) corresponds to the map reference in Table H1.

Table H1. Publications referred to in Figures H1–H4; reference ID number in first column corresponds to number labels on figures.

Ref ID	Reference
1	Thayer, T. P., 1939, Geology of the Salem Hills and North Santiam River Basin: Oregon Department of Geology and Mineral Industries Bulletin B-15, 40 p., 1 plate.
2	Baldwin, E. M., 1964, Geology of the Dallas and Valsetz [15′] quadrangles, Oregon (revised ed.): Oregon Department of Geology and Mineral Industries Bulletin B-35, 56 p., 3 plates.
3	Allison, I. S., 1953, Geology of the Albany [15′] quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Bulletin B-37, 18 p., 1 plate.
4	Schlicker, H., and Deacon, R. J., 1967, Engineering geology of the Tualatin Valley region, Oregon: Oregon Department of Geology and Mineral Industries Bulletin B-60, 103 p., 4 plates.
5	Ramp, L., 1972, Geology and mineral resources of Douglas County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin B-75, 106 p., 1 plate.
6	Beaulieu, J. D., Hughes, P. W., and Mathoit, R. K., 1974, Environmental geology of western Linn County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 84, 117 p., 22 plates.
7	Schlicker, H., Deacon, R. J., Newcomb, R. C., and Jackson, R. L., 1974, Environmental geology of coastal Lane County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin B-85, 116 p., 3 plates.
8	Bela, J. L., 1979, Geologic hazards of eastern Benton County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin B-98, 122 p., 5 plates.
9	Bela, J. L., 1981, Geologic map of the Rickreall and Salem West [7.5′] quadrangles, Oregon; Geologic map of the Monmouth and Sidney [7.5′] quadrangles, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-18, 2 plates.
10	Brownfield, M. E., 1982a, Geologic map of the Sheridan quadrangle, Polk and Yamhill Counties, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-23, 1 plate.
11	Brownfield, M. E., 1982b, Geologic map of the Grande Ronde quadrangle, Polk and Yamhill Counties, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-24, 1 plate.
12	Miller, P. R., and Orr, W. N., 1984a, Geologic map of the Wilhoit quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-32, 1 plate.
13	Miller, P. R., and Orr, W. N., 1984b, Geologic map of the Scotts Mills quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-33, 1 plate.
14	Orr, W. N., and Miller, P. R., 1984, Geologic map of the Stayton NE quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-34, 1 plate.
15	Priest, G. R., Woller, N. M., and Ferns, M. L., 1987, Geology of the Breitenbush River area, Linn and Marion Counties, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-46, 4 p., 1 plate.
16	Black, G. L., Woller, N. M., and Ferns, M. L., 1987, Geologic map of the Crescent Mountain area, Linn County, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-47, 1 plate.
17	Priest, G. R., Black, G. L., Woller, N. M., and Taylor, E. M., 1988, Geologic map of the McKenzie Bridge [15′] quadrangle, Lane County: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-48, 2 plates.
18	Orr, W. N., and Miller, P. R., 1986, Geologic map of the Elk Prairie quadrangle, Marion and Clackamas Counties, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-51, 1 plate.
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GEOLOGIC HAZARD LAYER DEVELOPMENT

We assigned susceptibility classes based on dominant lithologies for each unit in the study area. Three earthquake-induced geologic hazards layers (ground-shaking amplification, liquefaction, and landslides) and the identified landslides map were developed using the following methods. It is important to note that the quality and scale of the available geologic maps precluded identification of all hazard areas, particularly in the Coast Range and Cascade Range portions of the study area.

Relative Ground-Shaking Amplification

We used the common means of categorizing regional ground-shaking amplification hazards developed by the National Earthquake Hazard Reduction Program (NEHRP). The NEHRP 1997 method classifies geologic locations into one of six geology/soil categories generally labeled hard rock (type A), rock (type B), very dense soil and soft rock (type C), stiff soils (type D), soft soils (type E), and soils requiring site specific evaluations (type F). Table H2 summarizes some of the defining characteristics of these categories. Because we did not have enough information to classify any soils as type F, this class was combined with type E soils in this study. A site-specific evaluation must be performed to differentiate these two classes.

Table H2. National Earthquake Hazards Reduction Program ground-shaking amplification site classes (FEMA, 2003b) and corresponding DOGAMI ground-shaking amplification hazard classes used in this study.

Site Class	Site Class Description	Shear Wave Velocity, $\bar{v}_s$ (m/s) Min.	Max.	DOGAMI Hazard Class
A	**Hard Rock**	1500	—	very low
B	**Rock**	760	1500	low
C	**Very Dense Soil and Soft Rock.** $s_u \geq$ 2,000 psf (100 kPa) or $N > 50$	360	760	moderate
D	**Stiff Soils** (stiff soil with undrained shear strength). 1,000 psf ≤ s_u ≤ 2,000 psf (50 kPa ≤ s_u ≤ 100 kPa) or 15 ≤ N ≤ 50	180	360	high
E	**Soft Soils**. Profile with more than 3 m of soft clay defined as soil with $PI > 20$, moisture content $w > 40\%$, and undrained shear strength $s_u <$ 2,000 psf (50 kPa) ($N < 15$ blows/ft)	—	180	very high*
F	**Soils Requiring Site-Specific Evaluations** 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peat and/or highly organic clays ($H > 3$ m of peat and/or highly organic clay) 3. Very high plasticity clays ($H > 8$ m with PI > 75) 4. Very thick, soft/medium stiff clays ($H > 36$ m) with $s_u <$ 1,000 psf (50 kPa)	—	—	

Min. is minimum, Max. is maximum, s_u is undrained shear strength; N is ; PI is plasticity index; H is soil thickness.
*Note that because site-specific information is needed to classify soils as type F, this class was lumped with the type E soils in this study; furthermore, type F soils may also be located within other hazard classes.

After we established the soil classes (amp_class), we converted them to relative susceptibility zones (amp_suscep), and then to the input parameters (hazus_type) necessary for HAZUS-MH as shown in Table H3. In general, areas characterized by loose Quaternary sedimentary deposits are mapped as Moderate and High hazard for ground-shaking amplification (mostly D, E, and F type soil profiles). Most areas adjacent to major rivers in the more populated central portion of the study area are mapped as High and Very High hazard. Upland areas in the eastern part of the study area are mapped as Low ground motion amplification hazard, reflecting bedrock exposures and thin mantles of soil overlying rock. The western portion of the study area is varied, with competent bedrock areas mapped as Low hazard, dense soil areas mapped as Moderate hazard, and younger landslide and alluvial deposit areas mapped as High hazard for ground-shaking amplification.

Using professional judgement, we assigned a site class to each polygon in the base geologic map. Table H4 displays the ground-shaking amplification (GSA) site class assignment for each map unit.

Table H3. Field attributes for the ground-shaking amplification layer.

Ground-Shaking Amplification id	amp_ class	amp_suscep	hazus_ type
1	a	very_low	a
2	b	low	b
3	c	moderate	c
4	d	high	d
5	e	very_high	e
6	f	site_spec	f

The ground-shaking amplification id column serves as a unique identifier. Amp_class relates the zone to the NEHRP 1997 site classes. Amp_suscep is a relative descriptive relation to the amp_class, and hazus_type is the corresponding value in the HAZUS-MH program.

Table H4. Relationship between geologic units and relative susceptibility of ground-shaking amplification (GSA), liquefaction (LIQ), and earthquake-induced landslide (LS_UNIT) site classes.

Map Unit	Description	General Rock Type	Site Class		
			GSA	LIQ	LS_ UNIT
OW	open water	water	3	3	2
Qa	fine-grained alluvium	Quaternary alluvium	4	3	2
Qaf	alluvial fans	Quaternary alluvium	4	3	2
Qal	alluvial deposits	Quaternary alluvium	4	3	2
Qas	alluvial silt and sand	Quaternary alluvium	4	3	2
Qat	major river alluvium	Quaternary alluvium	4	2	2
Qau	undifferentiated alluvium and colluvium	Quaternary alluvium	4	3	2
Qay	minor river alluvium	Quaternary alluvium	4	3	2
Qbf	minor river fine-grained alluvium	Quaternary alluvium	4	3	2
Qc	colluvium	Quaternary colluvium	4	4	2
Qd	dune sand	Quaternary dune	5	3	2
Qda	debris avalanche deposit	Quaternary landslide	5	3	3
Qes	eolian silt and sand	Quaternary eolian	4	4	2
Qf	braided fan	Quaternary alluvium	4	3	2
Qfd	sand gravel fan	Quaternary alluvium	4	3	2
Qff	Missoula Flood fine-grained alluvium	Quaternary alluvium	4	3	2
Qgf	glacial and fluvial alluvium	Quaternary gravels	3	2	2
Qj	block and ash flow	Tertiary volcanic alluvium	4	2	2
Qlg	gravel alluvium	Quaternary gravels	3	2	2
Qls	landslide	Quaternary landslide	5	3	3
Qmg	Missoula Flood sand and gravel	Quaternary terrace deposits	4	2	2
Qoa	older alluvium	Quaternary alluvium	4	3	2
Qoam	old alluvium of Mohawk	Quaternary alluvium	4	3	2
Qs	lacustrine and fluvial alluvium	Quaternary alluvium	5	5	2
QTat	Quaternary and Tertiary strongly weathered sand/ gravel terraces	Quaternary terrace deposits	4	2	2
QTb	young basalt - Boring Lavas and Pigeon Prairie Basalt	Quaternary volcanics	2	1	1
Qtg	terrace gravel	Quaternary gravel	3	2	2
Qth	high terrace deposits	Quaternary terrace deposits	4	2	2
Qtlb	low and bottomland terrace deposits	Quaternary low terrace deposits	5	3	2
Qtm	middle terrace deposits	Quaternary terrace deposits	4	2	2
QTs	siltstone, sandstone, and conglomerates- Parkette Creek Formation	Quaternary-Tertiary fluvial al-luvium	3	1	2
QTt	siltstone, sandstone, and conglomerates - Troutdale Formation	Quaternary -Tertiary fluvial al-luvium	3	1	2
Qt	terrace deposits	Quaternary alluvium	4	3	2
QTtg	terrace Gravels	Quaternary gravels	3	2	2
Qws	Willamette silts	Quaternary terrace deposits	4	2	2
Rf	recent fill	Quaternary fill	5	4	2
Tal	sand-gravel mixture / weak conglomerate	Tertiary fluvial alluvium	3	1	2
Tb	basalt flows and volcaniclastic	Tertiary volcanic Cascade*	2	1	2
Tbac	Basalt of Camp Creek	Tertiary volcanic Cascade*	2	1	2
Tbah	basalt and andesite of Coberg Hills	Tertiary volcanic Cascade*	2	1	2
Tbd	basalt dikes	Tertiary intrusive	2	1	2
Tbm	Basalt of Mohawk	Tertiary volcanic Cascade*	2	1	2
Tbmp	Basalt of Mount Pigsah	Tertiary volcanic Cascade*	2	1	2
Tbr	basalt flows	Tertiary volcanic Cascade*	2	1	2
Tco	Cowlitz Formation	Tertiary marine sedimentary rock	3	1	2
Tcr	Columbia River Basalt	Tertiary volcanic Cascade*	2	1	2

(table continued on next page)

Table H4, continued.

Map Unit	Description	General Rock Type	Site Class		
			GSA	LIQ	LS_ UNIT
Tcs	Miocene continental sedimentary rocks	Tertiary sedimentary rock	3	1	2
Tdc	Tuff of Daniels Creek	Tertiary volcanic Cascade*	2	1	2
Tdxt	Tuff of Dexter	Tertiary volcanic Cascade*	2	1	2
Te	Eugene Formation	Tertiary fluvial alluvium	3	1	2
Tf	siltstone and sandstone - Fisher Formation	Tertiary sedimentary rock	3	1	2
Tfc	Miocene andesite/basalt rocks, flows, and clastic rocks	Tertiary volcanic Cascade*	2	1	2
Tfe	Fisher and Eugene Formations and correlative rocks	Tertiary Fluvial alluvium	3	1	2
Thi	hypabyssal intrusive rocks	Tertiary Intrusive	2	1	2
Ti	intrusive	Tertiary Intrusive	2	1	2
Tib	basalt and andesite intrusions	Tertiary Intrusive	2	1	2
Tiba	basaltic andesite Intrusive	Tertiary Intrusive	2	1	2
Tid	dacite dike	Tertiary Intrusive	2	1	2
Tim	mafic and intermediate intrusive rocks	Tertiary Intrusive	2	1	2
Tl	Loane Shale	Tertiary Sedimentary	3	1	2
Tlb	basalt - Little Butte Formation	Tertiary volcanic Cascade*	2	1	2
Tm	marine sedimentary rocks - Tyee, Yamhill Formations, etc.	Tertiary Marine Sedimentary Rock	3	1	2
Tmba	basalt andesite	Tertiary volcanic Cascade*	2	1	2
Tomb	basaltic andesite	Tertiary volcanic Cascade*	2	1	2
Tos	volcaniclastic sedimentary	Tertiary Volcanic alluvium	4	2	2
Tpb	porphyritic basalt	Tertiary Volcanic Coast	3	2	2
Tpb	pyroxene basalt	Tertiary volcanic Cascade*	2	1	2
Tr	ryolite intrusive rocks	Tertiary intrusive	2	1	2
Ts	Spencer Formation	Tertiary sedimentary	3	1	2
Tsmc	volcanic conglomerate and mudstone - Scotts Mills Formation	Tertiary volcanic alluvium	3	2	2
Tsr	Siletz River volcanics and related rocks	Tertiary volcanic Coast†	3	2	2
Tss	tuffaceous siltstone and sandstone	Tertiary marine sedimentary rock	3	1	2
Tsv	silicic vent complexes	Tertiary volcanic Cascade*	2	1	2
Tt	Tyee Formation	Tertiary marine sedimentary rock	3	1	2
Ttb	Tuff of Bond Creek	Tertiary volcanic Cascade*	2	1	2
Ttd	Tuff of Daniels Creek	Tertiary volcanic Cascade*	2	1	2
Ttf	Tuff of Fox Hollow	Tertiary volcanic Cascade*	2	1	2
Ttg	Tuff of Gimp Hill Road	Tertiary volcanic Cascade*	2	1	2
Ttq	Tuff of Quaker Road	Tertiary volcanic Cascade*	2	1	2
Tts	tuff	Tertiary volcanic Cascade*	2	1	2
Ttv	Tillamook Volcanics	Tertiary volcanic Coast†	2	1	2
Ttw	Tuff of Willamette Street	Tertiary volcanic Cascade*	2	1	2
Tty	Tyee Formation	Tertiary sedimentary	3	1	2
Tu	Miocene-Oligocene tuffaceous, sedimentary clastic, basalt flows/breccias	Tertiary volcanic Cascade*	2	1	2
Tub	undifferentiated basaltic lava flows	Tertiary volcanic Cascade*	2	1	2
Tus	undifferentiated sedimentary and volcaniclastic rocks	Tertiary volcanic alluvium	4	2	2
Tut	undifferentiated tuff - welded	Tertiary volcanic alluvium	4	2	2
Tv	vent deposits	Tertiary volcanic Cascade*	2	1	2
Tvc	volcaniclastic rocks	Tertiary volcanic Cascade*	2	1	2
Tvs	Volcaniclastic sedimentary	Tertiary volcanic Cascade*	2	1	2
Twc	volcaniclastic rocks of Wallace Creek	Tertiary volcanic alluvium	4	2	2
Ty	Yamhill Formation and related rock	Tertiary marine sedimentary rock	3	1	2

* Tertiary Cascade Range volcanic bedrock.
† Tertiary Coast Range volcanic bedrock.

Liquefaction Susceptibility

Liquefaction hazard groupings were primarily based on lithologies or type of deposit (Table H5). To develop the regional liquefaction hazard maps for this study, we started by collecting the best available geologic information, as we did for the assessment of ground-shaking amplification hazards. We based hazard groupings primarily on lithologies. With the available information compiled, we assigned liquefaction susceptibility classes based on the dominant lithologies for each geologic unit in the study area, checked source data boundaries, and simplified the GIS outputs into six relative hazard classes: Rare, Very Low, Low, Moderate, High, and Very High.

Table H5. Liquefaction susceptibility rating system (Youd and Perkins, 1978).

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments when Saturated would be susceptible to Liquefaction (by Age of Deposit)			
		Modern < 500 yr	Holocene < 11 ka	Pleistocene 11 ka - 2 Ma	Pre-Pleistocene > 2 Ma
		(a) Continental Deposits			
River channel	locally variable	very high	high	low	very low
Flood plain	locally variable	high	moderate	low	very low
Alluvial fan and plain	widespread	moderate	low	low	very low
Marine terraces and plains	widespread	—	low	very low	very low
Delta and fan-delta	widespread	high	moderate	low	very low
Lacustrine and playa	variable	high	moderate	low	very low
Colluvium	variable	high	moderate	low	very low
Talus	widespread	low	low	very low	very low
Dunes	widespread	high	moderate	low	very low
Loess	variable	high	high	high	unknown
Glacial till	variable	low	low	very low	very low
Tuff	rare	low	low	very low	very low
Tephra	widespread	high	high	?	?
Residual soils	rare	low	low	very low	very low
Sebka	locally variable	high	moderate	low	very low
		(b) Coastal Zone			
Delta	widespread	very high	high	low	very low
Esturine	locally variable	high	moderate	low	very low
Beach					
—high wave energy	widespread	moderate	low	very low	very low
—low wave energy	widespread	high	moderate	low	very low
Lagoonal	locally variable	high	moderate	low	very low
Fore shore	locally variable	high	moderate	low	very low
		(c) Artificial			
Uncompacted fill	variable	very high	—	—	—
Compacted fill	variable	low	—	—	—

After we established the relative liquefaction classes (liq_class), we converted them to relative susceptibility zones (liq_suscep), and then to the input parameters (hazus_type) necessary for HAZUS-MH as shown in Table H6.

Table H6. Field attributes for the liquefaction layer.

liquefaction id	liq_class	liq_suscep	hazus_type
1	a	rare	0
2	b	very_low	1
3	c	low	2
4	d	moderate	3
5	e	high	4
6	f	very_high	5

Liquefaction id serves as a unique identifier of classes. Liq_class relates the zone to the type of deposit (Table H2). Liq_suscep is a relative descriptive relation to liq_class. Hazus_type is the corresponding value in the HAZUS-MH program.

Earthquake-Induced Landslide Susceptibility

In this study, we used a combination of approaches to develop the primary earthquake-induced landslide hazard identification classes. First, we developed a regional landslide hazard map that distinguishes different areas based on simple geologic group as shown in Table H7 (Low, Moderate, High).

Crystalline and well-consolidated rocks have the lowest susceptibility, weakly cemented sedimentary rocks and unconsolidated sediments have moderate susceptibility, and existing landslides and colluvium deposits have high susceptibility. Table H2 displays the relationship between the geologic unit and the landslide susceptibility groups.

We then combined these geologic groups with the slope gradient derived from a 10-m digital elevation model (DEM). Landslide hazard class assignments based on the combination of material type categories (Low, Moderate, High, and Very High) and slope gradient values in degrees were made as shown in Table H7. We derived the hazard classes of low, moderate, high, and very high from the combination of the slope map and the material type categories according to Table H7.

Table H7. Landslide hazard class assignments based on the combination of material type categories (low, moderate, high) and slope gradient values in degrees.

Geologic Group (relative slope instability susceptibility)	Slope					
	0°–10°	10°–15°	15°–20°	20°–30°	30°–40°	40°+
Low (consolidated rock)	low	low	low	moderate	high	very high
Moderate (highly weathered rock and unconsolidated sediments)	moderate	moderate	moderate	high	very high	very high
High (existing landslides, landslide topography, and colluvium)	high	high	high	very high	very high	very high

After we established the relative landslide classes (ls_class), we converted them to relative susceptibility zones (ls_suscep), and then to the input parameters (hazus_type) necessary for HAZUS-MH as shown in Table H8.

Table H8. Field attributes for the earthquake-induced landslide layer.

Landslide id	ls_class	ls_suscep	hazus_type
1	—	—	0
2	low	low	1
3	—	—	2
4	—	—	3
5	moderate	moderate	4
6	—	—	5
7	—	—	6
8	high	high	7
9	—	—	8
10	—	—	9
11	very_high	very_high	10

The landslide column serves as a unique identifier. The ls_class relates the zone to the type of deposit (Table H2). The ls_suscep is a relative descriptive relation to the ls_class and the hazus_type are the related values which HAZUS-MH can read. Since we could not determine if any of the geologic groups within the study area are not susceptible to landsliding at any slope, the hazus_type=0 was not used. Hazus_types 2, 3, 5, 6, 8, and 9 were not subdelineated due to the lack of detail of the original geology base map.

Existing Geologic Hazard Data

In addition to the hazard maps developed for this study, we used other hazard maps to develop the geologic layers (Figure H3, Table H1). Figure H3 is a geographic reference to these previous studies. The existing hazard maps have several different classification schemes. We converted the classifications to match those used in this study and assigned required parameters for HAZUS-MH according to the scheme listed in Table H8. Then we simply overlaid the layers on top of the countywide hazard maps developed for this study. Because the existing studies use more stringent procedures, such as collecting shear wave velocities in the field to develop the hazard zones, we used these layers rather than countywide data wherever data existed.

We used the following procedures to convert individual hazard maps.

- GMS-105 (Wang and Leonard, 1996): Existing study has six liquefaction categories, so, we set liquefaction categories 0 and 1 to 1, and left 2, 3, 4, and 5 as is. The landslide layer has six categories, so we set 5 to Very High, 4 and 3 to High, 1 and 2 to Moderate, and 0 to Low. The earthquake-induced landslide data from IMS-17 and IMS-18 were both stamped onto GMS-105 where they overlapped. We used the common means of categorizing regional ground-shaking amplification hazards developed by NEHRP for ground-shaking amplification.
- IMS-7 (Madin and Wang, 2000c): Existing study has four liquefaction categories, so we set None to 2, Low to 3, Moderate to 4, and High to 5. Ground-shaking amplification and landslide layers were left as is. The earthquake-induced landslide data from IMS-17 and IMS-18 were both stamped onto IMS-7 where they overlapped.
- IMS-8 (Madin and Wang 2000a): Existing study has four liquefaction categories, so we set None to 2, Low to 3, Moderate to 4, and High to 5. Ground-shaking amplification and landslide layers were left as is.

- IMS-9 (Madin and Wang, 2000b): Existing study has four liquefaction categories, so we set None to 2, Low to 3, Moderate to 4, and High to 5. Ground-shaking amplification and landslide layers were left as is.
- IMS-10 (Madin and Wang, 1999): Existing study has four liquefaction categories, so we set None to 2, Low to 3, Moderate to 4, and High to 5. Ground-shaking amplification and landslide layers were left as is.
- IMS-14 (Black and others, 2000): Existing study had five landslide categories, so we set 1 and 2 to Low, 3 to Moderate, 4 to High, and 5 to Very High. Ground-shaking amplification was left as is. There is no liquefaction layer included in this study.
- IMS-17 (Hofmeister and others, 2000): Existing study has four landslide categories, so we set Very Low to Low, Low to Moderate, Moderate to High, and High to Very High. There are no liquefaction or ground-shaking amplification layers included in this study.
- IMS-18 (Hofmeister and Wang, 2000): Existing study has four landslide categories, so we set very Very Low to Low, Low to Moderate, Moderate to High, and High to Very High. The earthquake-induced landslide data from IMS-17 were stamped onto IMS-18 where they overlapped. There are no liquefaction or ground-shaking amplification layers included in this study.
- Open-File Report O-01-05 (Wang and others, 2001): The earthquake-induced landslide layer was left as is. The ground-shaking amplification layers were left as is. The liquefaction layer was left as is. The landslide hazard map has four categories, so we extracted the "existing hazard" or existing landslides category and combined it with the identified landslides from the geologic map discussed in the next subsection of this appendix. These GIS files had many topology problems, so we converted all polygons to grids and then recombined the separate grids by stamping the Very High category onto the High onto the Moderate onto the Low. This is a conservative approach of correcting the topology and attribute errors in the original files.

Existing Landslides

We extracted existing landslide polygons from the final geologic map (Figure 3, main text) to create the identified landslide hazard layer included in this study. This GIS compilation of previously identified landslide areas was derived from published geologic reports and existing geologic hazard studies.

GIS Topology Cleanup Process

Each GIS file was subjected to the following topology cleanup process:

1. Convert the final polygon file to a 10-m grid using MapInfo® Vertical Mapper™,
2. Reclassify the grid in Vertical Mapper back into the original relative hazard classes,
3. Recontour the grid to polygons,
4. Process the file in MapInfo Geometry Manager and manually check the topology and attributes, and
5. Define the final attributes.

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APPENDIX I:
VOLCANIC HAZARD MAPS

The U.S. Geological Survey has published descriptions of volcanic hazards in the Mount Jefferson and Three Sisters regions. Figure I1 is a map of the eastern half of the study area showing locations of volcanoes. The three oversize maps that follow in this appendix are reproduced from these publications:

Scott, W. E., Iverson, R. M., Schilling, S. P., and Fisher, B. J., 1999, Volcano hazards in the Three Sisters region, Oregon: U.S. Geological Survey Open-File Report 99-437, 14 p., 1 plate.
http://geopubs.wr.usgs.gov/open-file/of99-437/
Plate 1: Volcano hazards in the Three Sisters region, Oregon

Walder, J. S., Gardner, C. A., Conrey, R. M., Fisher, B. J., and Schilling, S. P., 1999, Volcano hazards in the Mount Jefferson region, Oregon: U.S. Geological Survey Open-File Report 99-24, 14 p., 2 plates.
http://geopubs.wr.usgs.gov/open-file/of99-24/
Plate 1 and Plate 2: Volcano hazards in the Mount Jefferson region, Oregon

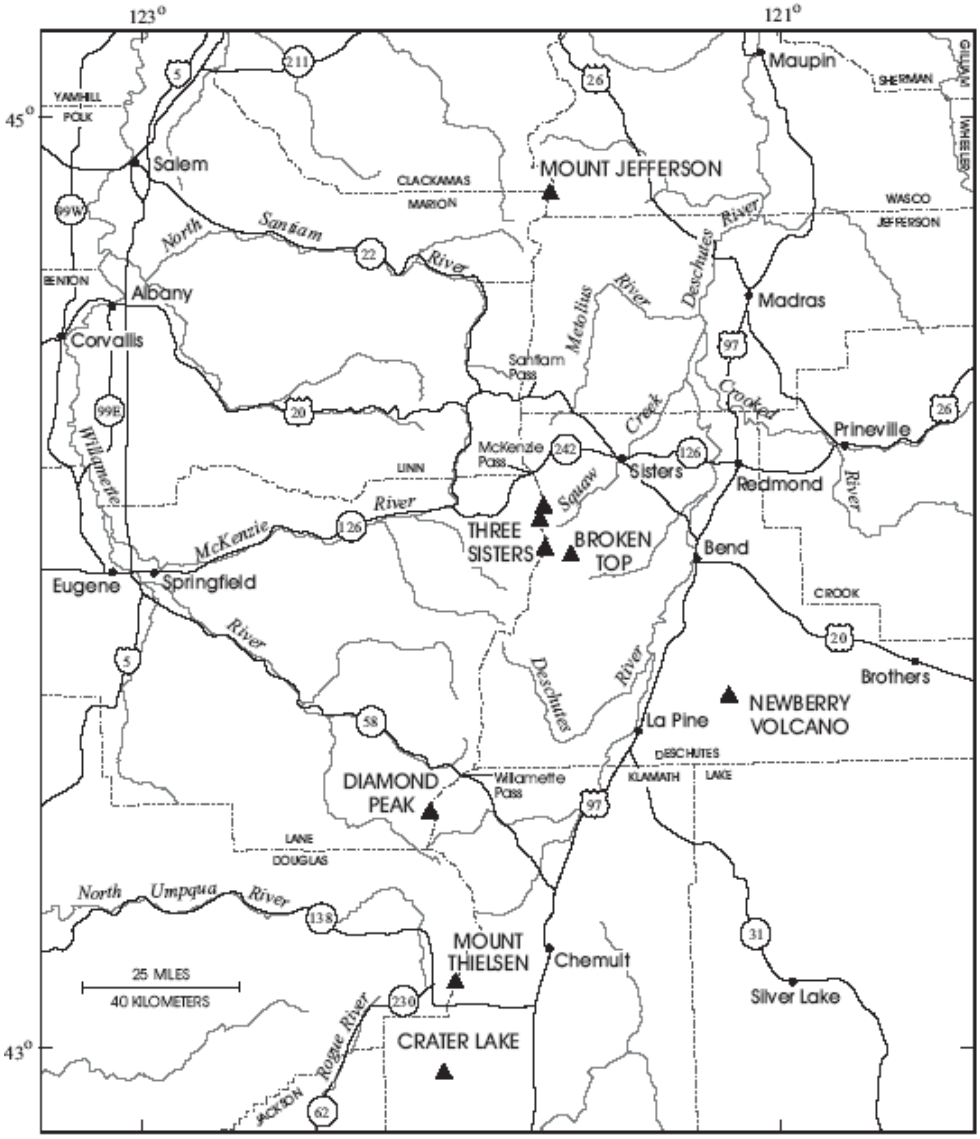
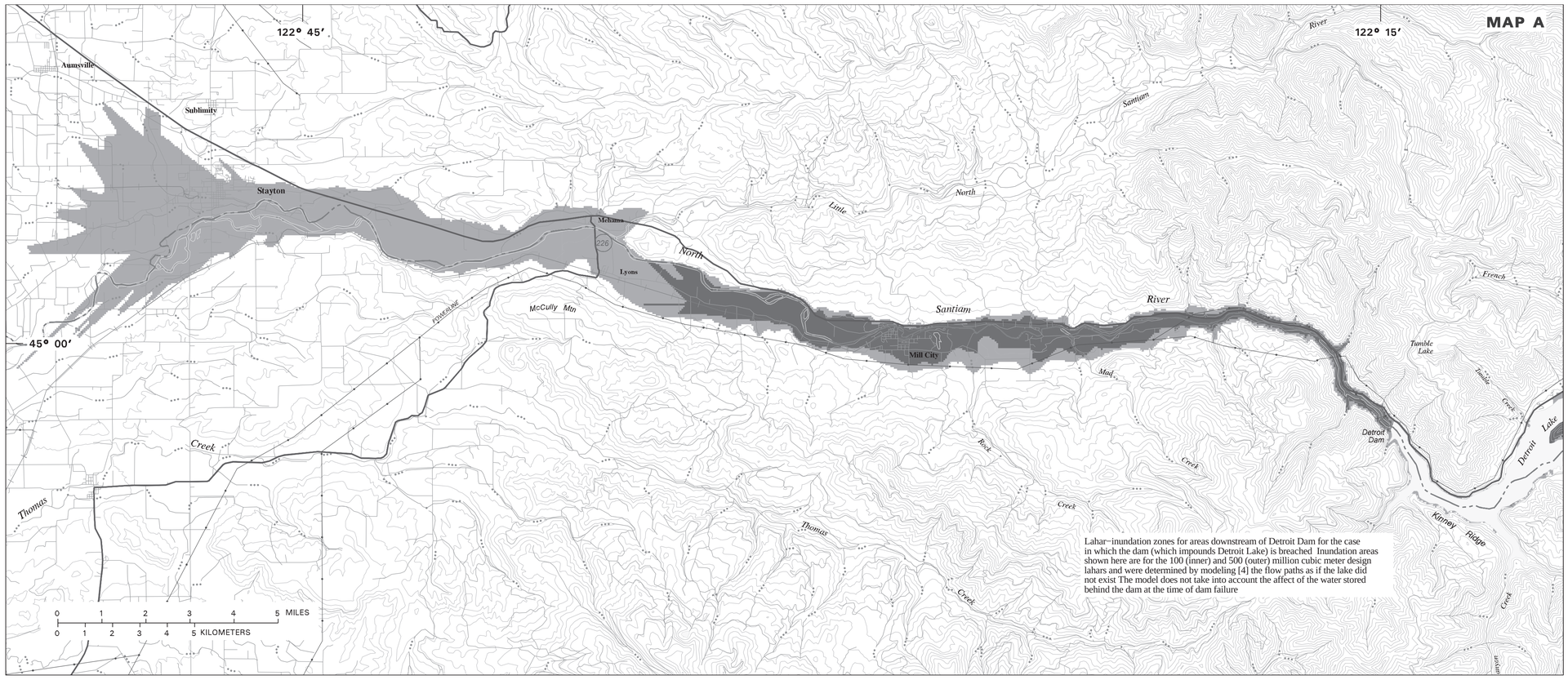
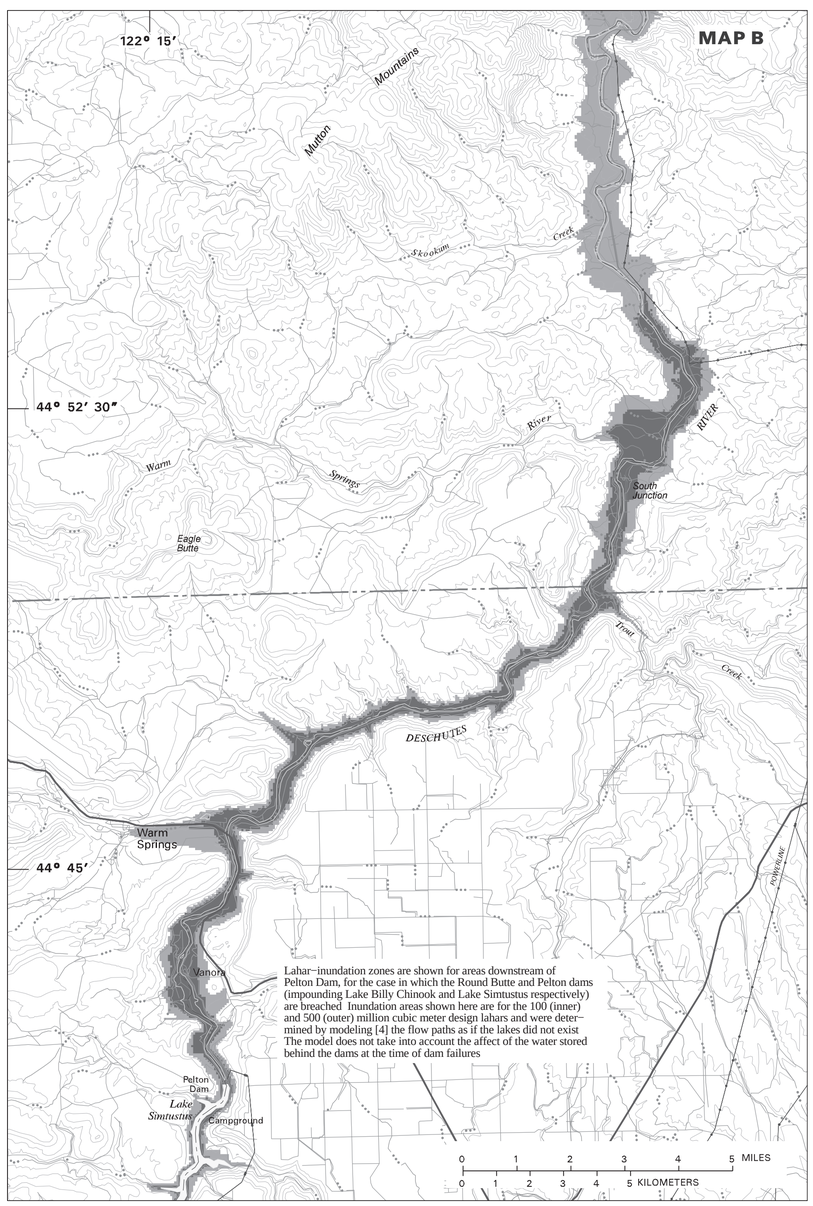
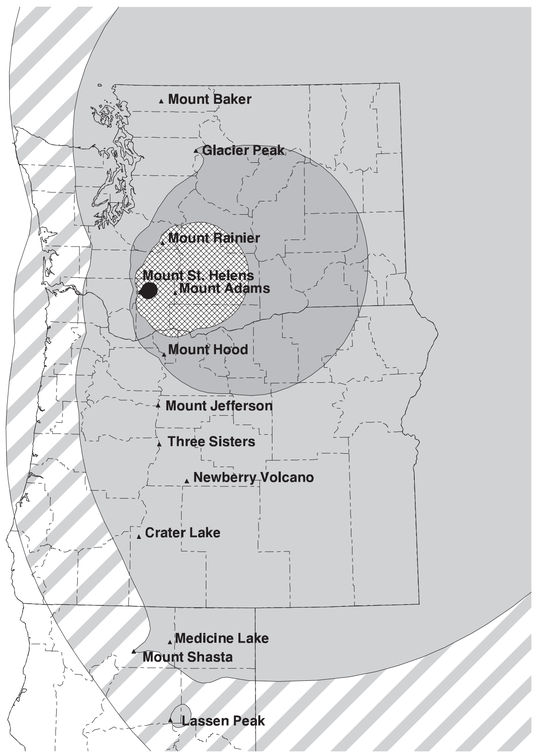


Figure I1. Map of the eastern half of the study area showing locations of volcanoes (Scott and others, 1999).

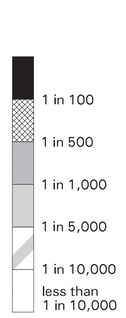


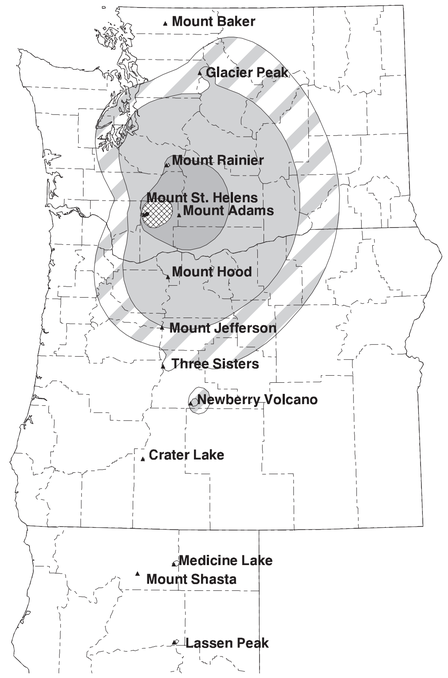


Regional Tephra-fall Maps



(1) Annual probability of the deposition of 1 centimeter (0.4 inches) or more of tephra from any of the major Cascade volcanoes.





(2) Annual probability of the deposition of 10 centimeters (4 inches) or more of tephra from any of the major Cascade volcanoes.

Base composited in digital form by Bruce J. Fisher from U.S. Geological Survey, North Santiam (1983) and Madras (1983) 1:100,000 scale maps. Data for hydrography, culture, transportation, and boundaries from U.S. Geological Survey (EROS Data Center) Digital Line Graph files. Digital Line Graph hypsography (topographic contours) created from U.S. Geological Survey blackline clear-films by Pacer Infotec, Inc., Portland, OR. Contour interval 50 meters.

Universal Transverse Mercator projection, Zone 10

1927 North American Datum

USGS
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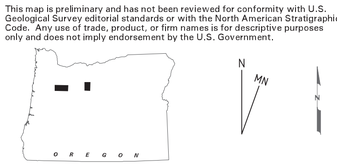
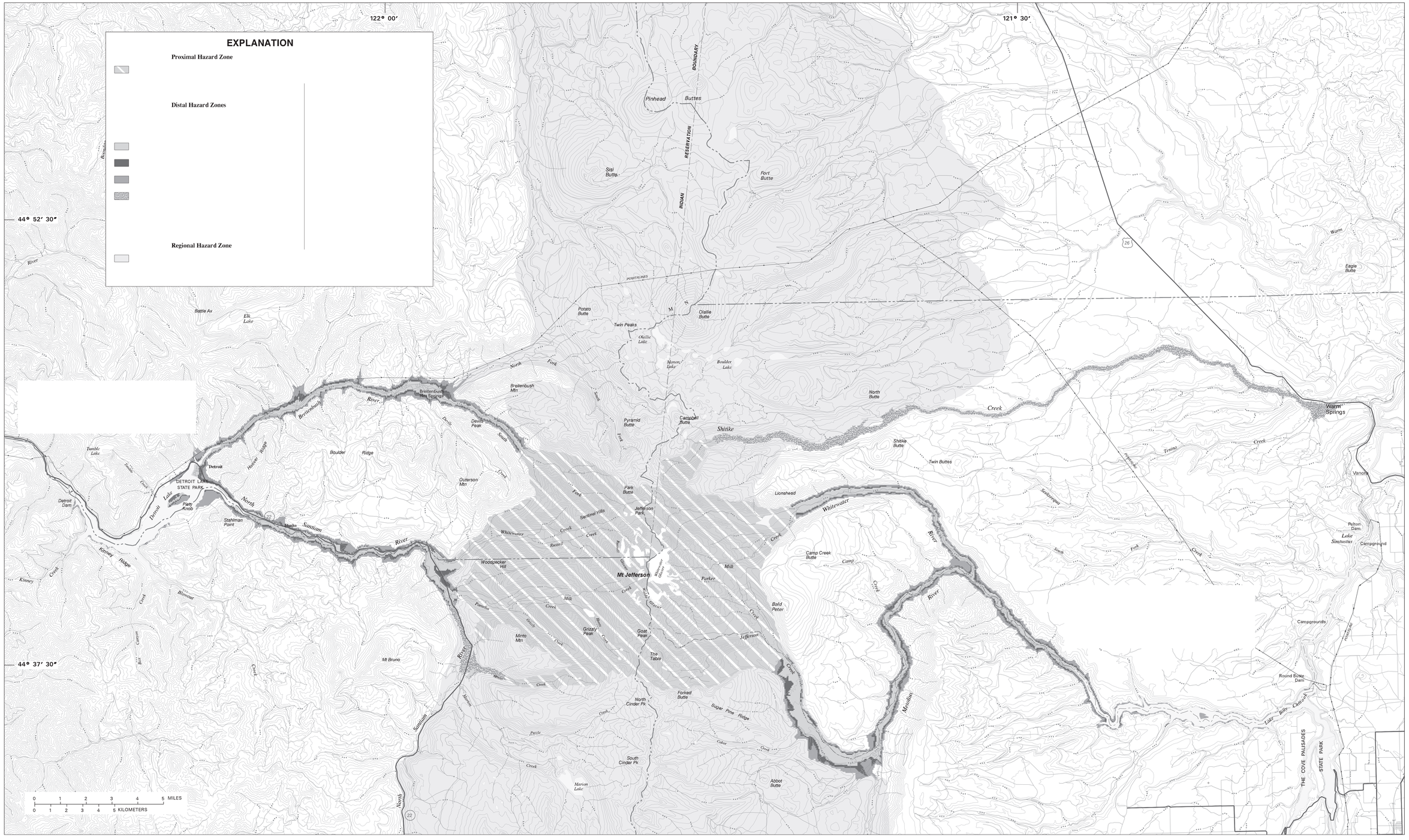
VOLCANO HAZARDS IN THE MOUNT JEFFERSON REGION, OREGON

By

Joseph S. Walder, Cynthia A. Gardner, Richard M. Conrey, Bruce J. Fisher and Steven P. Schilling

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.





VOLCANO HAZARDS IN THE MOUNT JEFFERSON REGION, OREGON

By

Joseph S. Walder, Cynthia A. Gardner, Richard M. Conrey, Bruce J. Fisher and Steven P. Schilling

Base composited in digital form by Bruce J. Fisher from U.S. Geological Survey, North Santiam (1983) and Madras (1983) 1:100,000 scale maps. Data for hydrography, culture, transportation, and boundaries from U.S. Geological Survey (EROS Data Center) Digital Line Graph files. Digital Line Graph hypsography (topographic contours) created from U.S. Geological Survey blackline clear-films by Pacer Infotec, Inc., Portland, OR. Contour interval 50 meters.

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Hazard-zonation map for Mount Jefferson adjoins this map. See USGS Open-File Report 99-24

122° 30′

121° 30′

44° 30′

43° 45

MAP EXPLANATION

P

R

regional tephra-hazard maps

W B B

Boundaries between hazard zones do not represent sharp changes in hazards.

R

R

B

B

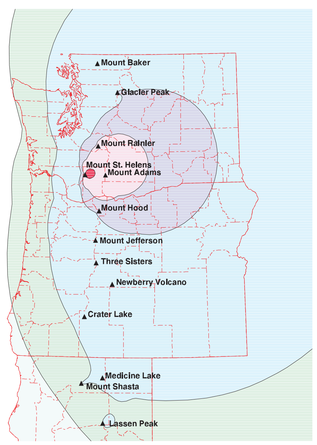
Proximal Hazard Zone

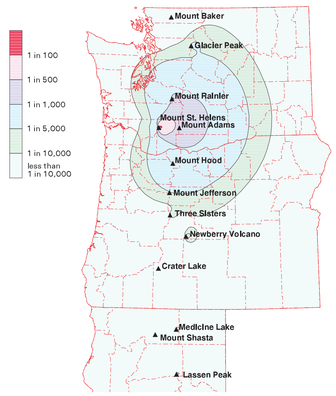
Distal Hazard Zones

B

Regional Lava Flow Hazard Zone

Regional Tephra- Hazard Maps





Newberry Volcano Hazard Zones

See USGS Open-File Report 97-513

0 5 10 MILES

0 5 10 KILOMETERS

Contour interval of 50 meters for upper- left and lower- left portion of map. Contour intervals of 40 or 50 meters with supplementary contour interval of 10 meters for upper- right portion of map. Contour interval of 50 meters with supplemental contours of 25 meters for lower- right portion of map.

Base compositied in digital form by Steven P. Schilling from U.S. Geological Survey, Bend (1980), La Pine (1986), Oakridge (1983) and McKenzie River (1983) 1:100,000 scale maps.
Data for hydrography, culture, transportation, and boundaries from U.S. Geological Survey (EROS Data Center) Digital Line Graph files. Digital Line Graph hypsography (topographic contours) created from U.S. Geological Survey blackline clear-films by Pacer Infotec, Inc., Portland, Oregon.

Universal Transverse Mercator projection, Zone 10

1927 North American Datum

VOLCANO HAZARDS IN THE THREE SISTERS REGION, OREGON

By

William E. Scott, Richard M. Iverson, Steven P. Schilling, Bruce J. Fisher

N MN

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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APPENDIX J:
PRE-DISASTER MITIGATION PLAN ACTION ITEMS

Table J1 lists pre-disaster mitigation (PDM) plan action items, sorted by hazard type.

Table J1. Pre-Disaster Mitigation Plan Action Items.

Hazard	Action Item	Rational for Item	Ideas for Implementation
Multi-hazard	Identify and pursue funding opportunities to implement mitigation actions.	The switch from planning to implementation is the step that begins the reduction of risk.	Form partnerships with city, other county, and state agencies. Use these partnerships to apply for federal and local (local bonds, measures) mitigation grants.
Multi-hazard	Integrate the hazard data into planning ordinances and regulatory documents and programs.	Without ordinances and regulations, the hazard data are used by only a few, instead of by all.	Work with local and regional governments.
Multi-hazard	Develop education programs aimed at mitigating the risk posed by hazards.	Education of the potential hazard and risk are sometimes the best way to reduce the risk.	Work with local and regional governments. Use internet websites, local fairs, news articles, brochures, etc. to get the data to the public.
Earthquake	Improve earthquake hazard zone maps through elimination of errors and omissions: groundshaking amplification, liquefaction, earthquake-induced landslides, and tsunami inundation.	The current earthquake hazard maps are frequently a compilation of the existing maps, and were not necessarily the result of a systematic approach. These maps were compiled at widely varying scales and therefore have similarly varying levels of detail. The coarse-scale maps may mislead people to believe that certain areas have no hazard, whereas those areas have simply not been evaluated in detail. Systematic upgrading of these maps will lead to greater understanding of hazard locales. This will improve land use planning and provide for more efficient and cost effective development.	Systematically utilize the new Oregon Geologic Digital Data Compilation project output. Use new digital elevation models including those derived from LIDAR surveys to significantly enhance the accuracy of hazard classification. Collect and compile engineering properties of the geologic units. Incorporate improved spatial (vertical and horizontal) engineering properties data of the geologic rock units (shear wave velocities, strength, grain size, density, etc). Include hydrologic database characteristics such as groundwater depth.
Earthquake	Improve understanding of vulnerability and risk to life, property, and critical infrastructure (lifelines) from earthquake hazards.	If we can understand the risk from earthquakes closer to reality, we can plan and use resources more appropriately to prepare against this hazard. Better data provides for better decisions to minimize loss. In the case of lifelines, minimizing direct losses also minimizes the "snowball effect" or indirect losses also.	Complete an inventory of critical public facilities, including schools, emergency facilities, first-responder buildings, other key public use structures, and infrastructure lifelines. This is particularly important for critical structures (schools and emergency facilities) and lifelines. After the improvement of the hazard layers and the vulnerability inventory, the risk analysis should be reevaluated.
Earthquake	Educate identified vulnerable residential and commercial building owners and occupants, decision makers, lifeline owners, and others.	Those at risk need to be made aware to effect change.	Provide education media to identified vulnerable residential and commercial building owners and occupants. Explain structural and non-structural rehabilitation techniques and encourage rehabilitation.

(table continued on next page)

Table J-1, continued.

Hazard	Action Item	Rational for Item	Ideas for Implementation
Earthquake	Rehabilitate identified vulnerable schools, emergency facilities, and public buildings/lifelines.	Performing the rehabilitation of vulnerable buildings is one of the final steps that actually reduces the risk.	Provide scientific basis in effort to obtain local state, federal, and private funding.
Earthquake	Improve knowledge of earthquake sources.	The source and location of an earthquake is a critical component of the expected damage to a particular site.	Improve the existing crustal fault database by expanding LIDAR survey coverage and interpreting the results. After the potentially active faults are identified, trenching should be conducted to associated data such as recurrence intervals and maximum magnitude. Expand the seismic instrument network.
Landslide	Improve landslide hazard area maps for a variety of types of landslides.	The current landslide hazard maps are a compilation of the existing maps. These maps are a "work in progress" and have been compiled at widely varying scales and sometimes only depict risk for certain types of landslides. These various scales and levels of detail may lead to people to believe that some areas have no slope hazard, when the case is that those areas just have not been evaluated yet. Systematic upgrading of these maps will lead to greater understanding of hazard locales. This will improve land use planning and provide for more efficient and cost effective development.	Incorporate new Oregon Geologic Digital Data Model. Sponsor and collect LIDAR surveys to inexpensively vastly improve the landslide hazard model. Continue field-based science research by detailed mapping of existing landslide-prone areas. Once sufficient data is collected, perform modeling to predict areas of future higher to lower instability potential.
Landslide	Improve understanding of risk to life and property in landslide hazard areas.	Better data provide for better decisions to minimize loss. Incorporating indirect economic loss better depicts the cost from natural hazard events.	Complete inventory of critical facilities including: schools and emergency facilities, vulnerable public and commercial buildings, vulnerable residential buildings, and lifelines (including roads). Evaluate risk to life and property, including indirect economic loss. After the improvement of the hazard layers and the vulnerability inventory, the risk analysis should be reevaluated.
Landslide	Educate identified vulnerable residential and commercial building owners, occupants, and developers.	With continued urban and near-urban development, areas with significant hazard risk will face development pressures. Land use development should provide for mitigating potential losses from landslide hazards.	Provide educational media to identified vulnerable residential and commercial building owners, occupants, and developers, which explain structural and non-structural reduction techniques such as local drainage improvements.
Landslide	Improve knowledge of debris flow (rapid moving) landslide hazard areas.	Debris flow landslides are rapidly moving and have caused the loss of life in Oregon. The current debris flow hazard maps are based mostly on computer modeling and could be improved through the incorporation of better topographic survey, geologic field data, and human impact data.	Incorporation and interpretation of new base geologic maps including the Oregon Geologic Data Compilation. Use new slope maps including LIDAR-derived DEM and improvement through future mapping. Collect data related to human impact. Improve rainfall thresholds.

(table continued on next page)

Table J-1, continued.

Hazard	Action Item	Rational for Item	Ideas for Implementation
Landslide	Evaluate and improve current debris flow landslide warning systems to ensure coverage and effectiveness.	The coordination of a warning alert to the local level is as important as the alert itself.	Improvements to the instrumentation network (real time rainfall monitoring, active debris flow trip instruments, etc) should be installed and implemented. Follow-through improvements to the warning alert can be done through improvements in the chain of warning system down to the local level.
Dam failure	Acquire or prepare detailed dam failure inundation maps.	Identifying the hazard is necessary prior to identifying public notification areas and evacuation routes.	Prepare maps with FEMA 100 and 500-year flood inundation maps along with the dam failure inundation zone. Complete inventory of critical facilities including: schools and emergency facilities, vulnerable public and commercial buildings, vulnerable residential buildings, and lifelines within the dam inundation zone.
Dam failure	Improve understanding of vulnerability and risk to life and property from natural hazard induced dam failure.	If we can understand the risk from dam failure closer to reality, we can plan and use resources more appropriately to prepare against this hazard.	After the improvement of the hazard layers and the vulnerability inventory, the risk analysis should be reevaluated. Provide educational media to identified vulnerable communities.
Dam failure	Rehabilitate identified vulnerable dams.	Reduce or eliminate the risk to life, property and infrastructure.	Provide support to assist in obtaining funding to perform rehabilitation.
Dam failure	Evaluate emergency response plan and identify areas of public notification and evacuation routes.	Ensure the plan is adequate to cope with a hazard event.	Evaluate existing plan and revise notification and evacuation routes based on vulnerability inventory.
Volcanic	Acquire or prepare detailed volcanic hazard maps.	Review volcanic hazard reports including Crater Lake, Mt. Hood, Mt. Jefferson, Newberry Volcano, and the Sisters Region. The many smaller volcanoes along the Cascade Mountains have not been evaluated for hazards. These smaller volcanoes may not pose far-reaching hazards, but are a hazard to local communities and travelers.	Prepare maps of hazards related to these smaller, yet important, volcanoes.
Volcanic	Improve understanding of vulnerability and risk to life and property from natural hazard induced dam failure.	If we can understand the risk from volcanic hazards closer to reality, we can plan and use resources more appropriately to prepare against this hazard.	This is particularly important for critical structures (schools and emergency facilities) and lifelines. After the improvement of the hazard layers and the vulnerability, the understanding of vulnerability and risk should be reevaluated.
Volcanic	Evaluate emergency response plan and identify areas of public notification and evacuation routes.	The coordination of a warning alert to the local level is as important is the alert itself.	Evaluate existing plan and revise notification and evacuation routes based on vulnerability inventory.

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APPENDIX K:
LANDSLIDE IMPACT INVENTORY DATA SHEET

The sample landslide impact inventory data form (shown on the next pages) may be used to collect information on future landslides. For example, the simple data form can be used in conjunction with the initial GIS database to efficiently gather new data on smaller numbers of landslide events. For more widespread events with larger numbers of landslide effects, GIS and/or spreadsheet applications can be used to efficiently incorporate new information and expand on this initial GIS file.

INVENTORY OF LANDSLIDES IN OREGON

This inventory sheet has been developed to facilitate the incorporation of slide information from a variety of sources. It was originally developed to inventory the 1996 and 1997 storm events but can be used to input data from other dates. If you have a large amount of data and /or other means of transfer would be more efficient, please contact Bill Burns directly (Bill Burns).

Please send completed forms to:
Oregon Department of Geology and Mineral Industries
800 NE Oregon Street #28, Suite 965
Portland, Oregon 97232

Questions? Please contact DOGAMI at (971) 673-1555 or bill.burns@dogami.state.or.us

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

800 NE Oregon Street #28, Suite 965, Portland, OR 97232
(971) 673-1555 WEB: http://www.oregongeology.com

LANDSLIDE INVENTORY DATA SHEET

Name: _____ Phone Number: _____

Title: _____ e-mail: _____

Organization: _____

Landslide Characteristics

1) Landslide ID: _____ (corresponding to your own system)

2) Landslide Name (if any):
_____

3) Location of Slide:
Coordinates (e.g. Longitude/Latitude or street address or property owner):
_____

Source of Location (e.g. field mapping on 1:24K Quads) or other (e.g. map attached, address, description):
_____
_____

4) Date(s) of Slide
Activity_____

5) Estimated Dimensions:

Length (down slope) _____ feet Width (across slope) _____ feet

Depth _____ feet

Volume _____ feet3

Estimated dimensions from (e.g. field evaluation, aerial photos):

_____

_____

(over)

LANDSLIDE INVENTORY DATA SHEET

6) Predominate type of material (circle all that apply):

Rock Debris (coarse soils) Earth (fine soils) Fill

7) Predominate type of movement (circle all that apply):

Fall/Topple Flow Translational Slide Rotational Slide Spread

8) Other Slide Characteristics:

a) Approximate original slope (e.g. 30° +/- 5°): _____

Estimated from (e.g. 1:24K USGS topo map): _____

b) Land use where slide occurred (please circle all that apply):

Forested area Harvested area Rural area Urban area Agriculture

c) Cause of slide (please circle all that apply):

Road Construction Road cut Road fill Earthquake

Pre-existing slide Steep natural slope Natural Drainage

Human built drainage Other (please describe)_____

_____

d) Damage caused by slide:

_____

_____

_____

9) Additional Comments (please use back if necessary)