2.0 EARTHQUAKES

Historically, awareness of seismic risk in Oregon has generally been low, among both the public at large and public officials. This low level of awareness reflected the low level of seismic activity in Oregon, at least in recent historical time. However, over the past several years, awareness of seismic risk in Oregon has significantly increased. Factors in this increased awareness include the 1993 Scotts Mills earthquake in Clackamas County, widespread publicity about possible large magnitude earthquakes on the Cascadia Subduction Zone, and recent changes in Seismic Zonation in the Oregon Building Code which increased seismic design levels for new construction in western Oregon.

Before reviewing the levels of seismic hazard and seismic risk in Lane County, we first present a brief earthquake "primer" that reviews some basic earthquake concepts and terms.

2.1 Earthquake Primer

In the popular press, earthquakes are most often described by their Richter Magnitude (M). Richter Magnitude is a measure of the total energy released by an earthquake. In addition to Richter magnitude, there are several other measures of earthquake magnitude used by seismologists, but such technical details are beyond the scope of this discussion. The Scotts Mills (Oregon) earthquake was M = 5.6, while the Northridge (California) earthquake was about M = 6.7. Great earthquakes, for example, on the San Andreas Fault or on the Cascadia Subduction Zone, may have magnitudes of 8 or greater.

It is important to recognize that the Richter scale is not linear, but rather logarithmic. A M8 earthquake is not twice as powerful as a M4, but rather thousands of times more powerful. A M7 earthquake releases about 30 times more energy than a M6, while a M8 releases about 30 times more energy than a M7 and so on. Thus, great M8 earthquakes may release thousands of times as much energy as do moderate earthquakes in the M5 or M6 range.

The public often assumes that the larger the magnitude of an earthquake. the "worse" the earthquake. Thus, the "big one" is the M8 earthquake and smaller earthquakes (M6 or M7) are not the "big one". However, this is true only in very general terms. Larger magnitude earthquakes affect larger geographic areas, with much more widespread damage than smaller magnitude earthquakes. However, for a given site, the magnitude of an earthquake is NOT a good measure of the severity of the earthquake at that site. Rather, the intensity of ground shaking at the site depends on the magnitude of the earthquake <u>and</u> on the distance from the site to the earthquake. An earthquake is located by its epicenter - the location on the earth's surface directly above the point of origin of the earthquake. Earthquake ground shaking diminishes (attenuates) with distance from the epicenter. Thus, any given earthquake will produce the strongest ground motions near the earthquake with the intensity of ground motions diminishing with increasing distance from the epicenter.

Thus, for a given site, a smaller earthquake (such as a M6.5) which is very close to the site could cause greater damage than a much larger earthquake (such as a M8) which is quite far away from the particular site.

However, earthquakes at or below M5 are not likely to cause significant damage, even locally very near the epicenter. Earthquakes between about M5 and M6 are likely to cause some damage very near the epicenter, with the extent of damage typically being relatively minor (e.g., the 1993 Scotts Mills earthquake). Earthquakes of about M6.5 or greater can cause major damage (e.g., the Northridge earthquake), with damage usually concentrated fairly near the epicenter. Larger earthquakes of M7+ cause damage over increasingly wider geographic areas with the potential for very high levels of damage near the epicenter. Great earthquakes with M8+ can cause major damage over wide geographic areas. For example, a M8+ on the Cascadia Subduction Zone could affect the entire Pacific Northwest from British Columbia, through Washington and Oregon, and as far south as Northern California.

The intensity of ground shaking varies not only as a function of M and distance but also depends on soil types. Soft soils may amplify ground motions and increase the level of damage. Thus, for any given earthquake there will be contours of varying intensity of ground shaking. The intensity will generally decrease with distance from the earthquake, but often in an irregular pattern, reflecting soil conditions (amplification) and possible directionality in the dispersion of earthquake energy.

There are many measures of the severity or intensity of earthquake ground motions. A very old, but commonly used, scale is the Modified Mercalli Intensity scale (MMI), which is a descriptive, qualitative scale that relates severity of ground motions to types of damage experienced. MMIs range from I to XII.

More useful, modern intensity scales use terms that can be physically measured with seismometers, such as the acceleration, velocity, or displacement (movement) of the ground. The most common physical measure, and the one used in the Mitigation Plan and in the Technical Appendix, is Peak Ground Acceleration or PGA. PGA is a measure of the intensity of shaking, relative to the acceleration of gravity (g). For example, 1.0 g PGA in an earthquake (an extremely strong ground motion) means that objects accelerate sideways at the same rate as if they had been dropped from the ceiling. 10% g PGA means that the ground acceleration is 10% that of gravity and so on.

Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures. Ground motions of only 1 or 2% g are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low. Ground motions below about 10% g usually cause only slight damage. Ground motions between about 10% g and 30% g may cause minor to moderate damage in well-designed buildings, with higher levels of damage in poorly designed buildings. At this level of ground shaking, only unusually poor buildings would be subject to potential collapse. Ground motions above about 30% g may cause significant damage in well-designed buildings and very high levels of damage (including collapse) in poorly designed buildings. Ground motions above about 50% g may cause high levels of damage in most buildings, even those designed to resist seismic forces.

2.2 Seismic Hazards for Lane County

Earthquakes in Western Oregon, and throughout the world, occur predominantly because of plate tectonics - the relative movement of plates of oceanic and continental rocks that make up the rocky surface of the earth. Earthquakes can also occur because of volcanic activity and due to other geologic processes. Current understand of earthquake hazards for Lane County are briefly summarized below.

The Cascadia Subduction Zone is a geologically complex area off the Pacific Northwest coast from Northern California to British Columbia. In simple terms, several pieces of oceanic crust (the Juan de Fuca Plate, Gorda Plate and other smaller pieces) are being subducted (pushed under) the crust of North America. This subduction process is responsible for most of the earthquakes in the Pacific Northwest as well as for creating the volcanoes in the Cascades. Figure 10-1 shows the geologic (plate-tectonic) setting for Oregon.

There are three source regions for earthquakes that can affect Lane County

1) “interface” earthquakes on the boundary between the subducting oceanic plates and the North American plate,

2) “intraslab” or “intraplate” earthquakes within the subducting oceanic plates, and

3) “crustal” earthquakes within the North American Plate.

The geographic and geometric relationships of these earthquake source zones are shown in Figure 10-2.

The “interface” earthquakes on the Cascadia Subduction Zone may have magnitudes of 8 or greater, with probable recurrence intervals of 500 to 800 years. The last major earthquake in this source region probably occurred in the year 1700, based on current interpretations of Japanese tsunami records. Such earthquakes are the great Cascadia Subduction Zone earthquake events that have received attention in the popular press. These earthquakes occur about 20 to 60 kilometers (12 to 40 miles) offshore from the Pacific Ocean coastline. Ground shaking from such earthquakes would be very strong near the coast and moderately strong ground shaking would be felt throughout Lane County, with the level of shaking decreasing towards eastern Lane County.

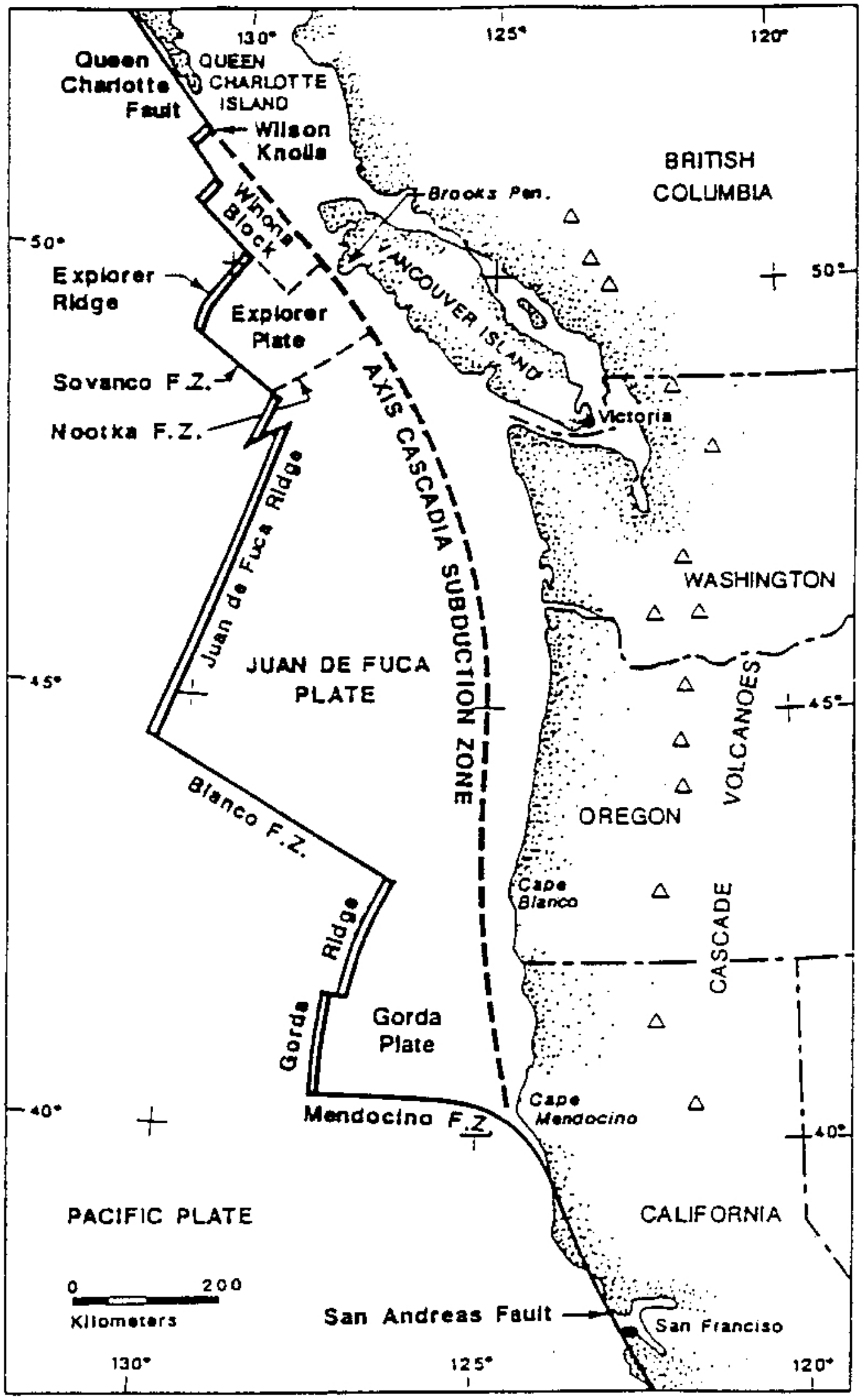


Figure 10-1. Cascadia Subduction Zone

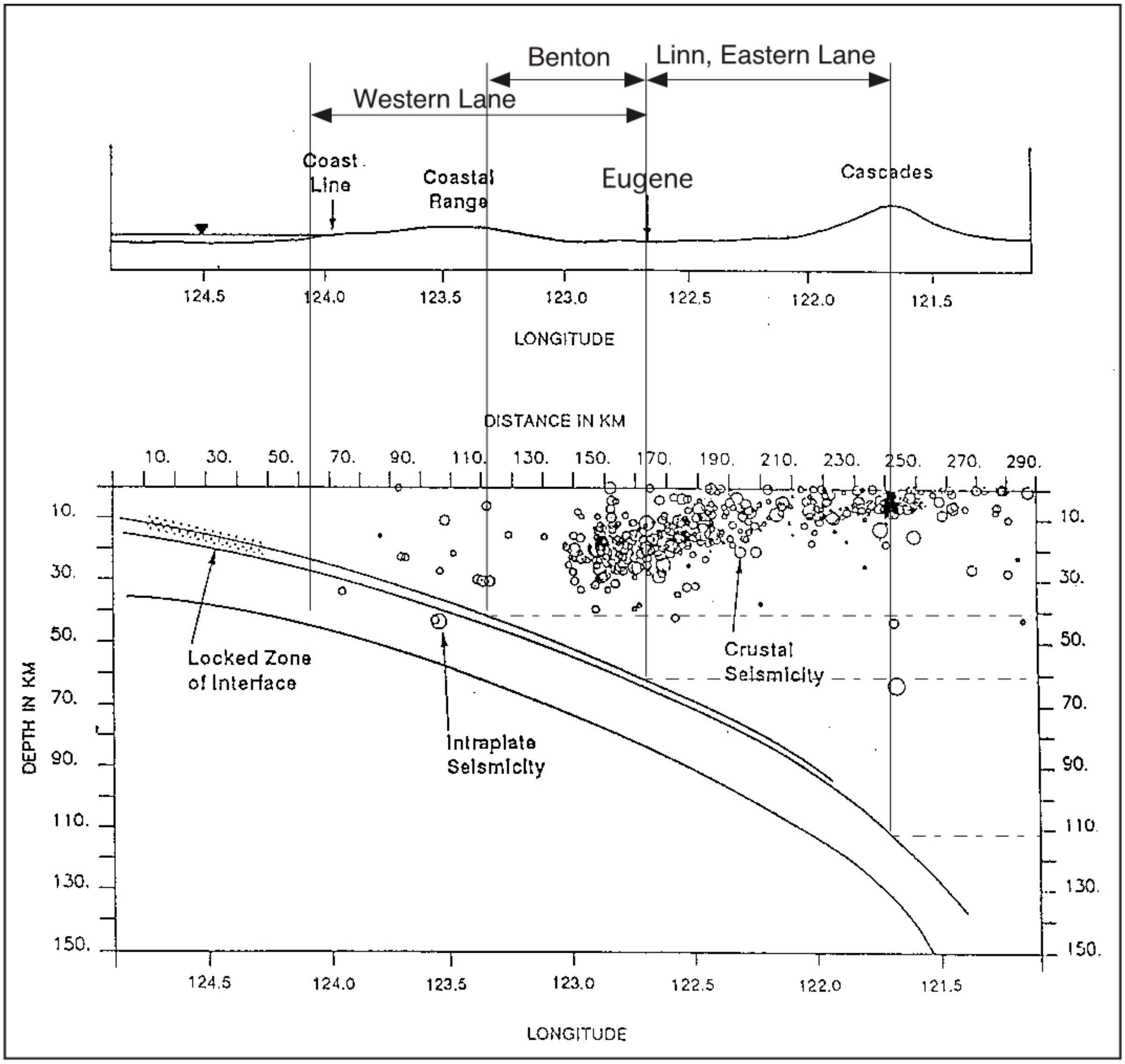


Figure 10-2. Cross Section of Seismicity Centered on Latitude 45.5 with Inferred Location of Subduction Portion of Juan de Fuca Plate

The "intraslab" earthquakes, which are also called "intraplate" earthquakes, occur within the subducting oceanic plate.   These earthquakes may have magnitudes up to about 7.5, with probable recurrence intervals of about 500 to 1000 years (recurrence intervals are poorly determined by current geologic data). These earthquakes occur quite deep in the earth, about 30 or 40 kilometers (18 to 25 miles) below the surface with epicenters that would likely range from near the Pacific Ocean coast to about 50 kilometers (30 miles) inland. Thus, epicenters from these types of earthquakes could be located in Lincoln County or western Lane County or possibly in western Benton County. Ground shaking from such earthquakes would be very strong near the epicenter and moderately strong ground shaking would be felt throughout all of Lane County, with the level of shaking decreasing towards eastern Lane County.

"Crustal" earthquakes within the North American plate are possible on faults mapped as active or potentially active as well as on unmapped (unknown) faults. Historically observed crustal earthquakes in Northern Oregon from 1841 to 1986 are shown in Figure 10-3. During this time period, several dozen, mostly small, earthquakes have occurred in Lane County.

In the Willamette Valley, the geological processes of erosion and deposition have obliterated most of the possible evidence for past surface fault ruptures. In Lane County and nearby counties, the mapped crustal faults are generally considered to be inactive, with no evidence for activity within the past 11,000 years.

Based on the historical seismicity in Western Oregon and on analogies to other geologically similar areas, small to moderate earthquakes up to M5 or M5.5 are possible almost anyplace in Western Oregon, including almost anyplace in Lane County. Such earthquakes would be mostly much smaller than the Scotts Mills earthquake up to about the magnitude of that 1993 earthquake. The possibility of larger crustal earthquakes in the M6+ range cannot be ruled out. However, in the absence of known, mapped faults, the probability of such events is likely to be very low.

Because the probability of large crustal earthquakes (M6 or greater) affecting Lane County is so low and because any damage in smaller crustal earthquakes is likely to be minor and very localized, crustal earthquakes are not considered significant for hazard mitigation planning purposes. Therefore, our analysis focuses on the larger, much more damaging earthquakes arising from the Cascadia Subduction Zone.

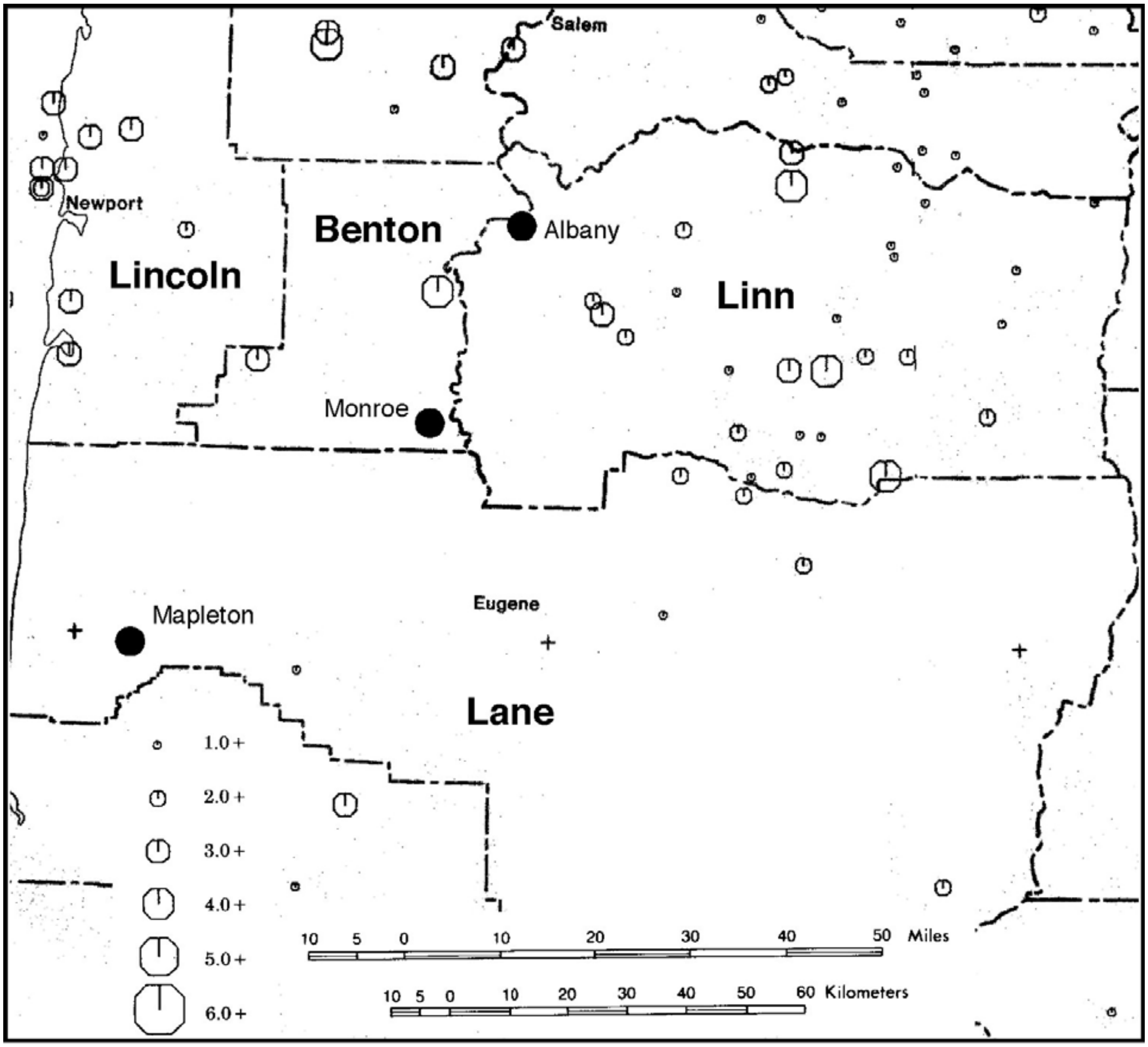


Figure 10-3. Central Oregon Seismicity, 1841-1986

The characteristics of the subduction zone earthquakes affecting Lane County are summarized in Table 2.4 below. The maximum magnitudes are estimated from the length and width of the mapped fault plane or from similar earthquakes elsewhere in the Pacific Northwest (for the intraslab earthquakes). Recurrence intervals are based on current best estimates.

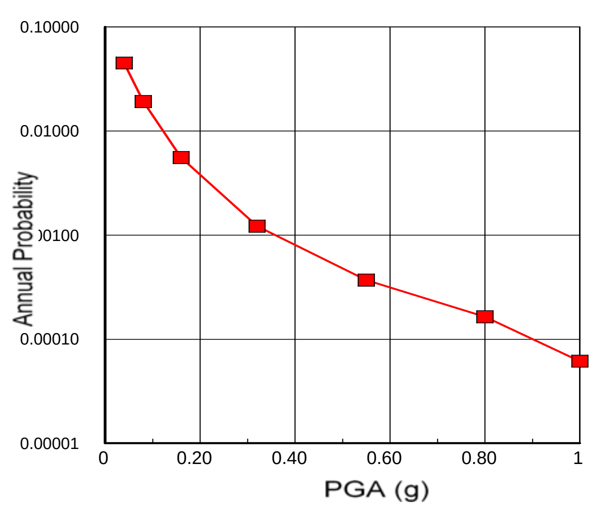
Table 2.4
Seismic Sources Affecting Lane County

Fault	Maximum Magnitude	Probable Recurrence Interval (years)
Cascadia Subduction Zone (interface earthquake)	8.5	500 to 800
Cascadia Subduction Zone (intraslab earthquake)	7.5	500 to 1000

The greatest potential impacts of earthquakes on Lane County arise from these two scenario earthquakes s: a Cascadia Subduction Zone interface earthquake (M8.5) and a Cascadia Subduction Zone intraslab earthquake (M7.5). For each of these earthquakes, appropriate attenuation relationships are used to calculate the levels of ground shaking (peak ground acceleration, PGA) with distance from the earthquake and seismic damage relationships are used to estimate the levels of damage in Lane County. Results are summarized in Section 2.4.

The level of seismic hazard in Lane County can also be expressed in probabilistic terms. A seismic hazard curve shows the probability of each level of ground shaking. An example seismic hazard curve for Mapleton is shown below in Figure 2.5.

Figure 2.5
Example Lane County Seismic Hazard Curve: Mapleton



Probabilistic seismic hazard data can also be shown in tabular form. The seismic hazard curve shown above corresponds to the following probabilities of seismic ground motions.

Table 2.6
Example Lane County Seismic Hazard Data: Mapleton

PGA Bin (% g)	Annual Probability	Return Period (years)
4 - 8	0.02579	39
8 - 16	0.01364	73
16 - 32	0.00435	230
32 - 55	0.00085	1180
55 - 80	0.00021	4861
80 - 100	0.00010	9730
>100	0.00006	16260

As an example, the data in Table 2.6 may be interpreted as follows. For ground shaking between 16% and 32% of g, the annual probability is 0.00435 and this level of ground shaking is expected in Mapleton about once every 230 years, on average. These seismic hazard data take into account all known earthquake faults and an "allowance" for possible earthquakes on unknown faults within Oregon.

The example seismic hazard data shown are applicable only to Mapleton (and immediate vicinity). Within Lane County, the level of seismic hazard varies markedly with distance from the coast. The highest seismic hazard areas are along the coast and the level of seismic hazard decreases more or less smoothly with increasing distance eastwards from the coast.

2.3 Other Aspects of Seismic Hazards in Lane County

Most of the damage in earthquakes occurs directly because of ground shaking which affects buildings and infrastructure. However, there are several other aspects of earthquakes that can result in very high levels of damage in localized sites: liquefaction, landslides, dam failures and tsunamis.

2.3.1 Soil Effects

Liquefaction is a process where loose, wet sediments lose strength during an earthquake and behave similarly to a liquid. Once a soil liquefies, it will tend to settle and/or spread laterally. With even very slight slopes, liquefied soils tend to move sideways downhill (lateral spreading). Settling or lateral spreading can cause major damage to buildings and to buried infrastructure such as pipes and cables.

Areas of high liquefaction potential in Lane County largely follow the main river and stream drainage channels; these are the areas with loose, wet sediments. Liquefaction does not occur in all such areas or in all earthquakes. However, in larger earthquakes with strong ground shaking and long duration shaking, liquefaction is likely in many of these high liquefaction potential areas. Settlements of a few inches or more and lateral spreads of a few inches to several feet are possible. Even a few inches of settlement or lateral spreading is likely to cause significant to major damage to affected buildings or infrastructure.

For the Eugene/Springfield Metro Area, a DOGAMI study of areas with soil types prone to amplification of seismic ground motions found scattered pockets of moderate hazard soils scattered throughout the Eugene/Springfield Metro Area. In total, these areas cover perhaps 10% of the total area ((DOGAMI, Relative Earthquake Hazard Map of the Eugene-Springfield Metropolitan Area, Lane County, Oregon IMS-14, 2000). These DOGAMI maps of Relative Amplification Hazard Zones are shown below as Maps 6E and 6S, for Eugene and Springfield, respectively.

For the Cottage Grove area, DOGAMI has completed a similar study to that described above (Relative Earthquake Hazard Maps for Selected Urban Areas in Western Oregon, IMS-9, 1999). The yellow shade areas in Cottage Grove shown on the map from IMS-9 are areas of soft soils subject to amplification of ground motions. Some of these areas may also be subject to liquefaction. However, further study is required to delineate specific levels of liquefaction hazard in Cottage Grove.

2.3.2 Landslides

Earthquakes can also induce landslides, especially if an earthquake occurs during the rainy season and soils are saturated with water. The areas prone to earthquake-induced landslides are largely the same as those areas prone to landslides in general. As with all landslides, areas of steep slopes with loose rock or soils are most prone to earthquake-induced landslides**.**

The areas identified in the Landslide Hazard (Chapter 8) as potential high landslide hazard areas for non-seismic landslides (i.e., heavy rain events) are generally similar to areas subject to earthquake-induced landslides. For the Eugene-Springfield Metropolitan area, the DOGAMI study referenced above (IMS-14) includes areas mapped as being subject to earthquake-induced landslides. At present, such detailed maps are not available for other populated areas in Lane County.

2.3.3 Dam Failures

Earthquakes can also cause dam failures in several ways. The most common mode of earthquake-induced dam failure is slumping or settlement of earthfill dams where the fill has not been properly compacted. If the slumping occurs when the dam is full, then overtopping of the dam, with rapid erosion leading to dam failure is possible. Dam failure is also possible if strong ground motions heavily damage concrete dams. In a few cases, earthquake induced landslides into reservoirs have caused dam failures.

Earthquake-induced dam failures are addressed in more detail in Chapter 12 which covers dam failures that could affect Lane County.

2.3.4 Tsunamis and Seiches

Tsunamis, which are often incorrectly referred to as “tidal waves,” result from earthquakes which cause a sudden rise or fall of part of the ocean floor. Such movements may produce tsunami waves, which have nothing to do with the ordinary ocean tides. In the open ocean, far from land, in deep water, tsunami waves may be only a few inches high and thus be virtually undetectable, except by special monitoring instruments. These waves travel across the ocean at speeds of several hundred miles per hour. When such waves reach shallow water near the coastline, they slow down and can gain great heights.

Tsunamis affecting the Oregon coast can be produced from very distant earthquakes off the coast of Alaska or elsewhere in the Pacific Ocean. For such tsunamis, the warning time for the Oregon coast would be at least several hours. However, interface earthquakes on the Cascadia Subduction Zone can also produce tsunamis. For such earthquakes the warning times would be very short, only a few minutes. Because of this extremely short warning time, emergency planning and public education are essential before such an event occurs.

The interface earthquakes on the Cascadia Subduction Zone are the only “local” earthquakes that would result in tsunamis on the Oregon Coast. Deep intraplate earthquakes are highly unlikely to cause a tsunami and shallow crustal earthquakes within the North American plate cannot cause tsunamis.

Small tsunamis were experienced along the Oregon coast following Alaskan earthquakes in the Aleutian Islands in 1946 and in Prince William Sound in 1964. The tsunami runups (i.e., the maximum water height) reached several feet above sea level. However, the 1964 tsunami in Crescent City, California killed over 20 people and caused considerable property damage to waterfront properties.

The height above sea level that a tsunami reaches depends on many factors. Important factors include the size of the earthquake, the type of movement of the ocean floor, the distance and direction of a site from the earthquake, and very importantly, the shape and topography of the local sea floor, and the topography of the coastline. In rare cases, tsunamis have reached over 100 feet above sea level, with virtually complete destruction in their path.

For emergency planning purposes, a runup of 30 feet above sea level is often assumed in the Pacific Northwest, with 50 feet above sea level being the minimum safe elevation for evacuations. A major tsunami with 10 feet or more of rapidly moving water is likely to completely destroy wood frame structures in the inundation zone and to heavily damage other types of structures. Major tsunamis will also damage or destroy above ground power and telephone lines, and scour may impact buried cables or pipes near the shoreline.

The entire immediate coastal area of western Lane County is subject to tsunamis, including the major population centers, such as Florence. Tsunami inundation maps have been prepared for the City of Florence, in western Lane County. Approximately 50% of the City is in the potential inundation area. The inundation area also extends upstream along the Suislaw River as far inland as Mapleton and several miles inland along the North Fork of the Suislaw River as well. A Community Emergency Notification System (CENS) has been established in the coastal communities to transmit warnings of potential tsunamis to affected residents.

Another earthquake related phenomenon is “seiches” which are waves from sloshing of inland bodies of waters such as lakes, reservoirs, or rivers. In some cases, seiches have caused damages to shorefront structures and to dams. However, for Lane County, the potential for seiches of sufficient magnitude to cause significant damage to upstream reservoirs or shorefront development appears low.

2.4 Risk Assessment for Scenario Earthquakes

A seismic risk assessment for Lane County was conducted by estimating the extent of damage and casualties likely in each of the two scenario earthquakes on the Cascadia Subduction Zone discussed above: a M8.5 interface earthquake and a M7.5 intraplate earthquake. For Level One Loss modeling, earthquake ground motions were calculated at the center of each census tract and these values were used for the entire census tract.

For each of these scenario earthquakes, building damage estimates for Lane County are approximately $1.6 to $1.7 billion. Injuries were estimated to be about 2,600 to 2,700 for daytime earthquakes and about 700 for nighttime earthquakes. Deaths were estimated to be about 45 for daytime earthquakes and about 4 for nighttime earthquakes. Casualties are much lower for nighttime earthquakes, because most of the population is in mostly wood-frame residential buildings, which typically have lower casualty rates than many other types of structures. Summary results are shown below in Tables 2.7 and 2.8.

2.4.1 M8.5 Cascadia Subduction Zone Interface Earthquake

The estimated impacts of this earthquake on the building stock in Lane County are summarized below in Table 2.7.

Table 2.7
M8.5 Cascadia Subduction Zone Interface Earthquake

Loss Estimate	Lane County
Building Damage	$1,732,000,000
Percent Damage[1]	11.30%
Daytime deaths[4]	48
Daytime injuries	2,736
Nighttime deaths[4]	4
Nighttime injuries	773
Heavily damaged residential buildings[2]	5,329
Estimated number of people needing emergency shelter[3]	10,658

[1] Percent damage is relative to building replacement value.
[2] Heavily damaged buildings are those in the extensive or complete damage states.
[3] Of the total displaced people, perhaps 1/3 will need public emergency shelter, with the rest finding shelter with relatives, friends, or in commercial lodgings.
[4] Fractional deaths are statistical results. For example, 0.1 death means about 10% chance of one death.

The direct loss estimates shown above are for the building stock only. Including the direct damages to contents, infrastructure and direct economic impacts from loss of function, the total direct economic impacts of these scenario earthquakes may be about double the estimates shown above

In addition to building damages, utility systems are also likely to experience significant damage. Expected outages to utility and transportation systems may include:

Water:	10 days with no water to about 25% of customers in urban areas, 20 days to restore water service to 99% of customers,
Wastewater:	loss of function at one or two treatment plants,
Natural gas:	similar to water service, in areas served by natural gas distribution systems,
Electric power:	widespread outages for 8 to 24 hours, local outages in rural areas up to 72 hours,

Phone systems: system overload for about 72 hours, most customers have normal service after 72 hours, similar situation with cellular customers,

Highways: about 10 days to make emergency repairs, about 3 to 5% of bridges in complete damage state.

2.4.2 M7.5 Cascadia Subduction Zone Intraplate Earthquake

The estimated impacts of this earthquake on the building stock in Lane County are summarized below in Table 2.8.

Table 2.8
M7.5 Cascadia Subduction Zone Intraplate Earthquake

Loss Estimate	Lane County
Building Damage	$1,633,000,000
Percent Damage[1]	11.65%
Daytime deaths[4]	45
Daytime injuries	2,561
Nighttime deaths[4]	4
Nighttime injuries	712
Heavily damaged residential buildings[2]	7,818
Estimated number of people needing emergency shelter[3]	15,636

[1] Percent damage is relative to building replacement value.
[2] Heavily damaged buildings are those in the extensive or complete damage states.
[3] Of the total displaced people, perhaps 1/3 will need public emergency shelter, with the rest finding shelter with relatives, friends, or in commercial lodgings.
[4] Fractional deaths are statistical results. For example, 0.1 death means about 10% chance of one death.

The direct loss estimates shown above are for the building stock only. Including the direct damages to contents, infrastructure and direct economic impacts from loss of function, the total direct economic impacts of these scenario earthquakes may be about double the estimates shown above

In addition to building damages, utility and transportation systems are also likely to experience significant damage. Expected levels of impacts are very similar to those summarized above in Section 2.4.1.

The probable impacts of major earthquakes on Lane County are summarized below in Table 2.9.

Table 2.9
Probable Impacts of Major Earthquakes on Lane County

Inventory	Probable Impacts
Portion of Lane County affected	Entire County and surrounding region, highest levels of ground shaking and damage percentages likely in western Lane County
Buildings	Many buildings will have no damage or light to moderate damage, with heavy damage concentrated in vulnerable buildings (wood frame buildings with cripple walls, unreinforced masonry, etc.). Total building damage estimated to be about $1.7 billion.
Streets within Lane County	Minor road damage possible in areas of soft soils. Many bridges may have significant damage, 3% to 5% may be in complete damage state.
Roads to/from Lane County	Minor road damage possible in areas of soft soils. Many bridges may have significant damage, 3% to 5% may be in complete damage state.
Electric power	Widespread outages for about 8 to 24 hours. Rural areas may have outages up to 72 hours.
Water utilities	About 10 days with no water to about 25% of customers in urban areas, about 20 days to restore water service to 99% of customers.
Other Utilities	Loss of function to one or two wastewater treatment plants. Natural gas system damages and outages similar to water systems. Phone systems (land and cellular) will have system overload for about 72 hours, then most customers will have normal service.
Emergency Shelter Needs	Approximately 10,000 to 15,000 people may need emergency shelter.
Casualties	About 45-50 deaths for daytime earthquake or several deaths for nighttime earthquake. Daytime injuries about 2,500 to 3,000; nighttime injuries about 500 to 1,000.

The above summary of potential impacts is for major earthquakes on the Cascadia Subduction Zone, as shown above in Tables 2.7 and 2.8. Smaller crustal earthquakes in or near Lane County would may much smaller impacts, a factor of 10 or more less than those shown above in Table 2.9.

In addition, there is a very low probability that a major earthquake could result in substantial damage or failure of one or more dams upstream of population centers in Lane County. If dam failure were to occur, the impact on downstream communities could be very large, with very high damage levels in inundation areas and potentially high casualties (deaths and injuries), depending on the extent of dam failure, the amount of warning time of dam failure, and the effectiveness of evacuations.

2.5 Earthquake Risk Assessment: Technical Guidance

2.5.1 Level Two Risk Assessment

The Level One earthquake loss estimates presented above are based on census-tract level data. For a given community, a more accurate loss estimate could be obtained by incorporating Level Two local data into the loss calculations. Such data could include:

1) better inventory data,
2) spatial distribution of inventory within census tracts,
3) overlay of soils information with inventory to identify areas subject to amplification, liquefaction, settling and displacements, and
4) refinement of building fragility curves to reflect local inventory.

Such Level Two loss estimates would be more accurate than the Level One assessments presented above. However, the Level One estimates probably provide accurate enough estimates of the approximate magnitude of losses for emergency planning purposes. Furthermore, conducting a Level Two loss estimate would require very intensive data collection and processing efforts, without providing enough detail for specific mitigation projects. Therefore, Level Two risk assessments may not be as useful for Lane County as the Level Three Assessments suggested below.

2.5.2 Level Three Risk Assessment

The potential damages and losses from earthquakes affecting Lane County are very high. However, the probability of such earthquakes is relatively low. Therefore, widespread mitigation of seismic hazards is probably not called for in the case of most ordinary or typical buildings. New buildings will be built in accordance with current Seismic Zone 3 requirements and thus the seismic capacity of the building stock will improve over time as the existing stock is gradually replaced and/or upgraded.

However, for some types of buildings, which are more vulnerable or more important than typical buildings, seismic retrofit may be highly desirable. Prime candidates for possible seismic retrofits include:

- any buildings that are substantially more vulnerable than typical buildings (e.g., unreinforced masonry buildings),
- buildings on soft soil sites, and
- essential service facilities such as major medical facilities, police and fire stations, schools, and emergency shelters.

Specific buildings may be substantially more vulnerable than typical buildings because of their structural system. Examples of vulnerable building types include: unreinforced masonry, precast concrete frame, concrete or steel frame with unreinforced masonry infill walls, concrete moment resisting frame, and precast concrete tiltup walls.

Buildings may also be substantially more vulnerable than typical buildings because of their design characteristics. Examples include buildings with soft first stories (taller than other stories and/or with large expanses of windows without shear walls) and buildings with major configurational irregularities, as well as wood frame buildings with cripple wall foundations or with sill plates not bolted to the foundation. Thus, we suggest that Level Three risk assessments focus primarily on such buildings, especially for essential service facilities.

A Level Three assessment provides a building-specific evaluation, more accurate than generic assessments based on typical buildings. Ideally, a Level Three assessment would include a site specific seismic hazard analysis, taking into account soil conditions, and a building-specific evaluation of the seismic vulnerability of each building under evaluation.

For such buildings, the seven-step Mitigation Planning methodology outlined in Chapter 1 is appropriate. For prioritizing between mitigation projects, the principles of benefit-cost analysis apply to mitigation projects for all hazards, including seismic hazard mitigation. FEMA has software available to conduct such analyses of prospective earthquake hazard mitigation projects. See also the example seismic mitigation project in the Appendix.

2.6 Other Earthquake Loss Estimates and Comments for Lane County

2.6.1 Probable Maximum Loss Study of City Buildings in Eugene

A probable maximum loss study for 20 City-owned buildings in Eugene was completed in 2001 for two levels of ground shaking, representing probabilistic levels of shaking with a 10% and 2% probability of occurring over a 50-year time period. Ground shaking levels range from 0.137 g to 0.16 g and from 0.296 g to 0.353 g respectively, for these two levels of probabilistic shaking. The variation for a given probability of shaking represents variation due to local soil conditions.

For the lower level of shaking, estimating building damages (as percentage of replacement value) range from 2.5% to 32% and from 8.3% to 60.2%, for the two levels of probabilistic shaking. Buildings with high seismic vulnerability (that is, expected high levels of damage) include City Hall, the Overpark at 10th and Oak, the Hult Center, the Hult Center Parking structure, the Public Works Administration Building, and the Public Works Maintenance Building #1, all of which are estimated to have 40% or greater damage at the higher level of ground shaking.

2.6.2 DOGAMI Study of 200 Buildings

DOGAMI (1999) completed a preliminary loss estimate study of 200 representative buildings in Eugene using FEMA's HAZUS loss estimation methodology. For ground shaking of 0.3 g (similar to the higher level in the 2001 probable maximum loss study discussed above). For 200 buildings only, total building structural and non-structural damages were estimated at about $39,000,000, with total direct economic losses of about $110,000,000, including contents, business inventory, and income losses.

2.6.3 Windshield Survey and General Comments

A "windshield" survey means a quick, preliminary seismic risk evaluation of a building or other facility, based on readily observable external attributes. A windshield survey may literally be done from a vehicle, but more commonly includes a quick walk around inspection. Conclusions drawn from such preliminary evaluations must be interpreted carefully as giving only a general indication of the probable level of seismic risk posed by the building or facility.

Overall, a majority of the building inventory in Lane County is residential, with most residential structures being wood frame buildings. In general, wood frame buildings perform well in earthquakes, with a few notable exceptions. Wood frame buildings with the following characteristics are generally substantially vulnerable to major seismic damage:

1) sill plates not bolted to foundation,
2) cripple wall perimeter systems, and
3) buildings on steep slopes, partially supported on "stilts."

Cripple wall perimeter systems are short wooden walls which raise the first floor elevation above grade by typically about 2 to 4 feet. Unbolted sill plates and cripple wall construction are common in pre-WW2 construction. Visual inspection and the general vintage of building stock in Lane County suggest that there are likely significant numbers of buildings in Lane County with cripple wall foundations or with unbolted sill plates.

Unreinforced masonry buildings are also subject to major damage in earthquakes. Lane County most likely has at least several dozen unreinforced masonry buildings most commercial or industrial, but also some public buildings including schools.

A detailed inventory of wood frame buildings with the above noted seismic deficiencies and inventory of unreinforced masonry buildings would be useful to further quantify the level of risk posed by such structures in Lane County.

2.7 Earthquake Hazard Mitigation Projects: General Examples

There are a wide variety of possible hazard mitigation projects for earthquakes. The most common projects include: structural retrofit of buildings, non-structural bracing and anchoring of equipment and contents, and strengthening of bridges and other infrastructure components.

The seismic hazard (frequency and severity of earthquakes) is moderate in Lane County. However, the risk (potential for damages and casualties) may be fairly high because some buildings and infrastructure may be highly vulnerable to earthquake damages. The risk assessment methodology outlined above for earthquakes provides the basis for identifying the high risk facilities that then become the primary targets for mitigation.

Structural retrofit of buildings should not focus on typical buildings, but rather on buildings that are most vulnerable to seismic damage. Priorities should include buildings on soft soil sites subject to amplification of ground motion and/or liquefaction and especially on critical service facilities such as hospitals, fire and police stations, emergency shelters, and schools.

Non-structural bracing of equipment and contents is often the most cost-effective type of seismic mitigation project. Inexpensive bracing and anchoring may protect very expensive equipment and/or equipment whose function is critical such as medical diagnostic equipment in hospitals, computers, communication equipment for police and fire services and so on. For utilities, bracing of control equipment, pumps, generators, battery racks and other critical components can be powerfully effective in reducing the impact of earthquakes on system performance. Such measures should almost always be undertaken before considering large-scale structural mitigation projects.
The strategy for strengthening bridges and other infrastructure follows the same principles as discussed above for buildings. The targets for mitigation should not be typical infrastructure but rather specific infrastructure elements that have been identified as being unusually vulnerable and/or are critical links in the lifeline system. For example, vulnerable overpasses on major highways would have a much higher priority than overpasses on lightly traveled rural routes.

See the Appendix (Mitigation Project Examples) for detailed sample evaluations of several possible seismic retrofits in Lane County, including: of the Eugene City Hall, the Cottage Grove City Hall, and the Mapleton Community Center.

The following table contains earthquake mitigation action items from the master Action Item table in Chapter 4.

Table 2.10
Earthquake Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Ideas	Plan Goals Addressed					
					Public Awareness	Life Safety	Protect Property Minimize Losses	Partnerships & Implementation	Emergency Services	Protect Environment
Earthquake Mitigation Action Items										
Short-Term #1	Complete inventory of public and commercial buildings that may be particularly vulnernable to earthquake damage	TBD	1-2 Years	pg. 4-4 pg. 10-15	X					
Short-Term #2	Complete inventory of wood-frame residential buildings that may be particularly vulnerable to eathquake damage, including pre-1940s homes and homes with cripple wall foundations.	TBD	1-2 Years	pg. 4-4 pg. 10-15	X					
Short-Term #3	Disseminate FEMA pamphlets to educate homeowners about structural and non-structural retrofitting of vulnerable homes and encourage retrofit	TBD	Ongoing	pg. 4-4 pg. 10-15	X	X	X	X		
Short-Term #4	Complete seismic vulnerability analysis of important public facilities with significant seismic vulnerabilities	TBD	1-2 Years	pg. 4-4 pg. 10-15	X					
Long-Term #1	Obain funding and retrofit important public facilities with significant seismc vulnerabilities	TBD	10 years	pg. 4-4 pg. 10-15		X	X	X	X	