

Section 11: Earthquake Updates

Earthquake Events Since 2002

The most recent earthquake event affecting Clackamas County occurred on July 11th, 2007 when a 3.3 M shook the south Clackamas County area. The earthquake was 12.6 miles deep, and was the largest of three earthquakes that occurred in a period of two weeks. Although many people felt the earthquake, there were no reports of injuries or major damage.

A similar event occurred on August 3rd, 2006, as a 3.8 M shook the Portland Metro area. The epicenter was in Cherrygrove, Washington, only 37 miles north of Clackamas County. It was a relatively shallow crustal earthquake at 7 miles deep, and was very short in duration. There were no reports of injuries or major damage.

The following listing of earthquake events in northwest Oregon illustrates the seismic potential of this area. None of the earthquakes reported in the following listing caused major damage or injuries, but the potential for large scale earthquakes is certainly present.

2002	June 29:	4.5 magnitude, 6.18k depth, 4.6k S of Mt. Hood, OR.
2003	April 24:	3.9 magnitude, 17k depth, 15.8k W of Portland, OR.
	April 28:	2.8 magnitude, 15k depth, 26.3k SE of Canby, OR.
	July 7:	3.3 magnitude, 6k depth, 5.7k SSE of Mt. Hood, OR.
	July 25:	3.0 magnitude, 17k depth, 14.8k NW of Portland, OR.
2004	February 25:	3.0 magnitude, 19k depth, 16.18k NW of Portland, OR.
2005	April 6:	2.8 magnitude, 1k depth, 0.8k WSW of Mt. Hood, OR
	June 25:	2.7 magnitude, 15k depth, 2.0k SW of Portland, OR.
2006	April 26:	3.0 magnitude, 19k depth, 27.0k ESE of Woodburn, OR
	August 3:	3.8 magnitude, 12k depth, 30.5k N of Portland, OR.
	November 5:	2.6 magnitude, 16k depth, 3.1k SW of Portland, OR.
2007	July 11, 2007	3.3 magnitude, 20.3 km, 1.0k W of Barlow, OR

Earthquake Legislation

In 2001, the passage of Senate Bills 14 and 15 requires public schools (kindergarten to universities) and emergency facilities (hospitals, fire, police) to improve life safety standards (focusing on seismic hazards). Measures 15 and 16 on the 2002 ballot were

passed by the voters and allow for state general obligations bonds to pay for earthquake mitigation. This was a huge success, but no funding was obligated.

In 2005, a number of Senate Bills were passed to support and implement this previous legislation. The first was Senate Bill 2, which directs the state Department of Geology and Mineral Industries (DOGAMI) to conduct statewide seismic needs assessment by January 1, 2007. This included surveying and ranking seismic safety of schools, colleges, police and fire stations, and hospitals.

Senate Bill 3 was passed to authorize Oregon Emergency Management as the fiscal agent for the general obligation funds. OEM was directed to create a grant program for local communities to undertake seismic rehabilitation of their schools, colleges, police and fire stations and hospitals. Senate Bill 4 authorizes bonding for seismic rehabilitation for education buildings, and Senate Bill 5 authorizes bonding for seismic rehabilitation for public safety buildings.

DOGAMI released the seismic needs survey in May, 2007. Clackamas County will work with the various facility owners to ensure that they are aware of structural and non-structural mitigation opportunities.

Hazard Assessment Update

Hazard Identification

In 2003, Clackamas County used Project Impact funding to partner with the Department of Geologic and Mineral Industries (DOGAMI) for the purpose of developing earthquake and landslide hazard maps and future damage estimates for Clackamas County, Oregon. The two main objectives of this study were to (a) develop a set of county-wide maps to identify areas of relatively low and high earthquake and landslide hazard (hazard maps), and (b) to improve the county's capabilities for earthquake damage and loss estimation (earthquake damage and loss modeling using HAZUS). The report is entitled, "Earthquake and Landslide Hazard Maps and Future Earthquake Damage Estimates for Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-03-10."

Mapping

Liquefaction: is a phenomenon in which the violent shaking of a saturated soil (e.g., by an earthquake) can cause a temporary loss of strength, and in some cases actually cause the affected materials to flow similar to a fluid. To develop a regional liquefaction hazard map (Map 10)for Clackamas County, DOGAMI started by collecting the best available geologic information.. Hazard groupings were primarily based on lithologies and checked with individual data points. With the available information compiled, DOGAMI 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 four relative hazard classes: None/Very Low, Low, moderate, and High. 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. Older river terrace and Missoula Flood deposits in the Willamette Valley were assigned a lower liquefaction hazard, yet are still considered susceptible to liquefaction in larger earthquakes. It is important to note that the quality and scale of the available base maps precluded identification of all liquefaction hazard areas, particularly in the eastern portion of the county.

Amplification: occurs when local soil conditions amplify the shaking of ground motions, such as those associated with subduction zone earthquakes. The degree of amplification greatly affects the performance of infrastructure in earthquake events. DOGAMI developed the ground shaking amplification map (Map 9) based generally on the NEHRP 1997 method of categorizing relative hazards, and simplified the GIS outputs into relative hazard classes— Low, Moderate, and High. The resulting map is not intended to be used in place of site-specific studies. The high hazard soils are located along and adjacent to streams and rivers in Clackamas County. The eastern portion of the county 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 amplification¹.

Relative Earthquake Hazards: DOGAMI and Clackamas County GIS worked together to combine the ground shaking, amplification, and liquefaction data to develop a composite Relative Earthquake Hazard Map (Map 10). This map represents the overall earthquake hazards in Clackamas County.

Geographic Extent: According to the Relative Earthquake Hazard Map (10), about 43% of the total county land area is in moderate to high hazard zones. In addition, 56% of total tax parcels have moderate to high earthquake hazards. Moderate to High earthquake hazard zones are concentrated along rivers, floodplains, and hillslopes due to the lack of soil stability in these areas.

Frequency: There have been about 16 events over 4.0M in past 150 years, meaning that this area averages about 1 crustal earthquake every 10 years. Subduction zone earthquakes in the Pacific northwest have a return interval of about 500 years. The last record of a major subduction zone earthquake was in 1700.

Vulnerability Assessment

Risk to Life and Property: High

The 56% of total parcels that are exposed to moderate and high earthquake hazards represent about 70% of total market value of all parcels in the county. This means that a great deal of public and private property could be damaged from earthquake events. In addition, the risk to life is extremely great, as much of the building stock was built prior to adoption of building codes designed for earthquake safety. Over 265 vulnerable population sites are in moderate to high hazard zones. Please see Table 11-1 for an estimation of loss to life from potential earthquake scenarios.

¹Hofmeister, Hasenberg, Madin, Wang, 2003. "Earthquake and Landslide Hazard Maps and Future Earthquake Damage Estimates for Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-03-10."

Risk to Critical Facilities and Infrastructure: High

The risk to critical facilities and infrastructure is invariably high. Over 74 critical and essential facilities are in moderate to high hazard zones. Many of these fire stations, law enforcement centers, and schools are unreinforced masonry, which perform extremely poorly to ground shaking. This means that emergency responders will have difficulty assisting others. Many miles of lots of road, water & sewer lines, 79 bridges, 6 cell towers, and 22 substations are in moderate to high hazard zones. To estimate the effect of this exposure on Clackamas County as a whole, please see Table 11-1.

Risk Assessment

DOGAMI used the HAZUS4 computer program developed by the Federal Emergency Management Agency (FEMA), to provide damage and loss estimates that can be used to identify areas where pre-planning and mitigation can be implemented most effectively.

The HAZUS4 software can be used to estimate regional damages, including building damage, lifeline damage (roads, utilities), injuries, and others. The majority of this data is based on national-scale information that often does not accurately reflect local conditions. To better account for local variability, DOGAMI and Portland State University used local information about the general building stock (e.g., characteristics of residential dwellings, business offices, warehouses), the essential facilities (e.g., hospitals, fire stations, emergency service centers), and the bridge inventories for the county.

The HAZUS software can be used to model a variety of earthquake scenarios and DOGAMI chose to model the two most likely scenarios for Clackamas County:

1. A magnitude 6.8 Portland Hills Fault earthquake
2. A magnitude 9.0 Cascadia Subduction Zone earthquake

Of the two scenarios, the Portland Hills Fault earthquake is the most damaging. Results of the two scenarios are compared in Table 11-1. The comparison table shows the expected damage from the Portland Hills Fault earthquake to be about four times more than the damage from the Cascadia Subduction Zone earthquake.

Table 11-1. Comparison of the HAZUS results for the two sample scenarios in Clackamas County: a magnitude 6.8 Portland Hills Fault earthquake and a magnitude 9.0 Cascadia Subduction Zone earthquake.

Impact(s) estimated by HAZUS for Clackamas County	M 6.8 Portland Hills Fault	M 9.0 Cascadia Subduction Zone
Maximum ground acceleration (fraction of g)	0.47 g	0.18 g
Direct losses from building damage	\$3.65 billion	\$940 million
Moderate or greater damage to total building stock	40% of total building stock	12% of total building stock
Transportation system losses	\$132 million	\$43 million
Deaths (during afternoon business hours; losses much less if earthquake occurs at night)	190	39
Total injuries and casualties	3200	900
Displaced households	5400	700
Fully functional fire/police stations day after the earthquake	10 out of 47	44 out of 47
Functional bridges the day after the earthquake	310 out of 422	401 out of 422

Source: “Earthquake and Landslide Hazard Maps and Future Earthquake Damage Estimates for Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-03-10.”

Current Mitigation Activities

Clackamas County and the cities therein have made great strides in improving seismic safety in critical and essential facilities as well as vulnerable population centers. The following listing shows a description of the mitigation projects the county has been engaged in by year.

2003 Earthquake Mitigation

Clackamas County was selected as a “Project Impact Community”, which provided FEMA grant funds for enhancing seismic safety until 2003. This grant program provided seed funding for many ongoing projects, including the Clackamas County Natural Hazards Mitigation Plan. The following elements were also completed under this grant program:

- Structural and non-structural mitigation
 - ✓ 3 schools in the Estacada school district nonstructural seismic upgrades
 - ✓ 2 mobile home parks received structural and nonstructural seismic upgrades
 - ✓ The Emergency Operations Center received non-structural upgrades.
- Public Education
 - ✓ “Earthquake Eyes” education materials geared for school audience
 - ✓ Children’s coloring book centered around preparedness
 - ✓ Brochures highlighting seismic considerations for older adults and people with disabilities
- Data Collection and Mapping
 - ✓ Mapped Stormwater Infrastructure
 - ✓ Expand Earthquake Mapping
 - ✓ Upgrade C-Map (county internet mapping tool)
 - ✓ Building Stock Inventory

2004 Earthquake Mitigation

- The County received two Pre Disaster Mitigation Grants (PDM) for seismic upgrades to the County EOC (\$272,000) and the Tri Cities Waste Water Treatment Facility (\$333,290). In addition, the county provided support to Oregon City for seismic upgrades to a water reservoir (\$910,000) and Canby for seismic upgrades to a telephone control facility (\$368,600) as they applied for and received PDM grants.
- Clackamas County Sheriff's Office (Emergency Management) was awarded \$1,527.45 in Oregon Hazard Mitigation Grant Program funding to prepare and distribute Partners for Loss Prevention's (PLP) award-winning Preschool Safety Education Program and Clackamas County emergency preparedness information to state-licensed childcare centers serving preschoolers, ages 3-5, in Clackamas County.

2005 Earthquake Mitigation

- The HMAC received 2 PDM grants for a seismic upgrades to Clackamas River Water infrastructure and facilities (\$2.1 Million), and retrofitting of the Burnside Park Bridge (\$160,000).
- Lake Oswego received a PDM grant (\$1,347,350) for seismic upgrades to City Hall
- County Building Services received ATC-20 training and developed excellent "Post Earthquake Damage Assessment Kits" that will be used as a first level damage evaluation. The kits contain explicit instructions and maps so that all building inspectors will have the necessary tools to assess building damage after an earthquake. Items in the kits include:
 - ✓ Building Stock Inventory
 - ✓ Priority list of buildings
 - ✓ Stapler
 - ✓ Tape
 - ✓ Evaluation notebook
 - ✓ Duct tape
 - ✓ ATC-20 Forms

Earthquake Mitigation Action Items

The earthquake mitigation action items provide guidance on suggesting specific activities that agencies, organizations, and residents in Clackamas County can undertake to reduce risk and prevent loss from earthquake events. Each action item is followed by ideas for implementation, which can be used by the steering committee and local decision makers in pursuing strategies for implementation.

EQ#1: Integrate new earthquake hazard mapping data for Clackamas County and improve technical analysis of earthquake hazards.

Ideas for Implementation

1. Utilize LIDAR technology to enhance earthquake mapping efforts.

Coordinating Organization: Clackamas County Geographic Information

Plan Goals Addressed: Systems
Partnerships and Implementation, Protect Life
and Property
Multi-Jurisdictional: Lake Oswego, West Linn
Priority: Medium

EQ#2: Identify funding sources for structural and nonstructural retrofitting of structures that are identified as seismically vulnerable.

Ideas for Implementation

1. Provide information for property owners, small businesses, and organizations on sources of funds (loans, grants, etc.); and
2. Work with owners of buildings included in the DOGAMI seismic survey to ensure that they are aware of potential grant opportunities.

Current Needs:

- ✓ Rivergrove Water has completed seismic analysis on reservoirs, and needs funding for seismic bracing.
- ✓ Milwaukie Community Center (owned by Milwaukie, maintained and operated by Clackamas County North Parks Recreation District) is in need of seismic upgrade. No engineering studies have been completed.
- ✓ Colton Fire has an engineering report and is in need of seismic upgrades

Coordinating Organization: Hazard Mitigation Advisory Committee
Plan Goals Addressed: Partnerships and Implementation, Public Awareness
Multi-Jurisdictional: Canby, Milwaukie, Lake Oswego, Gladstone, West Linn
Priority: Medium

EQ#3: Encourage purchase of earthquake hazard insurance.

Ideas for Implementation

1. Provide earthquake insurance information to Clackamas County residents; and
2. Coordinate with insurance companies and organizations such as the Insurance Information Service of Oregon and Idaho to produce and distribute earthquake insurance information.

Coordinating Organization: Hazard Mitigation Advisory Committee
Plan Goals Addressed: Protect Life and Property, Public Awareness
Priority: Low

EQ#4: Encourage seismic strength evaluations of critical facilities in the county to identify vulnerabilities for mitigation of schools and universities, public infrastructure, and critical facilities to meet current seismic standards.

Ideas for Implementation.

1. Encourage owners of non-retrofitted reservoirs to upgrade them to meet seismic standards;
2. Encourage all water providers to replace all old cast iron pipes with more ductile iron, and identify partnership opportunities with other agencies for pipe replacement; and
3. Perform FEMA 154 seismic evaluations on all buildings not included in the recent DOGAMI inventory.

Coordinating Organization: Hazard Mitigation Advisory Committee
Plan Goals Addressed: Protect Life and Property, Emergency Services
Multi-Jurisdictional: Canby, Milwaukie, Lake Oswego, Gladstone, West Linn
Priority: High

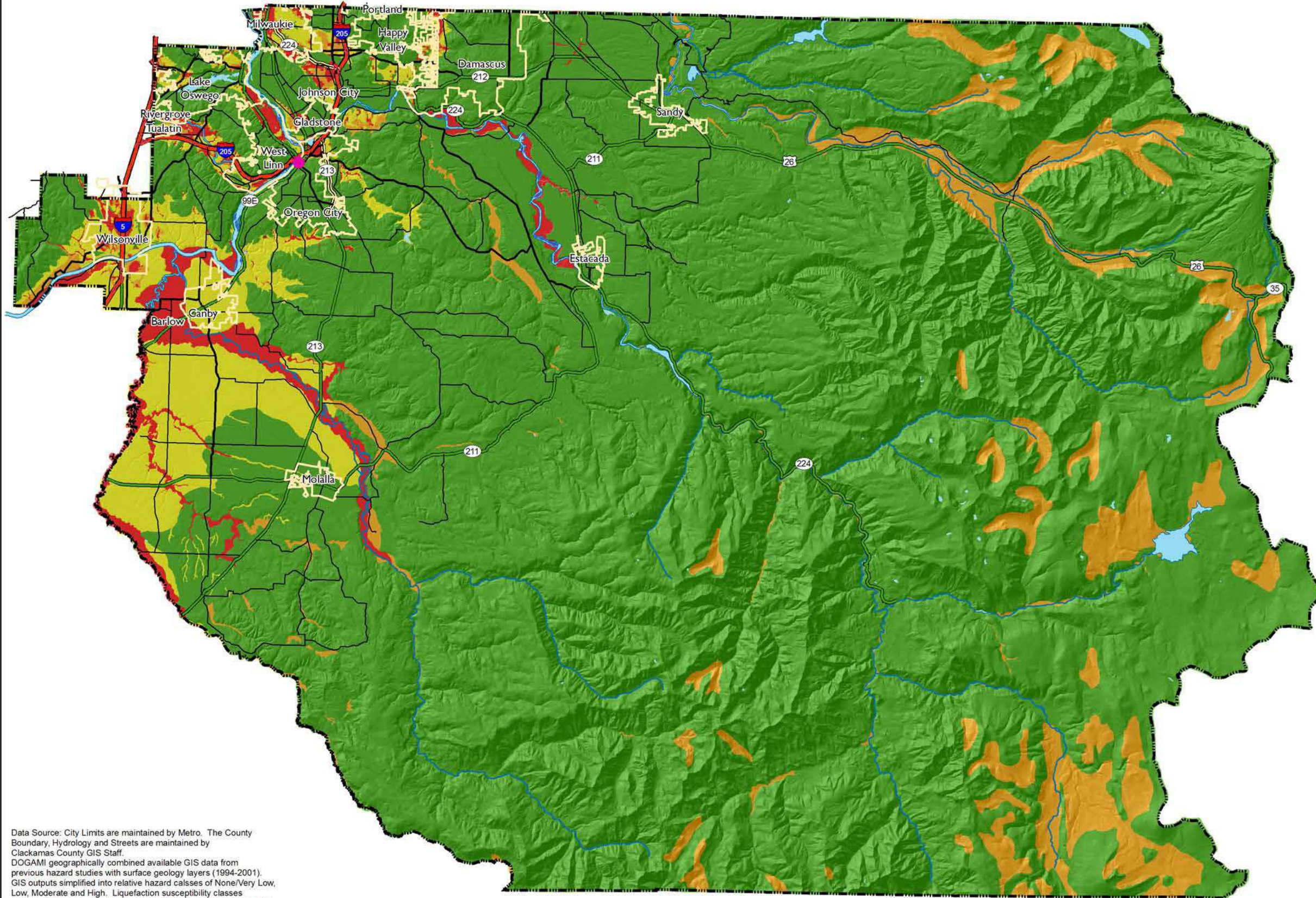
EQ#5: Encourage reduction of nonstructural and structural earthquake hazards in homes, schools, businesses, and government offices through public education.

Ideas for Implementation

1. Provide information to government building and school facility managers and teachers on nonstructural mitigation techniques including: securing bookcases, filing cabinets, light fixtures, and other objects that can cause injuries and block exits;
 - ✓ Encourage facility managers, business owners, and teachers to refer to FEMA's practical guidebook: *Reducing the Risks of Nonstructural Earthquake Damage*;
 - ✓ Encourage homeowners and renters to use *Is Your Home Protected from Earthquake Disaster? A Homeowner's Guide to Earthquake Retrofit* (IBHS) for economic and efficient mitigation techniques;
2. Use the FEMA 154 seismic evaluations generated by DOGAMI to prioritize critical and essential buildings for upgrades ;
3. Explore partnerships to provide retrofitting classes for homeowners, renters, building professionals, and contractors; and
4. Target development located in potential fault zones or in unstable soils for intensive education and retrofitting resources.

Coordinating Organization: Hazard Mitigation Advisory Committee
Plan Goals Addressed: Protect Life and Property, Public Awareness
Multi-Jurisdictional: Canby, Milwaukie, Lake Oswego, Gladstone, West Linn
Priority: Medium

Map 8 Clackamas County Soil Liquefaction



County Features

- County Seat
- Cities
- County Boundary

Liquefaction Hazard

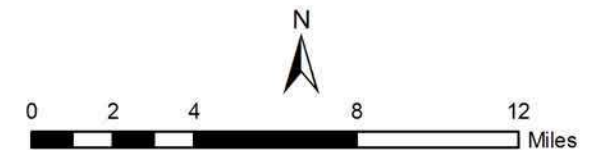
- HIGH - Areas with a thickness of liquefiable material > 30 ft where water table is 15 - 30 ft deep or areas with liq material where the water table is < 15 ft.
- MODERATE - Areas with a thickness of liquefiable material less than 20 ft where the water table is 15-30 ft.
- LOW - Area with materials that are liquefiable when they are intermittently saturated.
- NONE/VERY LOW - Areas not liquefiable or liquefiable only due to unusual local conditions

Water Features

- Major Rivers and Lakes
- ~ Rivers, Creeks and Streams

Streets

- Freeway
- Expressway / State Highway
- Major Arterial / State Highway
- Major Arterial



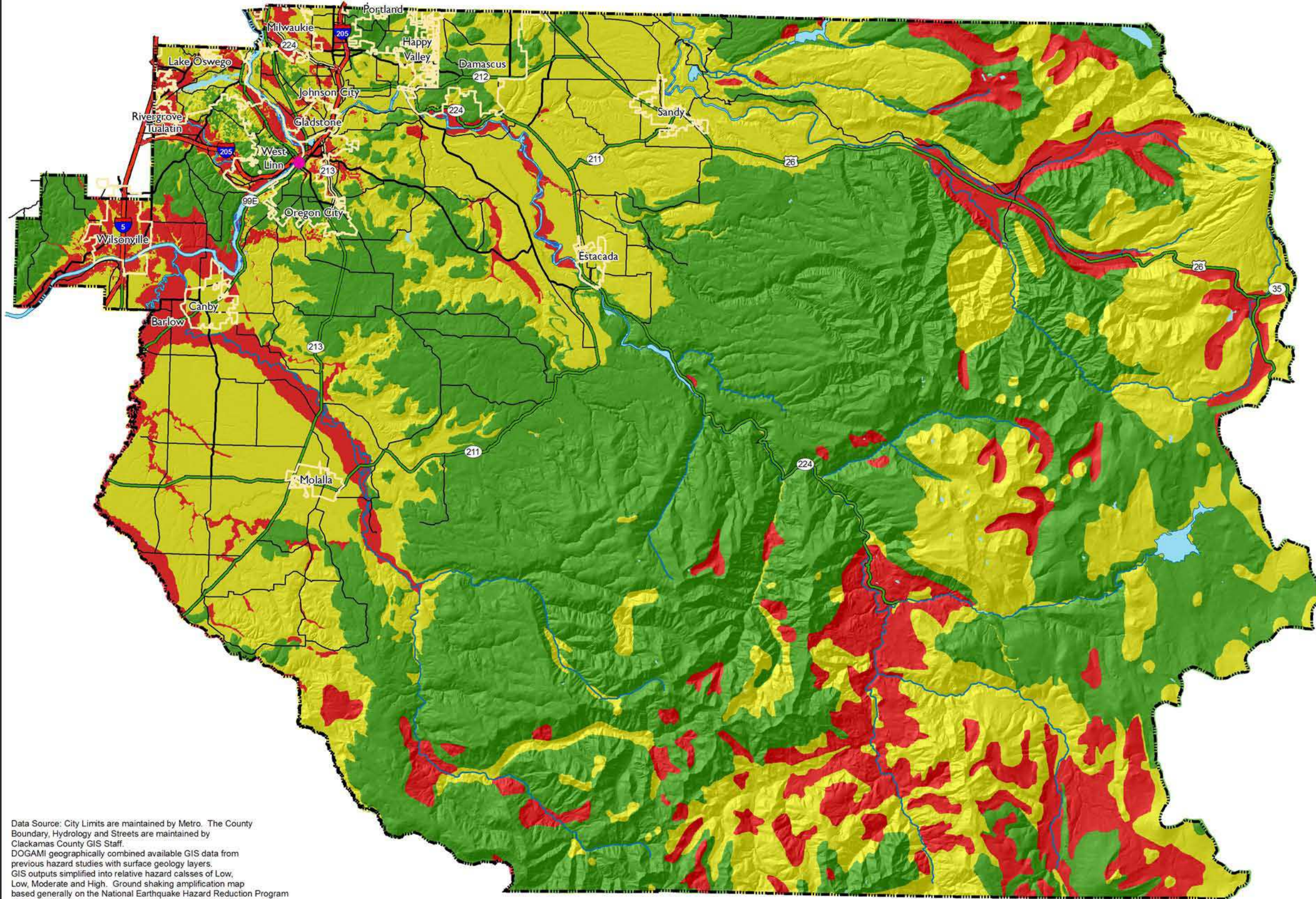
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Data Source: City Limits are maintained by Metro. The County Boundary, Hydrology and Streets are maintained by Clackamas County GIS Staff. DOGAMI geographically combined available GIS data from previous hazard studies with surface geology layers (1994-2001). GIS outputs simplified into relative hazard classes of None/Very Low, Low, Moderate and High. Liquefaction susceptibility classes were assigned based on dominant lithologies for each geologic unit. (Youd and Perkins 1978 classification system).

Map 9 Clackamas County Soil Amplification



County Features

- County Seat
- Cities
- County Boundary

Soil Amplification Hazard

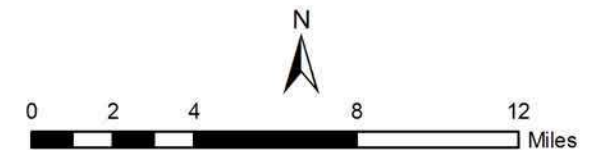
- HIGH - Areas with amplification greater than 1.50.
- MODERATE - Areas with amplification between 1.25 and 1.50.
- LOW - Areas with amplification less than 1.25

Water Features

- Major Rivers and Lakes
- Rivers, Creeks and Streams

Streets

- Freeway
- Expressway / State Highway
- Major Arterial / State Highway
- Major Arterial
- Minor Arterial



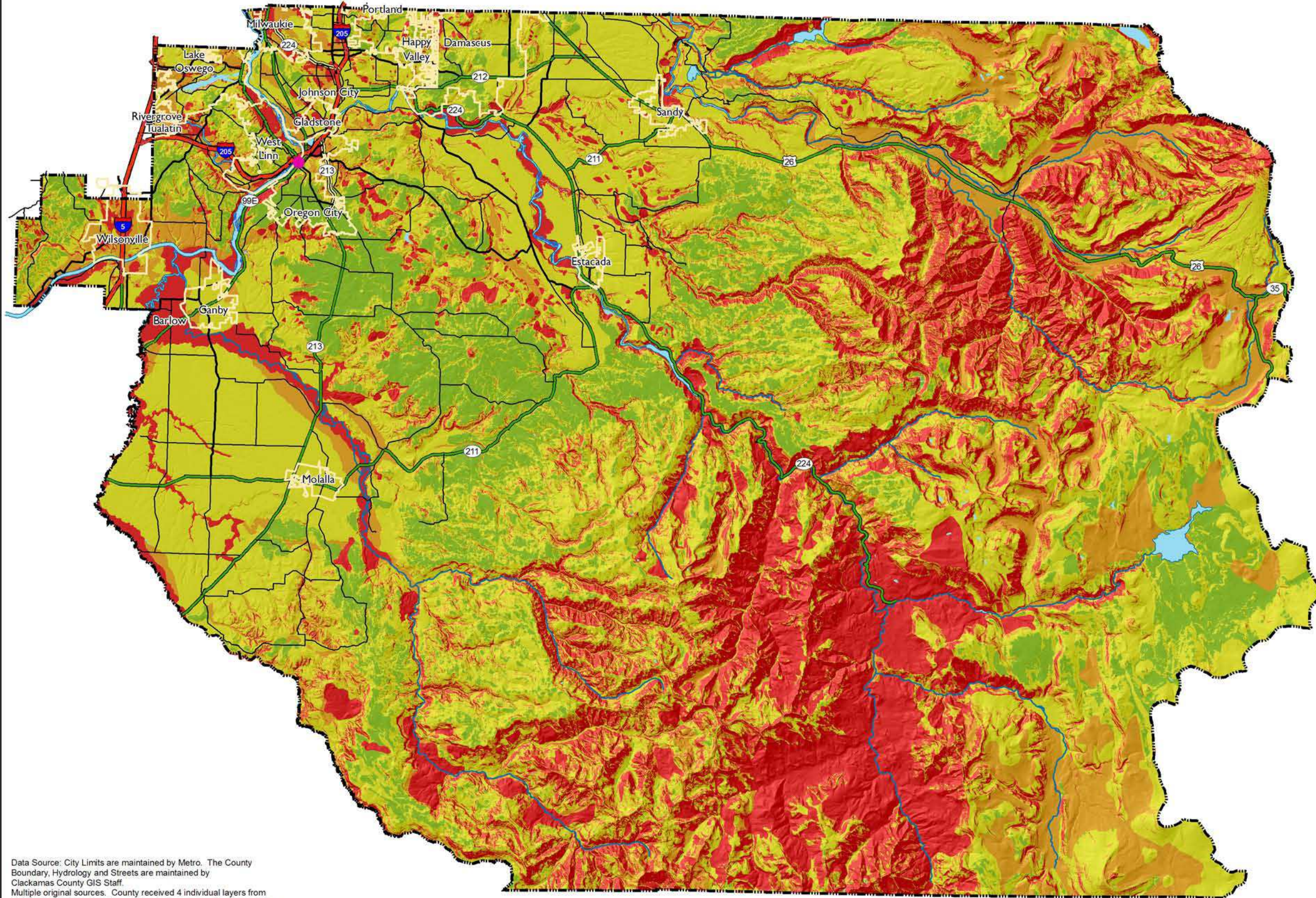
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Map 10 Clackamas County Earthquake Hazard



County Features

- County Seat
- Cities
- County Boundary

Relative Earthquake Hazard

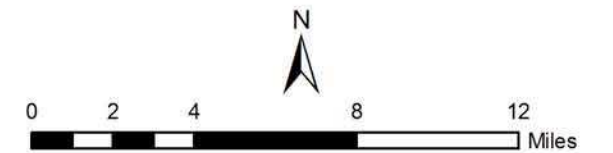
- HIGH
- MODERATE
- LOW
- NONE/VERY LOW

Water Features

- Major Rivers and Lakes
- ~ Rivers, Creeks and Streams

Streets

- Freeway
- Expressway / State Highway
- Major Arterial / State Highway
- Major Arterial
- Minor Arterial



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Data Source: City Limits are maintained by Metro. The County Boundary, Hydrology and Streets are maintained by Clackamas County GIS Staff. Multiple original sources. County received 4 individual layers from DOGAMI and determined the relative hazard areas with a reclassing of layers and then a "MAX" operation in GRID.