Section 9
Earthquake

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Why are Earthquakes a threat to Portland?

Oregon is rated third highest in the nation for potential loss due to earthquakes. This is due, at least in part, to the fact that until recently, Oregon was not considered to be an area of high seismicity, and the majority of its buildings and infrastructure were not designed for ground shaking at the magnitude now expected. Recent studies of geological records show that Oregon has a history of seismic events, and that the Cascadia Subduction Zone is capable of producing magnitude 9.0 earthquakes.

Within the City of Portland, there are more than 1,600 unreinforced masonry buildings and many other older structures that are not expected to fare well in a major seismic event. Within the city limits, $59 billion in residential and commercial assets are at risk. A major event could displace 2,000 households, cause 2,500 people to suffer major injuries, and result in as many as 200 fatalities. Many parts of the infrastructure, including pipelines, transportation routes, and utility lifeline systems, are also likely to experience heavy damage. The mitigation measures outlined in this plan are meant to reduce the loss of life and property, to sustain infrastructure and services to population, and to protect the economic welfare of the region.

Geologists scrutinizing soil layers in a 12-foot-deep trench in Milwaukie have uncovered more evidence that the Portland Hills Fault is still able to generate earthquakes. The fault runs in a northwest-southeast direction from the northern edge of Forest Park along the foot of Portland's West Hills and under downtown Portland. It crosses beneath the Willamette River between the Marquam and Ross Island bridges, runs under Milwaukie, and ends about a mile south of the Clackamas River near Oregon City and Gladstone. Sediment layers in the trench were deformed by an earthquake roughly 10,000 years ago, recent enough for the fault to be labeled "active." Deformation of soil suggests that the ancient earthquake may have measured about a magnitude 6.5, a moderate quake that could cause substantial damage.[1]

The existence of other active faults in the Portland Metro Area and other areas of the State is suspected. Where faults are known to exist, it is believed that they are capable of generating magnitude 7 earthquakes.

Earthquakes pose a serious threat to many Oregon communities. The State ranks third in the nation for future earthquake damage estimates. Projected losses in the Cascadia region could exceed $12 billion; 30,000 buildings could be destroyed and 8,000 lives lost in the event of a magnitude 8.5 Cascadia Subduction Zone earthquake. Identifying locations susceptible to seismic activity generated by local faults or the Cascadia Subduction Zone, adopting strong policies and implementing measures, and using other mitigation techniques are essential to reducing risk from seismic hazards in Portland.[2]

Historical Earthquake Events

Several moderate earthquakes have affected Portland in the past century. Little damage has occurred in Portland as a result, but the earthquakes have rattled nerves and served to remind residents that their community is at risk of experiencing more damaging earthquakes. Multiple small quakes have been occurring in the Portland metro area over the past several years. Though most have been too small to be felt in Portland, the quakes demonstrate the seismic instability of the region. Recent small events of note included a magnitude 3.0 earthquake on July 25, 2003 that occurred 9.19 miles NW of Portland, and a magnitude 3.3 earthquake that occurred 3.54 miles SSE of Mt. Hood on July 7, 2003.[3] Larger earthquake events in the Portland region are described below.

April 24, 2003, 3.9 Magnitude Earthquake

A 3.9 magnitude earthquake occurred in the Portland area on April 24, 2003. This quake was the largest quake to be generated by a fault under the Portland area in over 40 years and was felt throughout the Portland area. The quake was followed by seven aftershocks and smaller-deeper tremors were detected for several weeks after.[4] The quake was centered 15.8 km northwest of Portland and 42.0 km north of Canby.

February 28, 2001, Nisqually Earthquake - Magnitude 6.8

The most recent large earthquake to be felt in Portland was the Nisqually earthquake, on February 28, 2001. This earthquake was centered northeast of Olympia, Washington, and measured a magnitude of 6.8 on the Richter scale. In the Puget Sound area, this quake caused 400 injuries, one quake-related death, and about $2 billion dollars in damage.[5] In Portland, many employees evacuated in reaction to the quake, but the event ultimately caused no damage. While Oregon experienced little damage from this earthquake, it reminded residents what can happen during major earthquakes.

Ironically, the Portland Metropolitan area was planning an earthquake drill in April of 2001 as part of Earthquake Awareness Month, called "Metroshake."[6] This drill involved all cities in the Portland Metropolitan area as well as Portland Emergency Management, Multnomah County, the State Office of Emergency Management, and the Tualatin Valley Water District, among others. The drill simulated a 6.0 Magnitude quake centered under Lake Oswego, and was run for the purpose of identifying problems in the emergency procedures and plans among cities and agencies.[7]

March 25, 1993, Scotts Mills Earthquake - Magnitude 5.6

In 1993, the Scotts Mills earthquake (also known as the "Spring Break Quake") shook Portland. It was a magnitude 5.7 on the Richter scale, and caused extensive damage primarily in the communities of Molalla, Woodburn, Newberg, McMinnville, and Salem. In addition, the *Valley Times* reported that only 4% of Oregonians were insured at the time of

this earthquake.[8] By comparison, the household survey indicated that 57% of respondents had earthquake insurance in 2003.

April 29, 1962, Puget Sound, Washington – Magnitude 6.5

On April 29, 1965, Portland residents felt an earthquake that was centered between Seattle and Tacoma, Washington. The quake caused 7 deaths in Washington.

November 5, 1962, Vancouver, Washington- Magnitude 5.5

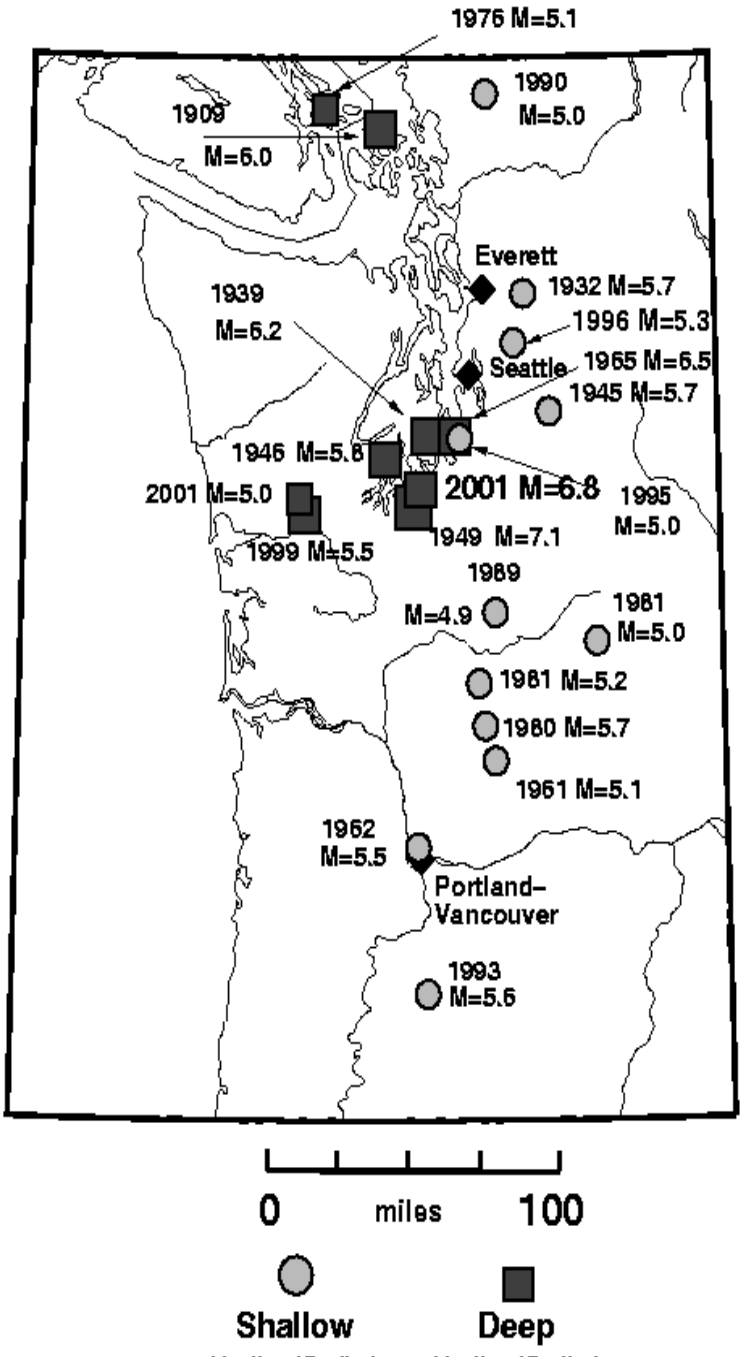
Three and a half weeks after the devastating Columbus Day Storm, an earthquake that measured approximately 5.5 on the Richter scale shook the Portland area. It was the largest quake to be generated by a fault under Portland and Vancouver.[9] This earthquake disappeared quickly from headlines, most likely because residents were still recovering from the Columbus Day Storm at the time of the earthquake.[10]

April 13, 1949, Olympia, Washington- Magnitude 7.1

On April 13, 1949, Portland residents felt an earthquake that was centered near Olympia, Washington. In Washington, this quake caused 8 deaths and caused extensive damage to buildings and infrastructure.

Figure 9-1 shows the location of selected Pacific Northwest earthquakes since 1872.

Figure 9-1. Selected Pacific Northwest Earthquakes since 1872



Source: Pacific Northwest Seismograph Network.
www.geophys.washington.edu/SEIS/PNSN/INFO_GENERAL/hist.html

Causes and Characteristics of Earthquake in Portland

Most large earthquakes in the Pacific Northwest are shallow crustal, deep intraplate, or subduction zone earthquakes. These earthquakes

can have great impact on Oregon communities. The City of Portland has at least three crustal faults beneath it that could generate an earthquake of magnitude 6.5 or larger.

Crustal Fault Earthquakes

Crustal fault earthquakes are the most common of earthquakes and occur at relatively shallow depths of 6-12 miles below the surface.[11] While most crustal fault earthquakes are smaller than magnitude 4.0 and generally create little or no damage, some can produce earthquakes of magnitudes 7.0 and higher and cause extensive damage. The 30-mile long Portland Hills Fault, which runs in a northwest to southeast direction through Portland, was confirmed to be an active fault by DOGAMI in May 2001.[12] This indicates that Portland and its neighbors could face future damages from a magnitude 6.5 or larger earthquake.[13]

Many of the natural hazards definitions found in this plan come from existing state resources, including the *Planning for Natural Hazards: Technical Resource Guide,* the *Oregon State Natural Hazards Plan,* and FEMA-adopted local plans. For more information on existing resources for natural hazards and mitigation planning in the state of Oregon, please visit www.OregonShowcase.org.

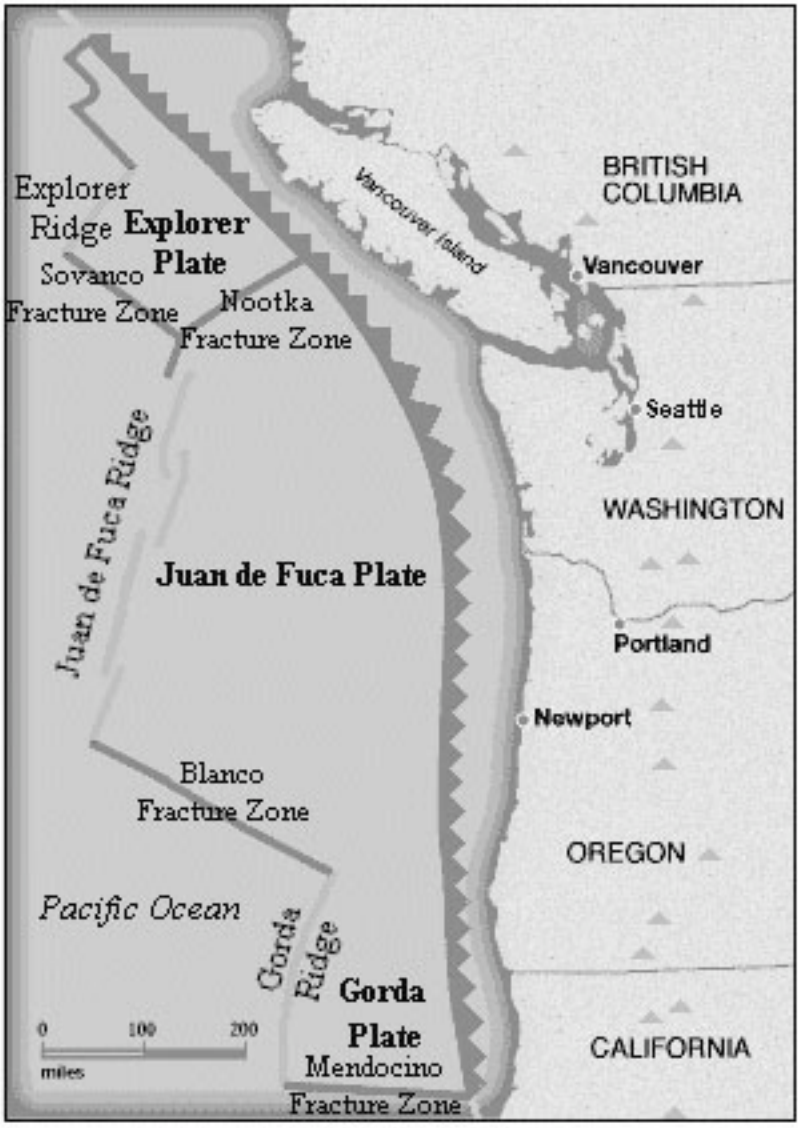
Deep Interplate Earthquakes

Occurring at depths from 25 to 40 miles below the earth's surface in the subducting oceanic crust, deep intraplate earthquakes can reach magnitude 7.5.[14] The February 28, 2001 earthquake in Washington State was a deep intraplate earthquake. It produced a rolling motion that was felt from Vancouver, British Columbia to Coos Bay, Oregon and east to Salt Lake City, Utah. A 1965 magnitude 6.5-intraplate earthquake centered south of the Seattle-Tacoma International Airport caused seven deaths.[15]

Subduction Zone Earthquakes

The Pacific Northwest is located at a convergent plate boundary where the Juan de Fuca and North American tectonic plates meet. The two plates are converging at a rate of about 1-2 inches per year. This boundary is called the Cascadia Subduction Zone (see Figure 9-2) and extends from British Columbia to northern California. Subduction zone earthquakes are caused by the abrupt release of slowly accumulated stress. Subduction zones similar to the Cascadia Subduction Zone have produced earthquakes with magnitudes of 8.0 or larger. Historic subduction zone earthquakes include the 1960 Chile (magnitude 9.5) and the 1964 southern Alaska (magnitude 9.2) earthquakes. Geologic evidence shows that the Cascadia Subduction Zone has generated great earthquakes, most recently about 300 years ago. The largest is generally accepted to have been magnitude 9.0 or greater. The average recurrence interval of these great Cascadia earthquakes is approximately 500 years, with gaps between events as small as 200 years and as large as 1,000 years. Such earthquakes may cause great damage to the coastal area of Oregon as well as inland areas in western Oregon including Portland. It is estimated that shaking from a large subduction zone earthquake could last up to five minutes.[16]

Figure 9-2. Cascadia Subduction Zone



Source: Department of Land Conservation and Development.
www.lcd.state.or.us/coast/hazards/juandefucaplates.htm

Earthquake Related Hazards

Ground Shaking

Ground shaking is the motion felt on the earth's surface caused by seismic waves generated by an earthquake. It is the primary cause of earthquake damage. The strength of ground shaking depends on the magnitude of the earthquake, the type of fault, and distance from the epicenter (where the earthquake originates). Buildings on poorly consolidated and thick soils will typically see more damage than buildings on consolidated soils and bedrock.

Surface Fault Ruptures

Earthquakes are caused by the sudden movement, or rupture, of a fault. As the rupture zone progresses upward to the earth's surface it can cause surface fault ruptures. The result is often displacement or offset of the ground surface. Generally, the larger the earthquake, the greater the potential for surface fault rupture. It is generally considered impractical to design structures to withstand damage under the stress of surface fault rupture. Additionally, once a structure is located astride a fault, it is impossible to mitigate the surface fault rupture hazard unless the structure is relocated.[17]

Earthquake-Related Landslides

Earthquake-induced landslides are secondary earthquake hazards that occur from ground shaking. They can destroy roads, buildings, utilities, and other critical facilities necessary to respond to and recover from an earthquake. Many communities in Oregon, including Portland, are likely to encounter such risks, especially in areas with steep slopes. As sloped lands to the northeast and southwest are developed, earthquake-related landslides will begin to pose a bigger threat to homes and infrastructure.

Liquefaction

Liquefaction occurs when ground shaking causes wet granular soils to change from a solid to a liquid state. This results in the loss of soil strength and three potential types of ground failure: lateral spreading, flow failure, and loss of bearing strength. Buildings and their occupants are at risk when the ground can no longer support buildings and structures.[18] Areas of susceptibility to liquefaction include areas with high ground water tables and sandy soils.[19]

Amplification

Soils and soft sedimentary rocks near the earth's surface can modify ground shaking caused by earthquakes. One of these modifications is amplification. Amplification increases the magnitude of the seismic waves generated by the earthquake. Amplification depends on the thickness of geologic materials and their physical properties. Buildings and structures built on soft and unconsolidated soils can face greater risk.[20] Amplification can also occur in areas with deep, sediment filled basins.

Community Earthquake Issues

Earthquake damage occurs because structures cannot withstand severe shaking. Buildings, airports, schools, and lifelines including water, sewer, stormwater and gas lines, transportation systems, electricity, and communication networks suffer damage in earthquakes and can cause death or injury to humans.

The welfare of homes, businesses, and public infrastructure is very important. Addressing the integrity of buildings, critical facilities, and infrastructure, and understanding the potential costs to government,

businesses, and individuals as a result of an earthquake are challenges that Portland must address.

Buildings

The built environment is susceptible to damage from earthquakes. Buildings that collapse can trap and bury people, putting lives at risk and creating great costs to clean up the damages. Changes in the State of Oregon Structural Specialty Code seismic zone rating for the Willamette Valley in 1990 and 1993 led to corresponding increases in the construction standards for buildings being built in Portland and the rest of the Willamette Valley. In 1993, the seismic zone for the Willamette Valley was upgraded from 2B to 3, requiring stricter construction standards.

In most Oregon communities including Portland, many buildings were built before 1993 when building codes had less stringent seismic design standards. Upgrading existing buildings to resist earthquake forces is expensive. Current building codes only require seismic upgrades when there is significant structural alternation to the building or where there is a change in use that puts building occupants and the community at a greater risk. Therefore, the number of buildings at risk remains high. The lack of funding for such activity is a major issue. Many buildings in the downtown area of Portland are more susceptible to earthquake damage because they are made of unreinforced brick or lightly reinforced concrete. Much work remains to be done to identify and plan for the risks to older structures.

Infrastructure and Communication

Portland is a hub for marine, rail, air and highway freight networks with two national railroads, an international airport, and the regional freeway system linked to I-5 and I-84. Residents in Portland commute frequently by automobile and public transportation such as buses and light rail. An earthquake can greatly damage bridges and roads, hampering the movement of people and goods. Damaged infrastructure strongly impacts the economy of the community; it disconnects people from work, school, food, and leisure, and separates businesses from their employees, customers, and suppliers.

Bridge Damage

With the Willamette River traversing through the center of the City, Portland is a city highly dependent on ten bridges. These bridges provide access for everyday community for buses, autos, light rail, pedestrians, and bicyclists and provide railroad connections as well. Even modern bridges can sustain damage during earthquakes, leaving them unsafe for use. Some bridges have failed completely due to strong ground motion, though even minor damages can render some bridges unusable. Because bridges vary in size, materials, location, and design, any given earthquake will affect them differently. Bridges built before the mid-1970's have a significantly higher risk of suffering structural damage during a moderate to large earthquake compared with those

built after 1980 when design improvements were made. Much of the interstate highway system was built in the mid to late 1960's.

Damage to Lifelines

Lifelines are the connections between communities and outside services. They include water and gas lines, transportation systems, electricity, and communication networks. Ground shaking, liquefaction, and amplification can cause pipes to break, power lines to fall, roads and railways to crack or move, and radio and telephone communication to cease. Disruption to transportation makes it especially difficult to bring in supplies or services. Damage to water systems can make a community particularly vulnerable to post-earthquake fires. All lifelines need to be usable after an earthquake to allow for rescue, recovery, and rebuilding efforts and to relay important information to the public.

Multnomah County Drainage District Levees

The US Army Corp of Engineers (Corps), in affiliation with the Multnomah County Drainage District No.1 (MCDD), studied the seismic performance of the Columbia River levee along NE Marine Drive. The MCDD maintains about 13 miles of levee along the Columbia River. The Columbia River levee system along NE Marine Drive is particularly important because it protects the airport, Interstate Highway 205, and many major roadways, municipal water pumping stations, treated wastewater outflow conduits, power and telecommunication lines, businesses, and homes. The levee's waterfront portion is used for recreational facilities and provides access to commercial maritime facilities along the river. Damage or failure of the levee during a concurrent flood event and an earthquake could result in flooding of extensive infrastructure protected by the levee. As reported in an August 2001 study, the levees should be safe in an earthquake as large as magnitude 7.0 depending on the amount of water in the Columbia River.

Disruption of Critical Services

Critical facilities include police stations, fire stations, hospitals, shelters, and other facilities that provide important services to the community. These facilities and their services need to be functional after an earthquake event. Many critical facilities are housed in older buildings that are not up to current seismic codes.

Businesses

Seismic activity can cause great loss to businesses – both large-scale corporations and small retail shops. When a company is forced to stop production for just a day, the economic loss can be tremendous, especially when its market is at a national or global level. Seismic activity can create economic loss that presents a burden to small shop owners who may have difficulty recovering from their losses. According to the business survey conducted as part of this plan, most businesses could remain closed for only two days before suffering serious economic hardship.

Individual Preparedness

A 1999 DOGAMI survey shows that about 39% of respondents think an earthquake will occur in Oregon within the next 10 years. Only 28% of Oregon residents say they are prepared for an earthquake, and 22% have earthquake insurance. In addition, only 24% correctly identified what to do during an earthquake.[21] Approximately 56.6% of respondents have insurance for earthquakes.

Because the potential for earthquake occurrences and earthquake-related property damage is relatively high, increasing individual preparedness is a significant need. Strapping down heavy furniture, water heaters, and expensive personal property as well as obtaining earthquake insurance are just a few steps individuals can take to prepare for an earthquake.

Death and Injury

Death and injury can occur both inside and outside of buildings due to falling equipment, furniture, debris, and structural materials. Downed power lines and broken water and gas lines can also endanger human life. Deaths can be prevented with proper building design and individual preparedness.

Fire

Downed power lines or broken gas mains can trigger fires. When fire stations suffer structural or lifeline damage, quick response to suppress fires is less likely. Therefore, it is necessary for fire stations and critical facilities to be well protected from natural disasters. It is also necessary that the water system be well protected so that water for fire fighting will be available if needed. In the San Francisco earthquake of 1906, 85% of the total damage was caused by post-earthquake structural fires that could not be effectively fought because of earthquake damage to the water system.

Debris

Following damage to structures, much time is spent cleaning up brick, glass, wood, steel or concrete building elements, office and home contents, and other materials. Developing strong debris management strategies can assist in post-disaster recovery. A 1999 study of the Metro region executed by the Department of Civil Engineering of Portland State University concluded that 1,117,433 tons of debris could be generated within the Portland city limits due to strong ground shaking. The fact that Portland contains about 20 times more unreinforced masonry and infill structures than the rest of the region contributes to the amount of potential debris.[22]

For more information on debris management strategies, refer to FEMA's Public Assistance Debris Management Guide. *(See resources at the end of this chapter.)*

Earthquake Hazard Assessment

Hazard Identification

Hazard identification, the first phase of a hazard assessment, refers to the process of estimating the geographic extent of the hazard, its intensity, and its probability of occurrence.[23] The Department of Geology and Mineral Industries (DOGAMI), in partnership with other state and federal agencies, has undertaken a rigorous program in Oregon to identify seismic hazards and risks including active fault identification, bedrock shaking, tsunami inundation zones, ground motion amplification, liquefaction, and earthquake induced landslides. Seismic hazard maps have been published and are available for many communities in Oregon through DOGAMI.[24] The Department continues to upgrade and improve earthquake hazard and risk information.

The Oregon Building Codes Division, through adoption of the State Building Code in 1990 and 1993, revised and upgraded its construction standards for new buildings to make them resistant to seismic events. The change in State Building Codes reflects updated seismic zones. An increase in zone number reflects increased risk of seismic activity. Many buildings in Portland were built prior to the imposition of the new seismic zone code requirements established in 1993.

Vulnerability Assessment

Vulnerability assessment is the second phase of a hazard assessment. It combines the information generated through the hazard identification with an inventory of the existing development exposed to earthquake hazards. Vulnerability assessments predict how different types of property and population groups will be affected by a hazard.[25]

This plan uses the results of a pilot study conducted with the Hazard US – Multi-Hazard software program. HAZUS-MH applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide defensible damage and loss estimates; these methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards and locations. Earthquake data from the HAZUS-MH software package was supplemented with local data for critical facilities and hazard areas. Inventory data were superimposed over the hazard areas to enable GIS queries to estimate the quantity of assets at risk (population, structures, critical facilities, etc.)

In general, all of the infrastructure of the City of Portland will be impacted by a major Cascadia Subduction Zone event, but some areas and buildings are more likely to be severely impacted than others. Buildings that are constructed of unreinforced masonry, bridges and overpasses that have not been seismically retrofitted, and buildings located on soils that are subject to liquefaction could experience serious damage. Utilities may also be impacted by a major event.

More detailed results of the HAZUS-MH study for earthquakes follows. They provide an overall summary description of the jurisdiction's vulnerability to the hazards and address the impacts of the hazards on the jurisdiction. Additionally, they identify the extent of the hazard and document previous occurrences of earthquake events in the Portland metropolitan area. A complete risk assessment for earthquakes is included in Appendix C, which contains *Risk Assessment Pilot Project Results for DMA 2000 Plan*.

Multnomah County Hazard Analysis		Summary of Risk Factors	
Severity Score	High	**Period of occurrence:**	At any time
History (2)	20	**Probability of event(s):**	Highly Likely
Vulnerability (5)	50	**Warning time:**	0 to 3 hours
Maximum Threat (10)	100	**Major contributor(s):**	Highly active seismic zone, local soil characteristics
Probability (7)	70	**Cause injuries?**	Yes, risk of death
Total Score	240	**Potential facilities shutdown?**	30 days or more

EARTHQUAKE HAZARD PROFILE

Background and Local Conditions

There are several different sources for hazardous earthquakes in the Pacific Northwest. Oregon sits on the Cascadia Subduction Zone where the Pacific / Juan de Fuca Plate is sliding under (or being pushed under) the less dense North American Plate. While earthquakes along this zone occur infrequently (none since records have been kept), plate movement can produce major earthquakes. In addition, the western part of Oregon is underlain by a large and complex system of faults (for example, the Portland Hills) that can produce significant and more frequent earthquakes.

Historic Frequency and Probability of Occurrence

The Metro 1999 study cites research indicating that "major geologic structures capable of magnitude (*M*) 7 earthquakes underlie the Portland study area. Since 1820, 7,000 earthquakes have been documented in Oregon. Fifty six significant earthquakes occurred in or near the Portland study area between 1872 and 1999. Severe local earthquakes occurred in 1877, 1880, 1953, 1962, and 1993 (Metro 1999). Strong Pacific Northwest earthquakes also include an 1872 M 7.4 North Cascades event, an *M* 6.8 earthquake in 1873, a 1949 *M* 7.1 event near Olympia, Washington, a 1965 *M* 6.5 event in Seattle-Tacoma, and a 2001 Olympia, Washington event that caused over $2 billion in property damage (Oregon OEM 2000). Regional earthquakes, such as the deep, intra-plate Nisqually Earthquake of 2001(Olympia, Washington) are felt widely in northwest Oregon.

Severity

There is a direct relationship between a fault's length and location and its ability to generate damaging ground motion. In Portland, smaller, local faults produce lower magnitude quakes, but their ground shaking can be strong and damage can be high as a result of the fault's proximity. In contrast, offshore or distant subduction zone quakes can generate grea magnitudes, but because of their distance and depth, may result in only moderate shaking in the Portland study area (Metro 1999). The Cascadia Subduction Zone fault could produce an earthquake of *M* 8.0 to 9.0 or greater. Geologic evidence shows that earthquakes of similar magnitude have occurred on average every 500 to 600 years in this area. Based on the Mutlnomah County analysis and pilot project data gathering and review, this hazard was given an initial profile ranking of severe.

Historic Losses and Impacts

Damage results from earthquakes because structures that cannot withstand the shaking, are situated on ground that amplifies shaking, or are located on soil that is subject to liquefaction. Structures can cause injury or fatalities and suffer content and functionality losses. The 2001 Nisqually event caused over $2 billion in losses. The two 1993 Klamath Fall earthquakes (*M* 5.9 and 6.0) caused damage to more than 1,000 buildings and $10 million in losses (DOGAMI 2002). Since 1872, there have been about 25 damaging earthquakes in Washington and Oregon (CREW 2003).

Designated Hazard Areas

The entire Pacific Northwest is subject to the earthquake hazard. However, certain local conditions can mitigate or amplify the effects. Figure 3-2 illustrates that the Portland study area has experienced earthquakes with various intensities of ground shaking. The figure shows major past earthquakes by moment magnitude.

Existing Mitigation Activities

The mitigation plan goals and action items are derived from a review of city, county, regional, state, and national natural hazards mitigation plans and planning literature and guidance from the Portland Natural Hazards Mitigation Steering Committee. The goals for the City of Portland Natural Hazards Mitigation Action Plan are broad based to include all of the identified hazards addressed in the plan. Goals for this mitigation plan address five categories:

1. Identify risk level and evaluate Portland's vulnerability to natural hazards.
2. Implement activities to protect human life, property and natural systems.
3. Promote public awareness, engage public participation, and enhance partnerships through education, outreach, and coordination of a diverse and representative group of the City's population.
4. Establish a disaster resilient economy.
5. Build and support the capacity and commitment to continuously become less vulnerable to hazards.

Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies or organizations.

City Programs

Construction Review and Inspection

The City's Bureau of Development Services is responsible for enforcing the State of Oregon Building Codes, which incorporate seismic structural design considerations. The Bureau reviews plans and specifications and inspects construction of all new structures on private property to assure compliance with the State Building Code seismic provision. These "Codes" are the laws that regulate how a building is to be constructed, ranging from how strong the walls must be to how much insulation they should contain.

Seismic Upgrades to Bridges – Portland Department of Transportation (PDOT)

PDOT completed a seismic prioritization study in the mid-1990's, and identified the City's most vulnerable structures in the event of an earthquake. Two of the top ten seismic retrofits have been completed. At this time, no additional seismic retrofits are planned due to lack of funding.

Fire, Police and Emergency Communication Facilities Seismic Status

A study of critical facilities was conducted for the Fire Bureau by Degenkolb Engineers in 1998; since then, the City of Portland has

seismically upgraded most of the existing fire stations within the Portland area and has prioritized the building of new or upgrading of old over the next three years. DOGAMI and the State of Oregon Emergency Management have recently conducted a survey of Portland's essential facilities. All Police and Emergency Communications buildings are either retrofitted or built to a higher standard depending on time of construction.

City Title 24.85, Seismic Design Requirements for Existing Buildings – Bureau of Development Services (BDS)

The Bureau of Development Services is responsible for enforcing existing building retrofits under specific conditions as required by this title. Unreinforced masonry buildings are strengthened when roof covering is removed and replaced or when the dollar cost of renovations exceeds a specified amount. All buildings are required to be strengthened when the occupant classification of the building is changed to a more critical level.

Portland Office of Emergency Management (POEM)

The City of Portland Office of Emergency Management is continuously upgrading the City's ability to survive an earthquake through preparedness activities, training, exercising, and planning. Earthquake exercises occur in one form or another every year. Exercises challenge multi-agency emergency responders, public officials, and community partners to work together to manage a disaster following pre-determined plans and protocols.

QuakEx

City personnel participated in QuakEx 2003 in April. This statewide drill simulated the occurrence of a magnitude 9.0 subduction zone earthquake off the coast of Oregon. The purpose of the drill was to train agencies throughout the State to cooperate and communicate during a large earthquake and to identify short and long term efforts needed to respond to a large-scale disaster.[26] In October of 2004, the City conducted a full-scale earthquake exercise incorporating partners in public health, mass transit, schools, and the business community as well as city respondents. The primary objectives of this drill were to test damage assessment reporting, search and rescue, communications and employee drop, and cover and hold response.

State Programs

State Building Codes[27]

The Oregon State Building Codes Division adopts statewide standards for building construction that are administered by the State, cities, and counties throughout Oregon. The codes apply to new construction and to the alteration of, or addition to, existing structures. The One and Two Family Dwelling Code and the Structural Specialty Code (both included in the State Building Code) prescribe seismic design requirements for new construction based on the seismology of the Portland region. These codes are State of Oregon amended additions of

national model codes from the International Code Council. These codes are based on maps that identify the various seismic zones for Oregon. The Structural Specialty Code is based on the 1997 edition of the Uniform Building Code published by the International Conference of Building Officials and amended by the State of Oregon. The Uniform Building Code contains specific regulations for development within seismic zones.[28]

Within these standards are six levels of design and engineering specifications that are applied to areas according to the expected degree of ground motion and site conditions that a given area could experience during an earthquake (ORS 455.447). The Structural Code requires a site-specific seismic hazard report for projects including essential facilities such as hospitals, fire and police stations, emergency response facilities, and special occupancy structures such as large schools and prisons.

The seismic hazard report required by the Structural Specialty Code for essential facilities and special occupancy structures must take into consideration factors such as the seismic zone, soil characteristics including amplification and liquefaction potential, any known faults, and potential landslides. The findings of the seismic hazard report must be considered in the design of the building. The Dwelling Code simply incorporates prescriptive requirements for foundation reinforcement and framing connections based on the applicable seismic zone for the area. The cost of these requirements is rarely more than a small percentage of the overall cost for a new building.[29]

The requirements for existing buildings vary depending on the type and size of the alteration and whether there is a change in the use of the building to house a more hazardous use. Oregon State Building Codes recognize the difficulty of meeting new construction standards in existing buildings and allow some exception to the general seismic standards. Upgrading existing buildings to resist earthquake forces is more expensive than meeting code requirements for new construction. State code only requires seismic upgrades when there is significant structural alteration to the building or where there is a change in use that puts building occupants and the community at a greater risk. The local building official is responsible for enforcing these codes.[17] Although there is no statewide building code for substandard structures, local communities have the option of adopting one to mitigate hazards in existing buildings. The State has adopted regulations to abate buildings damaged by an earthquake in Oregon Administrative Rules (OAR) 918-470. Oregon Revised Statutes (ORS) 455.020 and 455.390-400 also allow municipalities to create local programs to require seismic retrofitting of existing buildings within their communities. The building codes do not regulate public utilities and facilities constructed in public right-of-ways such as bridges that are regulated by the Department of Transportation.

Senate Bill 13: Seismic Event Preparation

Signed by Governor John Kitzhaber on June 14, 2001, Senate Bill 13 requires each state and local agency and persons employing 250 or more full-time employees to develop seismic preparation procedures and inform their employees about the procedures. Further, the Bill requires agencies to conduct drills in accordance with Office of Emergency Management guidelines. These drills must include "familiarization with routes and methods of exiting the building and methods of duck, cover, and hold during an earthquake."

Senate Bill 14: Seismic Surveys For School Buildings

The Governor signed Senate Bill 14 on July 19, 2001. It requires the State Board of Higher Education to provide for seismic safety surveys of buildings that have a capacity of 250 or more persons and are routinely used for student activities by public institutions or departments under the control of the board. A seismic safety survey is not required for any building that has previously undergone a seismic safety survey or that has been constructed to the state building code standards in effect for the seismic zone classification. If a building is found to pose an undue risk to life and safety during a seismic event, a plan shall be developed for seismic rehabilitation or other seismic risk reducing activities. (Plans are subject to available funding.) All seismic rehabilitation or other actions to reduce seismic risk must be completed before January 1, 2032.

DOGAMI and the Oregon University System joined to design a pilot program to begin the process to fulfill ORS 455.400 (2001). Through university maintenance funds and FEMA Pre-Disaster Mitigation grants, they have initiated seismic safety surveys of university buildings and selected several particularly vulnerable buildings for seismic safety upgrades. Buildings on the Portland State University campus in downtown Portland have been selected for the pilot project and are slated for partial upgrades to be completed by 2007.

Senate Bill 15: Seismic Surveys For Hospital Buildings

Governor John Kitzhaber signed Senate Bill 15 on July 19, 2001. It requires the Health Division to provide for seismic safety surveys of hospital buildings that contain an acute inpatient care facility. Seismic surveys shall also be conducted on fire stations, police stations, sheriffs' offices, and similar facilities subject to available funding. The surveys should be completed by January 1, 2007. A seismic survey is not required for any building that has undergone a survey or that has been constructed to the state building code standards in effect for the seismic zone classification at the site. If a building is evaluated and found to pose an undue risk to life and safety during a seismic event, the acute inpatient care facility, fire department, fire district or law enforcement agency using the building shall develop a plan for seismic rehabilitation of the building or for other actions to reduce the risk. (Again, plans are subject to available funding.) All seismic rehabilitations or other actions to reduce the risk must be completed before January 1, 2022.

Earthquake Awareness Month

April is Earthquake Awareness Month. During the month, the State Office of Emergency Management encourages individuals to strap down computers, heavy furniture, and bookshelves. In addition, the Oregon Natural Hazards Workgroup distributed a flyer with educational information about how to prepare for an earthquake.

Earthquake Education

Earthquake education in schools is ongoing in Oregon. Public schools are required to conduct periodic earthquake drills and educate students on how to respond when an earthquake event occurs (ORS 455.447 and 336.071). An example of voluntary compliance is St. Cecelia, a local private school, which performs earthquake drills along with fire drills.[30]

Federal Programs

National Earthquake Hazards Reduction Program (NEHRP)

NEHRP's mission includes improved understanding, characterization, and prediction of hazards and vulnerabilities; improved model building codes and land use practices; risk reduction through post-earthquake investigations and education; development and improvement of design and construction techniques; improved mitigation capacity; and accelerated application of research results. The Act designates FEMA as the lead agency of the program and assigns several planning, coordinating, and reporting responsibilities.

DOGAMI and the U.S. Geological survey are conducting a NEHRP mapping project in the Portland area to better locate the Portland Hills fault zone.

National Earthquake Loss Reduction Program (NEP)

NEP was formed as a result of the report "Strategy for National Earthquake Loss Reduction" prepared by the Office of Science and Technology Policy (OSTP) in April 1996. The NEP "aims to focus scarce research and development dollars on the most effective means for saving lives and property and limiting the social disruptions from earthquakes, coordinate federal earthquake mitigation research and development and emergency planning in a number of agencies beyond those in NEHRP to avoid duplication and ensure focus on priority goals, and cooperate with the private sector and with state and local jurisdictions to apply effective mitigation strategies and measures." The NEP does not replace NEHRP but encompasses a wider range of earthquake hazard reduction activities than those supported by the NEHRP agencies and provides a framework within which these activities can be more effectively coordinated.

The National Earthquake Technical Assistance Program (NETAP)

The NETAP is a technical assistance program created to provide ad hoc, short-term architectural and engineering support to state/local communities as they are related to earthquake mitigation. The program was designed to enhance the state/local communities' ability to become

more resistant to seismic hazards. This assistance cannot be used for actions that are covered under the State's/Territories Performance Partnership Agreement (PPA). This program assists in carrying out the statutory authorities of the National Earthquake Hazards Reduction Act of 1977, as amended.

Technical assistance under the NETAP is available for use by the state/local communities within the 45 eligible and or participating seismic states and U.S. territories. This assistance is provided at no cost to the requesting local community/state government.

Examples of NETAP projects are seismic retrofit/evaluation training, evaluation of seismic hazards critical/essential facilities, post earthquake evaluations of buildings, and development of retrofit guidance for homeowners.

National Seismic Hazard Mapping Project

National maps of the earthquake shaking hazard in the United States have been produced since 1948. Scientists revise these maps as new earthquake studies improve their understanding of this hazard. After thorough review, professional organizations of engineers in turn update the seismic-risk maps and seismic design provisions contained in building codes. More than 20,000 cities, counties, and local government agencies use building codes, such as the International Building Code, to help establish the construction requirements necessary to preserve public health and safety in earthquakes.http://quake.wr.usgs.gov/prepare/factsheets/RiskMaps/HazMap.gif The 1996 U.S. Geological Survey shaking-hazard maps for the United States are based on current information about the rate at which earthquakes occur in different areas and on how far strong shaking extends from quake sources.

Other programs

Bonneville Power Administration

While BPA does not have many facilities within the city limits of Portland, it has completed Phase One hardening of 500kV substations that support local utilities in the Portland metro area. Non-structurally, BPA has installed seismic isolators on critical control cabinets.

Transmission towers and transmission lines generally have a good performance history during seismic events. During several past significant earthquakes some towers failed; however, those failures were foundation-related. Other towers bent but did not cause a critical situation and were repaired on a routine schedule.

BPA has investigated the performance of their tower designs and feels that the system should perform adequately with the following exceptions: liquefaction at river crossings and earthquake generated landslides. BPA has not yet addressed these concerns.

Another reason for the failure of a minimal number of towers during significant seismic events had to do with towers being located on

hillsides and having un-equal legs. There has been some suggestion that this un-equal leg configuration contributed to tower failure. BPA is communicating with a Japanese researcher investigating this possible mode of failure.

BPA also continues education and awareness efforts for employees and their families along with frequent testing of emergency plans and procedures.

Earthquake Mitigation Action Items

The earthquake mitigation action items provide direction on specific activities that the City, organizations, and residents can undertake to reduce risk and prevent loss from earthquake events. There are four short-term action items and five long-term earthquake action items described below. Each action item is followed by ideas for implementation that can be used by the steering committee and local decision makers in pursuing strategies for implementation.

Short-term Action Items

ST-EQ#1: Using television and print media, educate the public about the importance of signs containing bridge identification information during an earthquake.

Key Issues Addressed

- In the past two years, the Office of Transportation participated with Oregon Department of Transportation to place identification signs on every bridge within the city limits. Each sign contains the structure's ID number and the phone number of the agency responsible for its maintenance. This was completed in an effort to help anyone calling in bridge damage to identify the structure, especially after an event such as an earthquake. Now that the signs are in place, the public needs to be made aware of the existence of the signs and their value during an earthquake. Calling the responsible agency instead of 911 will ensure faster response and keep the 911 lines clear for other emergencies.

Ideas for Implementation

- Design and implement a public education campaign regarding bridge ID signs.
- Consider using the next earthquake drill to increase press coverage.

Coordinating Organization:	Portland Office of Transportation
Internal Partners:	none
External Partners:	Oregon Department of Transportation, Multnomah County
Level of Immediate Capability:	High
Estimated Timeline:	1 month
Plan Goals Addressed:	Promote public awareness, engage public participation, and enhance partnerships through education, outreach and coordination of a diverse and representative group of the City's population.

ST-EQ#2: Assess existing earthquake related mitigation plans and vulnerability studies to identify areas of conflict, duplication, or gaps.

Key Issues Addressed

- Multiple bureaus have multiple earthquake plans and studies in place; there is a need for increased coordination. The City needs the ability to quickly compile, access, and disseminate key information about city structure and operations.

Ideas for Implementation

- Create a committee of bureau representatives to catalogue existing plans. Run a gap analysis to begin filling in the holes.

Coordinating Organization:	Portland Office of Emergency Management
Internal Partners:	Fire Bureau, Office of Transportation, Bureau of Environmental Services, Water Bureau, Bureau of Development Services, Bureau of Planning
External Partners:	none
Level of Immediate Capability:	High
Estimated Timeline:	1 year
Plan Goals Addressed:	Build and support the capacity and commitment to continuously become less vulnerable to hazards.

ST-EQ#3 Update the vulnerability analysis of Columbia Boulevard Wastewater Treatment Plant (CBWTP), Tyron Creek Wastewater Treatment Plant (TCWTP), and wastewater pump stations.

Key Issues Addressed

- Currently, the vulnerability analysis of CBWTP and TCWTP these pump stations is incomplete.

Ideas for Implementation

- Hire a structure consultant to update the current CBWTP and TCSTP vulnerability analysis, develop a comprehensive vulnerability analysis for wastewater pump stations.

General Comments

- CBWTP and TCWTP facilities have a number of known seismic deficiencies. CBWTP is especially vulnerable to liquefaction.

Coordinating Organization:	Bureau of Environmental Services
Internal Partners:	none
External Partners:	none
Level of Immediate Capability:	Low
Estimated Timeline:	3 years
Plan Goals Addressed:	Identify risk level and evaluate Portland's vulnerability to natural hazards.

ST-EQ#4 Prioritize the return of power to treatment plants (Tryon Creek and Columbia Boulevard) and pump stations.

Key Issues Addressed

- Should power be interrupted over a large area for long periods of time, the treatment plants may be unable to fully treat wastewater flow; raw sewage overflows to the Columbia Slough or Willamette River would occur. System pump stations are primarily fed from a single source and may have standby power. If power fails at the pump station, sewers would back possibly into streets, private property, or into streams and rivers.

Ideas for Implementation

- Coordinate with regional power companies to the CBSTP and TCWTP are on the list of high priority services requiring rapid response to re-establish power.

Coordinating Organization:	Bureau of Environmental Services
Internal Partners:	Portland Office of Emergency Management
External Partners:	Regional Utility Planning Group, REMTEC
Level of Immediate Capability:	High
Estimated Timeline:	1 year
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

ST-EQ#5 Lobby to implement legislation of General Obligation Bonds to fund rehabilitation of critical structures.

Key Issues Addressed

- Oregon Law 797 requires seismic rehabilitation program for schools and life safety buildings and arranges for long term funding for upgrades through the state legislature.

Ideas for Implementation

- Develop partnerships with state and local stakeholders.

General Comments

- There will be funding and staff available in late 2003 to design a plan.

Coordinating Organization:	Governmental Relations
Internal Partners:	Bureau of Development Services, Portland Development Commission, Portland Office of Emergency Management, Office of Transportation, Parks and Recreation
External Partners:	none
Level of Immediate Capability:	Low
Estimated Timeline:	1-3 years
Plan Goals Addressed:	Build and support the capacity and commitment to continuously become less vulnerable to hazards.

ST-EQ#6 Address earthquake-generated landslide issues.

Key Issues Addressed

- The failure of a critical transmission lines, distribution lines, and/or substations as a result of earthquake-generated landslides will affect the electric power lifeline system.

Ideas for Implementation

- Assess the potential for earthquake-generated landslides to damage critical transmission and distribution lines and substation sites.
- Recommend mitigation and/or recovery solutions.

General Comments

- Within the Portland Metro area, this may not be a significant issue; however, earthquake-generated landslides could significantly affect the cross-mountain transmission line system.

Coordinating Organization:	Portland Office of Emergency Management
Internal Partners:	none
External Partners:	Bonneville Power Administration
Level of Immediate Capability:	Low
Estimated Timeline:	1-2 years
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

ST-EQ#7 Work with local jurisdictions to assess the capacity of landfills to accommodate earthquake debris; develop coordinated plans for disposal of debris in the aftermath of an earthquake.

Key Issues Addressed

- Earthquakes have the potential to generate a tremendous amount of debris that would need to be cleared from streets and homes quickly after the event. This influx of debris is likely to be beyond the capacity of local landfills. The failure to clear debris could result in slowed recovery from the event.

Ideas for Implementation

- Alternate disposal approaches (such as the use of debris as fill for berms) should be considered.
- Work with other cities and agencies to evaluate different scenarios and develop a coordinated plan.

Coordinating Organization:	Portland Office of Emergency Management

	Management
Internal Partners:	Bureau of Maintenance, Office of Sustainable Development
External Partners:	Metro, neighboring cities and counties, Multnomah County
Level of Immediate Capability:	Medium
Estimated Timeline:	1 year
Plan Goals Addressed:	Establish a disaster-resilient economy.

ST-EQ#8 Study the feasibility of mandatory or voluntary installation of seismic shutoff valves on natural gas meters at commercial and residential buildings.

Key Issues Addressed

- Natural gas flow into structures from broken gas lines in the structure is a major hazard after an earthquake; it can lead to structure fires and threaten human life. The installation of excess flow valves at the meters might rectify this problem.

Ideas for Implementation

- Convene a committee of representatives from the Bureau of Fire, Bureau of Development Services, natural gas and utility providers, and other interested parties to look at practicality of the issue.
- This committee should complete a study that verifies the effectiveness, cost and reliability of such valves.

General Comments

- These valves are used in other areas of the country.

Coordinating Organization:	Bureau of Fire
Internal Partners:	Bureau of Development Services, Bureau of Fire, Portland Office of Emergency Management
External Partners:	NW Natural Gas
Level of Immediate Capability:	High
Estimated Timeline:	1-2 years
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

ST-EQ#9 Develop emergency evacuation plans for residential areas that are near significant hazardous materials storage facilities and heavy industrial areas.

Key Issues Addressed

- During and earthquake, hazardous materials containment areas can be damaged affecting any nearby residential areas. The community of Linnton is situated between hazardous materials storage areas and other heavy industrial facilities, and is located adjacent to the alignment of the Olympic Pipeline. The majority of Linnton's residents live on the adjacent steeply sloping hillside, which is served by a substandard street system. Similar residential pockets in other heavy industrial areas, such as Guild's Lake, could be endangered if pipelines or hazardous materials' storage facilities ruptured in an earthquake event. Evacuation from these areas could be complicated by earthquake-related debris.

Ideas for Implementation, and General Comments

- Develop vulnerability studies and evacuation plans for residential and employment areas with highest risk

Coordinating Organization:	Fire Bureau
Internal Partners:	Portland Office of Emergency Management
External Partners:	Industrial users, utility companies, neighborhood associations
Level of Immediate Capability:	Medium
Estimated Timeline:	1 year
Plan Goals Addressed:	Identify risk level and evaluate Portland's vulnerability to natural hazards. Implement activities to protect human life, property and natural systems.

Long-term Action Items

LT-EQ#10 Evaluate funding alternatives that might accelerate seismic retrofitting of the City of Portland's bridges.

Key Issues Addressed

- Portland's bridges are critical to the mobility of Portland's residents and to the economy of the region. The bridges don't reflect current seismic design and need to be retrofitted. Though a priority list exists for retrofitting, funds specific to these projects may not be immediately available. Instead, consider retrofitting bridges with existing funds as other repairs occur.

Ideas for Implementation

- Evaluate retrofit priority list and potentially match with proposed maintenance list; determine if opportunities exist to combine efforts.

General Comments

- While a retrofit priority list with estimated cost does exist, no retrofits have been accomplished to date.

Coordinating Organization:	Portland Office of Transportation
Internal Partners:	none
External Partners:	Oregon Department of Transportation
Level of Immediate Capability:	High
Estimated Timeline:	15 yrs.
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems. Establish a disaster-resilient economy.

LT-EQ#11 Conduct a vulnerability analysis of Portland's sewer system to identify elements with the potential for failure.

Key Issues Addressed

- Sewer line failure in an earthquake could impact emergency transportation routes and affect public health and safety.

Ideas for Implementation

- Update Environmental Services Sewer Map to show vulnerable sewers, and overlay them with critical transportation routes. Consider pump stations and standby power capability in the assessment.
- Develop mitigation plan for collection system most likely to be impacted by liquefaction.

General Comments

- Ruptured sewer pipelines could cause raw sewage to back up into private property or overflow into streets. Repair on large diameter sewers would be involved and take a significant amount of time.

Coordinating Organization:	Bureau of Environmental Services
Internal Partners:	Corporate Geographic Information Systems, Portland Department of Transportation, Fire Department, Police Department, Portland Office of Emergency Management, Bureau of Water

External Partners:	none
Level of Immediate Capability:	Medium
Estimated Timeline:	5 years
Plan Goals Addressed:	Identify risk level and evaluate Portland's vulnerability to natural hazards.

LT-EQ#12 Develop a plan to strengthen sewer infrastructure in areas where street overlays and sewers have potential to collapse in a seismic event.

Key Issues Addressed

- Sewer pipes cannot be readily assessed post earthquake; conducting a pre assessment could identify vulnerabilities in key routes.

Ideas for Implementation

- Convene key groups to review below level street systems.
- HAZUS mapping can be used. Maps of large diameter pipes are available through Portland Office of Emergency Management.
- Develop capital program to strengthen pipelines in/under critical transportation corridors (e.g. rail, light rail, streets).

General Comments

- Failure of large diameter sewers can cause large sink holes in the surrounding ground.

Coordinating Organization:	Portland Office of Transportation
Internal Partners:	Corporate GIS; Bureau of Maintenance, Bureau of Environmental Services, Bureau of Water, Portland Office of Emergency Management
External Partners:	none
Level of Immediate Capability	Low
Estimated Timeline:	3-5 years
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

LT-EQ#13 Develop a sewer failure response plan.

Key Issues Addressed

- Currently, there is no plan in place to address response to failure of sewer lines as a result of seismic (or other) events,

Ideas for Implementation

- Develop a list of pre-qualified contractors to provide emergency response.
- Address public health and water quality issues that may result from sewer backups and overflows.

General Comments

- Action item should be dependent on completion of a vulnerability assessment.

Coordinating Organization:	Environmental Services
Internal Partners:	Corporate GIS, Maintenance, Environmental Services, Bureau of Water
External Partners:	Department of Environmental Quality, NOAA Fisheries, US Fish and Wildlife Service, Utilities, COMNet, Private industry
Level of Immediate Capability:	Low
Estimated Timeline:	5 + years
Plan Goals Addressed:	Build and support the capacity and commitment to continuously become less vulnerable to hazards.

LT-EQ#14 Develop an educational program that targets homeowners, providing them with inexpensive methods that they can use to strengthen their homes against earthquake damage.

Key Issues Addressed

- Inexpensive methods (such as anchoring a home to its foundation and strapping water heaters to walls) are available to lessen the damage earthquakes can cause. Widespread implementation of these measures would reduce earthquake losses in existing residential developments, and will cost very little for the city.

Ideas for Implementation

- Convene a committee from City bureaus that have frequent contact with the public to discuss ways of increasing inexpensive in-home mitigation.
- Add an employee to develop public education materials that show home mitigation methods.
- Simplify the permit process required to perform in-home mitigation.

Coordinating Organization:	Portland Office of Emergency Management
Internal Partners:	Bureau of Development Services, Bureau of Water, Fire Department
External Partners:	residential homeowners, neighborhood associations
Level of Immediate Capability:	medium
Estimated Timeline:	2 years
Plan Goals Addressed:	Promote public awareness, engage public participation, and enhance partnerships through education, outreach and coordination of a diverse and representative group of the City's population. Implement activities to protect human life, property and natural systems.

LT-EQ#15 Assess the vulnerability of the water distribution system to seismic events; work toward hardening the system.

Key Issues Addressed

- Portland's water system serves approximately a quarter of the State's population, and many parts of the system are more than 100 years old. The water system would not be able to withstand a significant seismic event without incurring substantial damage. Substantial damage to the water system could take months or even years to repair.

Ideas for Implementation

- Complete the Distribution System Master Plan and Condition Assessment to identify vulnerabilities in the distribution system, including seismic vulnerabilities in key components of the distribution system.
- Periodically update the Infrastructure Master Plan and System Vulnerability Assessment.
- Develop an asset management plan to prioritize long term maintenance and replacement of water system infrastructure
- Improve or replace facilities at Interstate in order to provide a seismically hardened site that will be functional after a seismic event.
- Replace one of the above ground conduit bridge crossings of the Sandy River with an underground crossing that will be hardened to withstand a seismic event.
- Replace conduit trestle crossings with underground piping, prioritize so that one conduit is hardened from Headworks into town.
- Increase the capacity of the secondary source of supply at Columbia South Shore Wellfield by 20 million gallons per day (MGD) to provide for adequate backup supply capacity during an emergency, and to complement previous seismic upgrades to the wellfield.
- Construct new conduit bypass to allow bypass of Powell Butte Reservoir in an emergency
- Seismically upgrade Powell Butte reservoir.

General Comments

- The Water Bureau has initiated several studies of the vulnerability of the water system to natural hazards, including seismic vulnerabilities. The most comprehensive assessment was completed in September 2000, and is known as the System Vulnerability Assessment (SVA). Several projects were identified in the SVA to harden the backbone

water supply system to withstand a seismic event, and the Bureau continues to make progress implementing the SVA recommendations. The Bureau plans to identify and address vulnerabilities in the distribution system with a Distribution System Master Plan.

- In addition to infrastructure improvements, the Bureau has also investigated emergency connections and mutual aid agreements with other water districts.

Coordinating Organization:	Bureau of Water
Internal Partners:	none
External Partners:	none
Level of Immediate Capability:	Medium for current projects, low for longer-term projects
Estimated Timeline:	5-10 years
Plan Goals Addressed:	Identify risk level and evaluate Portland's vulnerability to natural hazards. Implement activities to protect human life, property and natural systems.

LT-EQ#16 Partner with DOGAMI and USGS to obtain funding for completion of fault mapping and improved technology for the transfer of data and information.

Key Issues Addressed

- The locations and ages of the fault strands that comprise the Portland Hills fault zone and the East Bank fault have not been well characterized. Subsequently, important information regarding land use in those areas cannot be made.

Ideas for Implementation

- Support ongoing geologic and geophysical research by DOGAMI and USGS through letters and in-kind matching funding when appropriate.

General Comments

- Scientific agencies have embarked on a five-year mapping project (2003-2008) focusing on the faults in the Portland Metro area, but have not yet secured complete funding for the project.

Coordinating Organization:	Portland Office of Emergency Management
Internal Partners:	none
External Partners:	Oregon Department of Geology and Mineral Industries
Level of Immediate Capability:	High
Estimated Timeline:	15 years
Plan Goals Addressed:	Identify risk level and evaluate Portland's vulnerability to natural hazards.

LT-EQ#17 Study development regulations and policies to ascertain if regulations can be made to limit development of high-risk facilities in known areas of earthquake hazards.

Key Issues Addressed

- Some areas of Portland are more prone to earthquake risk; they are more likely to experience landslides, liquefaction, and ground amplification. Zoning and policy regulations could be used to regulate buildings that house critical facilities, large public assembly spaces, or hazardous materials in such high-risk areas.

Ideas for Implementation

- Convene a committee of Bureaus that regulate development to study ways to revise regulations. Incorporate future known data such as earthquake fault locations when data becomes available.

General Comments

- Hazardous developments can be moved from the high-risk earthquake areas without large increases in development costs.

Coordinating Organization:	Portland Office of Emergency Management
Internal Partners:	Bureau of Development Services, Bureau of Planning, Portland Department of Transportation, Bureau of Fire
External Partners:	Private developers, general public
Level of Immediate Capability:	Low
Estimated Timeline:	5-10 years
Plan Goals Addressed:	Build and support the capacity and commitment to continuously become less vulnerable to hazards.

LT-EQ#18 Assess the stability of levees in the Columbia Corridor area, and develop appropriate emergency response plans to address potential levee failure and associated hazards.

Key Issues Addressed

- Much of the Columbia corridor (which contains a high concentration of industrial and employment uses) is protected by levees; the ability of these levees to survive an earthquake is not fully known.

Ideas for Implementation

- Work with the U.S. Army Corps of Engineers, the Port of Portland, and the Multnomah County Drainage District to assess levee stability.
- Based on these assessments, plans to (1) strengthen the levees against damage in earthquakes, (2) evacuate the area in the event of levee failure, and (3) mitigate potential ground or surface water contamination from hazardous materials should be developed.

Coordinating Organization:	Portland Office of Emergency Management
Internal Partners:	Bureau of Water, Fire Bureau, Bureau of Environmental Services, Bureau of Maintenance
External Partners:	U.S. Army Corps of Engineers, Multnomah county Drainage District, Port of Portland, Department of Environmental Quality.
Level of Immediate Capability:	Medium
Estimated Timeline:	3-5 years
Plan Goals Addressed:	Build and support the capacity and commitment to continuously become less vulnerable to hazards. Implement activities to protect human life, property and natural systems.

Earthquake Resource Directory

City Resources

Portland Office of Emergency Management (POEM)

POEM coordinates citywide emergency management programs including citizens, businesses, employees, and partners of the City. As the largest city in the State, Portland's resources are extensive, without boundaries, and multi-faceted. To be effective, the City partners and collaborates across the region to ensure that activities of mitigation, preparedness, response, and recovery are intertwined with the greater region for greater citizen protection, greater economic stability, and greater in-depth coverage of our assets.

Contact: Director, POEM
Address: 1001 SW 5th Ave, Suite 650, Portland, OR 97204
Phone: 503-823-4375
Fax: 503-823-3903

Portland Fire & Rescue

The Portland Bureau of Fire & Rescue is the responding agency in charge of plan development for the coordination of an earthquake event. With 27 stations across the Portland area and many more regional partners in the fire service, the Bureau of Fire and Rescue lends a trained force that has familiarized itself with the buildings' plans, the street network, and the neighborhood of their fire management areas. With this knowledge they know where vulnerable people live and can work with the community to save lives and property expediently.

Contact: Chief Ed Wilson
Address: 55 SW Ash; Portland, OR 97204
Phone: 503-823-3700

Bureau of Development Services

Bureau of Development Services issues building permits, performs land use reviews, and promotes compliance with the zoning codes and the state adopted construction codes.

Contact: Director
Address: 1900 SW 4th Ave; Portland, 97201
Phone: 503-823-7300

County/ Regional Resources

Metro

Metro manages the urban growth boundary and developed the 2040 growth concept. Metro provides land-use planning services and provides maps and data to businesses, local government, and citizens. Metro helps residents and governments protect fish and wildlife habitat. Metro's transportation planning section develops the regional

transportation plan, sets transportation funding priorities, and leads the region's efforts to plan and implement roadway and transit improvements. Metro's programs provide travel options and design livable streets.

Contact: Metro Regional Center
Address: 600 NE Grand Ave., Portland, OR 97232-2736
Phone: (503) 797-1700

Regional Emergency Management Technical Committee (REMTEC)
Regional Emergency Management Group (REMG)

Emergency Management professionals coordinate regional resources and resolve regional issues through the "hands on" technical committee which proposes and reports to the "public official level" REMG. Recently, the committee has developed maps for regional emergency response routes.

Contact: Committee Chair
Phone: 503-642-0371

Multnomah County Emergency Management

Responsible for the coordination of county programs such as Public Health, County Roads, Animal Control, libraries, county jails, and the cities within the un-incorporated areas of the county.

Contact: Tom Simpson, Director
Address: 501 SW Hawthorne; Portland, OR 97214
Phone: 503-988-4233

State Resources

Department of Land Conservation and Development (DLCD)

DLCD administers the State's Land Use Planning Program. The program is based on 19 Statewide Planning Goals including Goal 7, the goal specifically related to flooding and other natural hazards. DLCD serves as the federally designated agency to coordinate floodplain management in Oregon. They also conduct various landslide related mitigation activities. In order to help local governments address natural hazards effectively, DLCD provides technical assistance and conducts workshops, reviews local land use plan amendments, and works interactively with other agencies.

Contact: Natural Hazards Program Manager
Address: 635 Capitol St. NE, Suite 200, Salem, OR 97301-2540
Phone: (503) 373-0050
Fax: (503) 378-6033
Website: http://www.lcd.state.or.us/hazards.html

Oregon Department of Geology and Mineral Industries (DOGAMI)

The mission of the Department of Geology and Mineral Industries is to serve a broad public by providing a cost-effective source of geologic information for Oregonians and to use that information to reduce the future loss of life and property due to potentially devastating earthquakes, tsunamis, landslides, floods, and other geologic hazards. The Department has mapped earthquake hazards in most of western Oregon.

Contacts: Deputy State Geologist, Geohazards and Coastal Hazards Team Leaders
Address: 800 NE Oregon St., Suite 965, Portland, Oregon 97232
Phone: (503) 731-4100
Fax: (503) 731-4066
Website: www.oregongeology.com

Oregon Department of Consumer & Business Services-Building Codes Division

The Building Codes Division (BCD) sets statewide standards for design, construction, and alteration of buildings that include resistance to seismic forces. BCD is active on several earthquake committees and funds construction-related continuing education programs. BCD registers persons qualified to inspect buildings as safe or unsafe to occupy following an earthquake and works with OEM to assign inspection teams where they are needed.

Contact: Building Codes Division
Address: 1535 Edgewater St. NW, P.O. Box 14470, Salem, Oregon 97309
Phone: (503) 378-4133
Fax: (503) 378-2322
Website: http://www.cbs.state.or.us/external

Oregon State Police (OSP)-Office of Emergency Management (OEM)

The purpose of OEM is to execute the Governor's responsibilities to maintain an emergency services system as prescribed in Oregon Revised Statutes Chapter 401 by planning, preparing, and providing for the prevention, mitigation, and management of emergencies or disasters that present a threat to the lives and property of citizens of and visitors to the state of Oregon. OEM coordinates disaster support to local governments and works with BCD to deploy additional building inspectors when needed for damage assessment.

Contact: Earthquake and Tsunami Program Coordinator
Address: 595 Cottage St. NE, Salem, Oregon 97301
Phone: (503) 378-2911
Fax: (503) 588-1378
Website: http://www.osp.state.or.us/oem/

The Nature of the Northwest Information Center

The Nature of the Northwest Information Center is operated jointly by the Oregon Department of Geology and Mineral Industries and the USDA Forest Service. It offers selections of maps and publications from state, federal, and private agencies. DOGAMI's earthquake hazard maps can be ordered from this site.

Address: Suite 177, 800 NE Oregon Street # 5, Portland, Oregon 97232
Phone: (503) 872-2750
Fax: (503) 731-4066
Email: Nature.of.NW@state.or.us
Website: http://www.naturenw.org/geo-earthquakes.htm

Federal Resources

Federal Emergency Management Agency (FEMA)

FEMA is heavily involved with seismic risks in Oregon and has aided in several projects in Portland and Klamath Falls. The Federal Emergency Management Agency (FEMA) is an independent agency of the Federal Government that reports to the President. FEMA's purpose is to reduce loss of life and property and to protect the nation's critical infrastructure from all types of hazards through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response, and recovery. FEMA coordinates the federal response and provides disaster relief funds following a natural hazard event and works most closely with Oregon Emergency Management (OEM).

Contact: Public Affairs Officer, FEMA, Federal Regional Center,
Address: 130 228th Street, St., Bothell, WA 98021-9796
Phone: (425) 487-4610
Fax: (425) 487-4690
Email: opa@fema.gov
Website: http://www.fema.gov/library/quakef.htm

US Geological Survey (USGS)

The USGS is an active seismic research organization that also provides funding for research. (For an example of such research, see Recommended Seismic Publications below).

Contact: USGS, National Earthquake Information Center
Address: Box 25046; DFC, MS 967; Denver, Colorado 80225
Phone: (303) 273-8500
Fax: (303) 273-8450
Website: http://neic.usgs.gov

Building Seismic Safety Council (BSSC)

The Building Seismic Safety Council (BSSC), established by the National Institute of Building Sciences (NIBS), deals with complex regulatory, technical, social, and economic issues and develops and promotes building earthquake risk mitigation regulatory provisions for the nation.

Address: 1090 Vermont Avenue, NW, Suite 700, Washington, DC 20005
Phone: (202) 289-7800
Fax: (202) 289-1092
Website: http://www.bssconline.org/

Western States Seismic Policy Council (WSSPC)

The WSSPC is a regional organization that includes representatives of the earthquake programs of thirteen states (Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon Utah, Washington, and Wyoming), three U.S. territories (American Samoa, Commonwealth of the Northern Mariana Islands and Guam), one Canadian Province (British Columbia), and one Canadian Territory (Yukon). The organization has primarily sought to improve public understanding of seismic risk, to improve earthquake preparedness, and to provide a cooperative forum to enhance transfer of mitigation technologies at the local, state, interstate, and national levels.

The mission of the Council is to provide a forum to advance earthquake hazard reduction programs throughout the western region and to develop, recommend, and present seismic policies and programs through information exchange, research and education.

Contact: WSSPC, Executive Director
Address: 121 Second Street, 4th Floor, San Francisco, CA 94105
Phone: (415) 974-6435
Fax: (415) 974-1747
Email: wsspc@wsspc.com
Website: http://www.wsspc.org/

Cascadia Region Earthquake Workgroup (CREW)

CREW provides information on regional earthquake hazards, facts, and mitigation strategies for the home and business office. CREW is a coalition of private and public representatives working together to improve the ability of Cascadia Region communities to reduce the effects of earthquake events. Members are from Oregon, Washington, California, and British Columbia. The workgroup seeks to

- Promote efforts to reduce the loss of life and property.
- Conduct education efforts to motivate key decision makers to reduce risks associated with earthquakes.
- Foster productive linkages between scientists, critical infrastructure provides, businesses and governmental agencies in order to improve the viability of communities after an earthquake.

Contact: CREW, Executive Director
Address: 1330A S. 2nd Street, #105, Mount Vernon, WA 97273
Phone: (360) 336-5494
Fax: (360) 336-2837
Website: http://www.crew.org/

Additional Resources

Publications

Planning for Natural Hazards: The Oregon Technical Resource Guide, Department of Land Conservation and Development (July 2000).

Produced by the Community Planning Workshop for the Department of Land Conservation and Development, this is a natural hazards planning and mitigation resource for Oregon cities and counties. It provides hazard-specific resources and plan evaluation tools and is written for local government employees and officials. The Technical Resource Guide includes a natural hazards comprehensive plan review, a hazard mitigation legal issues guide, and five hazard-specific technical resource guides that cover flooding, wildfires, landslides, coastal hazards, and earthquakes. You can write, call, fax, or go on-line to obtain this document.

Contact: Natural Hazards Program Manager, DLCD
Address: 635 Capitol St. NE, Suite 200, Salem, OR 97301-2540
Phone: (503) 373-0050
Fax: (503) 378-6033
Website: http://www.lcd.state.or.us/hazards.html

Special Paper 32: Geologic Hazards: Reducing Oregon's Losses, John D. Beaulieu and Dennis L. Olmstead, (1999) Oregon Department of Geology and Mineral Industries.

The authors summarize the more technical Special Paper 31 on mitigating geologic hazards in Oregon. The paper outlines the strategy to mitigate for natural hazards and offers specific information on geologic hazards and multi-hazard scenarios.

Contact: DOGAMI
Address: 800 NE Oregon St., Suite 965, Portland, Oregon 97232
Phone: (503) 731-4100
Fax: (503) 731-4066
Website: http://www.oregongeology.com/

Special Paper 29: Earthquake damage in Oregon: Preliminary estimates of future earthquake losses, Yumei Wang and J.L. Clark, (1999) Oregon Department Of Geology And Mineral Industries.

The authors analyzed all young faults with a 500-year return interval and projected potential damage. The study notes that Multnomah, Washington, and Clackamas counties are among those with the highest risk due to located faults and large numbers of unreinforced masonry buildings.

Contact: DOGAMI
Address: 800 NE Oregon St., Suite 965, Portland, Oregon 97232
Phone: (503) 731-4100
Fax: (503) 731-4066
Website: http://sarvis.dogami.state.or.us/homepage

Land Use Planning for Earthquake Hazard Mitigation: A Handbook for Planners, Wolfe, Myer R. et. al., (1986) University of Colorado, Institute of Behavioral Science, National Science Foundation.

This handbook provides techniques that planners and others can utilize to help mitigate for seismic hazards. It provides information on the effects of earthquakes, sources on risk assessment, and effects of earthquakes on the built environment. The handbook also gives examples on application and implementation of planning techniques to be used by local communities.

Contact: Natural Hazards Research and Applications Information Center
Address: University of Colorado, 482 UCB, Boulder, CO 80309-0482
Phone: (303) 492-6818
Fax: (303) 492-2151
Website: http://www.colorado.edu/UCB/Research/IBS/hazards

Using Earthquake Hazard Maps: A Guide for Local Governments in the Portland Metropolitan Region; Evaluation of Earthquake Hazard Maps for the Portland Metropolitan Region Spangle Associates, (1998/1999) Urban Planning and Research, Portola Valley, California.

These two publications are useful for local governments concerned with land use in earthquake hazard areas. The proximity of Washington County to Portland and their interactive communities make these guides applicable to the County. The publications are written in clear and simplistic language and address issues such as the application of earthquake hazard maps to land use decisions.

Contact: DOGAMI
Address: 800 NE Oregon St., Suite 965, Portland, Oregon 97232
Phone: (503) 731-4100
Fax: (503) 731-4066
Website: http://sarvis.dogami.state.or.us/homepage

Public Assistance Debris Management Guide, Federal Emergency Management Agency (July 2000).

The Debris Management Guide was developed to assist local officials in planning, mobilizing, organizing, and controlling large-scale debris clearance, removal, and disposal operations. Debris management is generally associated with post-disaster recovery. While it should be compliant with local and county emergency operations plans, strong debris management should also be integrated into mitigation activities. The *Public Assistance Debris Management Guide* is available in hard copy or on the FEMA website.

Contact: FEMA Distribution Center
Address: 130 228th Street, SW, Bothell, WA 98021-9796
Phone: (800) 480-2520
Fax: (425) 487-4622
Website: http://www.fema.gov/r-n-r/pa/dmgtoc.htm

City of Portland Earthquake Plan; Portland Office of Emergency Management; Portland Bureau of Fire & Rescue – January 2003

This plan lists the organizations and contacts that are partners in the response and recovery of an earthquake event. Updated every 5 years, this plan outlines the responsibilities of the City.

Contact: Director
Address: 1001 SW 5th Suite 650 Portland OR 97204
Phone: 503-823-2691
Website: portlandonline.com/oem

Earthquake Loss Estimation Pilot Study for the Portland Metropolitan Region; National Institute of Building Sciences; Federal Emergency Management Agency ; Metro Natural Hazards Mitigation Planning Workshop – March 13, 1997

Loss estimations in this report were generated by using the FEMA/NIBS Earthquake Loss Estimation Methodology. The loss estimation study was implemented using a software program called HAZUS. The study area included was the Portland Metro's Urban Growth Boundary with a population of 1.16 million people. This was the first use of HAZUS to study Portland's losses; the estimates cover fire losses, debris, and direct economic loss for buildings, shelter, transportation, and utilities.

Contact: METRO GIS Specialist
Address: Metro, 600 NE Grand Ave. Portland 97232
Phone: 503-797-1595

Earthquake Endnotes

[1] Northwest Geology News - Milwaukie trench yields evidence of ancient quakes, Oregon Department of Geology and Mineral Industries (DOGAMI), *http://www.oregongeology.com/news&events/MilwaukieTrench.htm*

[2] Interagency Hazard Mitigation Team, State Hazard Mitigation Plan (2000) Oregon State Police – Office of Emergency Management

[3] The Pacific Northwest Seismograph Network - Notable Pacific Northwest Earthquakes Since 1993, *http://www.geophys.washington.edu/SEIS/EQ_Special/pnwtectonics.html*

[4] Oregonlive.com, (May 14, 2003) http://www.oregonlive.com/search/index.ssf?/base/science/105291437197590.xml?oregonian?scg

[5] Hill, Richard. "Geo Watch Warning Quake Shook Portland 40 Years Ago." *The Oregonian*, October 30, 2002

[6] *The Valley Times* March 8, 2001 Vol.81 No.10

[7] ibid.

[8] ibid.

[9] Hill, Richard. "Geo Watch Warning Quake Shook Portland 40 Years Ago." *The Oregonian*, October 30, 2002

[10] Hill, Richard. "Geo Watch Warning Quake Shook Portland 40 Years Ago." *The Oregonian*, October 30, 2002

[11] Wong, Ivan G and Bott Jacqueline D.J. (November 1995). A look back at Oregon's earthquake history, 1841- 1994. Oregon Geology 57 (6). 125.

[12] Wong, Ivan G and Bott Jacqueline D.J. (November 1995). A look back at Oregon's earthquake history, 1841- 1994. Oregon Geology 57 (6). 125.

[13] DOGAMI Risk Perception Survey (1999)

Page 9-4 Community Planning Workshop, September 2001

[14] Wong, Ivan G and Bott Jacqueline D.J. (November 1995). A look back at Oregon's earthquake history, 1841- 1994. Oregon Geology 57 (6). 125.

[15] Hill, Richard. "Geo Watch Warning Quake Shook Portland 40 Years Ago." *The Oregonian*, October 30, 2002

[16] Community Planning Workshop, 2002

[17] California Department of Conservation, California Geological Survey, 2002; Guidelines for Evaluating the Hazard of Surface Fault Rupture, Note 49.

[18] Planning for Natural Hazards: The Oregon Technical Resource Guide, Department of Land Conservation and Development (July 2000), Ch. 8, pp.7

[19] Personal Interview, Burns, Scott. Portland State University, Department of Geology, June 2003

[20] Ibid

[21] Community Planning Workshop, 2002

[22] Debris Quantity Analysis for a Far-Field Seismic Event in the Portland Metro Region; 5-1-99; Hasenberg, Rad, Delco; PSU DCE

[23] Burby, R. (Ed.) *Cooperating with Nature* (1998) Washington D.C.: Joseph Henry Press.

[24] Planning for Natural Hazards: The Oregon Technical Resource Guide, Department of Land Conservation and Development (July 2000), Ch. 8, pp.7

[25] Burby, R. (Ed.) *Cooperating with Nature*. (1998) Washington D.C.: Joseph Henry Press.

[26] Quakex 2003, "Generic Player's Handbook"
http://www.osp.state.or.us/oem/programs/earthquake/quakex%202003/quakex_2003.htm

[27] Planning for Natural Hazards: The Oregon Technical Resource Guide, Department of Land Conservation and Development (July 2000), Ch. 8, pp.13

[28] Personal Interview, Peggy Collins, February 24, 2000

[29] United States Geological Survey, Geologic Division, Earthquake Information: reducing hazards, http://quake.wr.usgs.gov, October 19, 1999

[30] Personal Interview, St. Cecelia School