

# UNDERSTANDING EARTHQUAKE HAZARDS IN WASHINGTON STATE

## Modeling a Magnitude 7.2 Earthquake near SeaTac in South-Central Puget Sound

### Geologic Description

This scenario is based on a M7.2 deep earthquake centered below SeaTac. Deep earthquakes—also called intraplate or Wadati-Benioff zone earthquakes—are common in western Washington. Over the last 65 years, the largest of these deep earthquakes occurred between Olympia and Seattle in 1949 (M7.0), 1965 (M6.5), and 2001 (M6.8).

Intraplate earthquakes are usually the result of normal faulting within the upper part of a subducting oceanic plate, and typically are not followed by large aftershocks. Beneath western Washington, the depth range of deep earthquakes begins near 30 kilometers (19 miles) and continues downward to about 60 kilometers (37 miles). This depth range is where all of the damaging deep earthquakes have been located. In some places, notably central and northern Puget Sound, a few deep events have been located much deeper, but their magnitudes tend to be small. The distribution of deep earthquakes allows seismologists to map the surface of the subducting Juan de Fuca plate as it descends into the mantle below western Washington.

Two mechanisms are often cited as the cause of these earthquakes:

1. The subducting plate is bent by gravity as it descends into the mantle and bending-moment forces cause normal faults to rupture in the upper part of the down-going slab
2. Dehydration and metamorphism of minerals in the down-going slab cause the plate to shrink and become denser, in turn causing stresses to build up that pull the plate apart.

Worldwide, deep earthquakes can reach M7.5 or greater. For example, a M7.5 deep earthquake

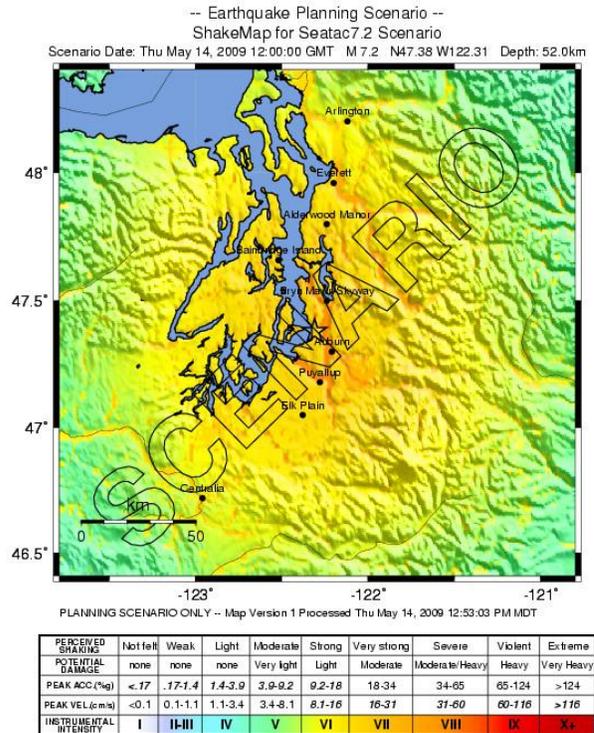


Figure 1. ShakeMap for a M7.2 deep earthquake near SeaTac, Washington.

beneath Oaxaca, Mexico, occurred on Sept. 30, 1999. Our historical record of these earthquakes in north-western Washington suggests an average recurrence interval of 30 years for a M6.5 or greater deep earthquake.

### Type of Earthquake

Most earthquake hazards result from ground shaking caused by seismic waves that radiate out from a fault when it ruptures. Seismic waves transmit the energy released by the earthquake: The bigger the quake, the larger the waves and the longer they last. Several factors affect the strength, duration, and pattern of shaking:



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- The type of rock and sediment layers that the waves travel through.
- The dimensions and orientation of the fault and the characteristics of rapid slippage along it during an earthquake.
- How close the rupture is to the surface of the ground.

**Deep vs. Shallow:** Like the M6.8 Nisqually earthquake in 2001, the M7.2 scenario earthquake modeled for the region around SeaTac is a deep earthquake. Deep earthquakes tend to be less damaging than shallow earthquakes of comparable magnitude, primarily because in deeper quakes, the seismic waves have lost more energy by the time they reach the surface. Nevertheless, a deep earthquake of this magnitude will cause serious damage. The shaking from a deep earthquake is also likely to be felt over a much larger area than that from a shallow earthquake.

**Aftershocks:** Unlike shallow earthquakes, which usually produce numerous aftershocks, a M7.2 deep earthquake like the one in this scenario is not likely to be followed by aftershocks strong enough to be felt.

## Other Earthquake Effects

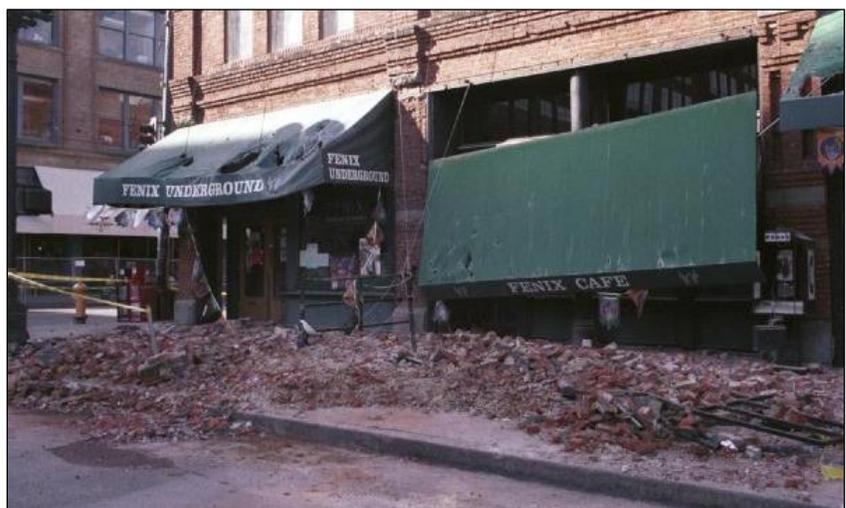
**Tsunamis:** Delta failures and landslides caused by the shaking may create local tsunamis. Geological and historical evidence shows that landslides and failures of the sediments in river deltas have generated tsunamis within Puget Sound in the past.

**Liquefaction:** If sediments (loose soils consisting of silt, sand, or gravel) are water-saturated, strong shaking can disrupt the grain-to-grain contacts, causing the sediment to lose its strength. Increased pressure on the water between the grains can sometimes produce small geyser-like eruptions of water and sediment called *sand blows*. Sediment in this condition is liquefied and behaves as a fluid. Buildings on such soils can sink and topple, and foundations can lose strength, resulting in severe damage or structural collapse. Pipes, tanks, and other structures that are buried in liquefied soils will float upwards to the surface.

Artificial fills, tidal flats, and stream sediments are often poorly consolidated and tend to have high liquefaction potential. For example, in the SeaTac scenario, the liquefaction susceptibility of many river valleys—such as the land on either side of the Puyallup and Green rivers—is rated moderate to high.

**Landslides:** Earthquake shaking may cause landslides on slopes, particularly where the ground is water-saturated or has been modified (for example, by the removal of stabilizing vegetation). Steeper slopes are most susceptible, but old, deep-seated landslides may be reactivated, even where gradients are as low as 15%. Catastrophic debris flows can move water-saturated materials rapidly and for long distances, mostly in mountainous regions. Underwater slides are also possible, such as around river deltas.

**Figure 2.** These historic buildings in Seattle’s Pioneer Square were damaged by the M6.8 Nisqually earthquake in 2001. (Photo: FEMA/Kevin Galvin)



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## Hazus Results for the SeaTac Scenario

*Hazus* is a nationally applicable standardized methodology developed by FEMA to help planners estimate potential losses from earthquakes. Local, state, and regional officials can use such estimates to plan risk-reduction efforts and prepare for emergency response and recovery.

Hazus was used to estimate the losses that could result from a M7.2 deep earthquake beneath SeaTac in King and Pierce counties. Such an event is expected to impact 16 counties in Washington, with the most significant effects apparent in King, Pierce, Snohomish, and Kitsap counties.

**Injuries:** The number of people injured in this scenario is likely to be high, particularly if the earthquake occurs during or at the end of the business day. King County is expected to have the highest number of injured people, followed by Pierce, Snohomish, and Kitsap. Many of these injuries may be serious enough to require hospitalization. Numerous fatalities are also likely: the highest numbers are in King and Pierce counties.

**Damage:** The earthquake will damage thousands of buildings in all of the affected counties, but King, Pierce, Snohomish, and Kitsap counties account for the greatest number (over 342,000) and will suffer damage to the highest percentages of their respective building stocks. For many buildings, the damage is expected to be slight to moderate, but a large number will be extensively damaged (over 5,000 in King County alone). Hundreds of buildings are expected to collapse or to be in imminent danger of collapse. Most of these are in King and Pierce counties. A majority of the damaged buildings will be residential, commercial, and industrial, but the total includes buildings of all types and occupancy classes. Many unreinforced masonry and non-ductile concrete buildings are subject to collapse.

**Economic Losses Due to Damage:** Capital stock losses are the direct economic losses associated with damage to buildings, including the cost of structural and non-structural damage, damage to contents, and loss of inventory. King County accounts for the largest portion of the capital stock loss estimate

<b>SEATAC SCENARIO EARTHQUAKE</b>	
End-to-end length of fault (kilometers)	38
Magnitude (M) of scenario earthquake	7.2
Number of counties impacted	16
Total injuries (*severity 1, 2, 3, 4)	>3,480
Total number of buildings extensively damaged	8,801
Total number of buildings completely damaged	1,123
Income losses in millions	\$1,684
Displaced households	6,489
People requiring shelter (individuals)	3,871
Capital stock losses in millions	\$8,241
Debris total in millions of tons	2.36
Truckloads of debris (25 tons per truckload)	94,480
People without potable water (Day 1)	132,577

**Table 1. Summary of significant losses in the M7.2 SeaTac earthquake scenario. Among the counties most likely to be affected are Clallam, Island, King, Kitsap, Lewis, Pierce, and Snohomish.**

**\*Injury severity levels: 1—requires medical attention, but not hospitalization; 2—not life-threatening, but does require hospitalization; 3—hospitalization required; may be life-threatening if not treated promptly; 4—victims are killed by the earthquake**

(over \$5 billion), followed by Pierce (over \$1 billion) and Snohomish (more than \$789 million).

Income losses, including wage losses and loss of rental income due to damaged buildings, are also highest in King County (over \$1 billion) and Pierce County (more than \$461 million).

**Impact on Households and Schools:** The number of people without water is highest in King County. This county also accounts for most of the displaced households and individuals in need of shelter. The earthquake is most likely to affect the functionality of schools in King, Pierce, and Kitsap counties.

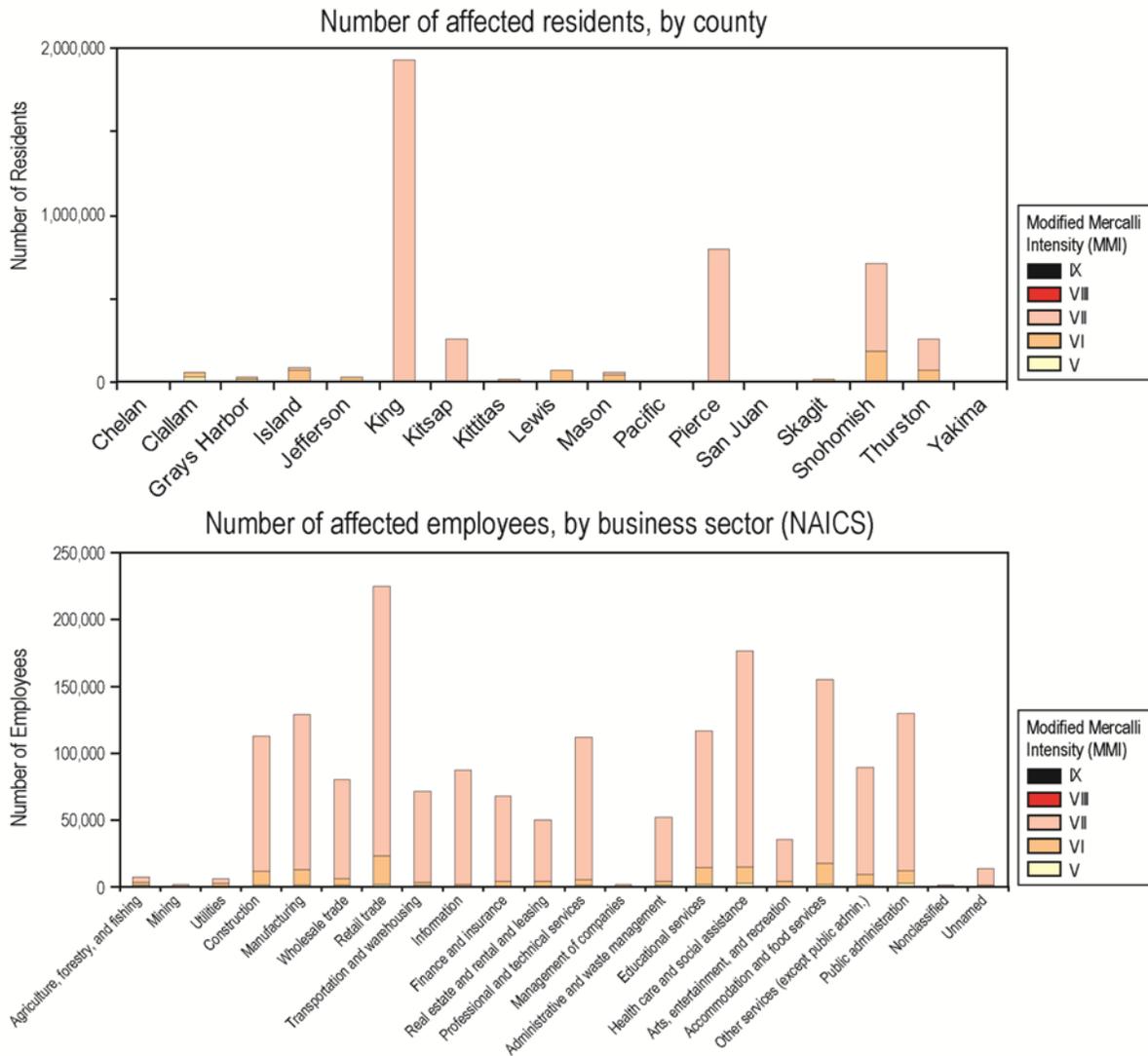
**Debris Removal:** Following an earthquake, debris (brick, wood, concrete, and steel) must be removed and disposed of. Much of this will come from King and Pierce counties (about 2,028,000 tons).

**Estimates vs. Actual Damage:** Although this M7.2 earthquake scenario was modeled using the best scientific information available, it represents a simplified version of expected ground motions. The damage resulting from an actual earthquake of similar magnitude is likely to be even more variable

and will depend on the specific characteristics and environment of each affected structure.

**Other Tools:** Community planners can also look at how a large earthquake may impact local resources and people’s lives and livelihoods. The following graphs illustrate variations in such impacts: The first

shows the levels of shaking that residents are likely to experience; the second shows the possible impact on different services and business sectors. Note that even where structural damage to buildings is slight, the shaking may be strong enough to damage furnishings and inventories.



**Figure 3. Number of residents and employees affected by the M7.2 earthquake projected for the SeaTac scenario. The Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.**

<b>V. Rather Strong</b> (PGA 3.9–9.2 g)	Felt outside by most. Dishes and windows may break. Large bells ring. Vibrations like large train passing close to house.
<b>VI. Strong</b> (PGA 9.2–18 g)	Felt by all; people walk unsteadily. Many frightened and run outdoors. Windows, dishes, glassware broken. Books fall off shelves. Some heavy furniture moved or overturned. Cases of fallen plaster. Damage slight.
<b>VII. Very Strong</b> (PGA 18–34 g)	Difficult to stand. Furniture broken. Damage negligible in buildings of good design & construction; slight-moderate in other well-built structures; considerable in poorly built/badly designed structures. Some chimneys broken.
<b>VIII. Destructive</b> (PGA 34–65 g)	Damage slight in specially designed structures; considerable in ordinary substantial buildings (partial collapse); great in poorly built structures. Fall of chimneys, factory stacks, columns, walls. Heavy furniture moved.
<b>IX. Violent</b> (PGA 65–124 g)	General panic; damage considerable in specially designed structures; well designed frame structures thrown out of plumb. Damage great in substantial buildings: partial collapse. Buildings shifted off foundations.