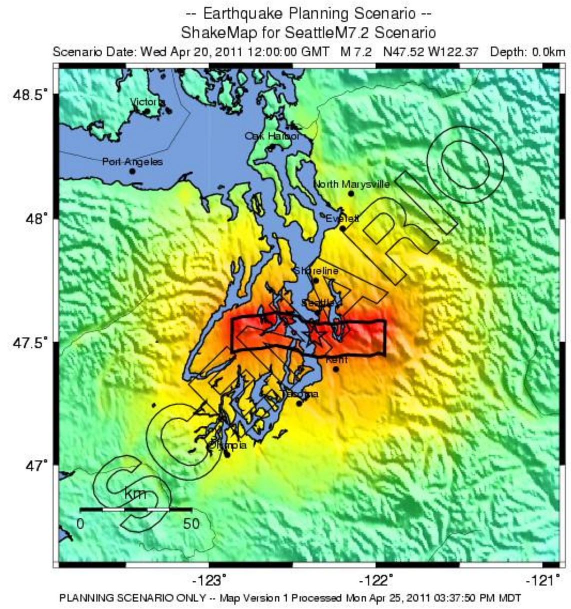
Modeling a Magnitude 7.2 Earthquake on the Seattle Fault Zone in Central Puget Sound

Geologic Description

The Seattle fault earthquake scenario posits a M7.2 earthquake caused by a 63 kilometer (40 mile)-long rupture on the northernmost strand of the Seattle fault zone from the Kitsap Peninsula to just east of Lake Sammamish. The scenario is based on an earthquake that probably caused a surface rupture on the fault in the Bellevue area thousands of years ago. That event caused about 2 meters (6.5 feet) of surface displacement west of Lake Sammamish near SE 38th Street.

The Seattle fault's location was originally determined using geophysical studies that showed a high-amplitude gravity anomaly between uplifted Tertiary volcanic rock to the south and down-dropped Tertiary and Quaternary sediments to the north. This is one of the strongest gravity anomalies in the continental U.S. Later researchers used geologic mapping and high-resolution aeromagnetic and seismic reflection data to locate several subparallel fault strands within an east-trending zone along the gravity anomaly.

A conspicuous platform bordering the shoreline of southern Bainbridge Island, parts of Kitsap County, and Alki Point in West Seattle is the best geological evidence for a large earthquake on the Seattle fault. This intertidal wave-cut platform, cut on Oligocene Blakeley Formation and Miocene Blakely Harbor Formation, was uplifted as much as 8 meters (26 feet) in a single earthquake about 1,100 years ago. Secondary effects of this large earthquake (a tsunami, landslides, and liquefaction) are also documented. Investigation of an 8,000-year history of activity on the Seattle fault found evidence for possibly one additional earthquake on the Seattle fault about 6,900 years ago, suggesting a recurrence interval of thousands of years for large earthquakes.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 1. ShakeMap for a M7.2 earthquake on the Seattle fault zone. The black polygon is the modeled fault rupture for this scenario.

Lidar (light detection and ranging) surveys found a fault scarp on southern Bainbridge Island. Subsequent trenching studies across this scarp revealed evidence for up to three surface-rupturing earthquakes in the past 2,500 years. Additional surveys and analysis of existing lidar identified potential fault scarps at several other locations within the fault zone. Trenching on scarps at Islandwood on Bainbridge Island and Waterman Point and Point Glover in Kitsap County showed evidence of possibly two surface-rupturing earthquakes about 1,100 years ago. Recent geologic mapping suggests that the Seattle fault zone extends to the Olympic Mountains on the west and the Cascades on the east.

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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:

- 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: The M7.2 scenario earth-quake modeled for the Seattle fault zone is a shallow or crustal earthquake. Shallow quakes tend to be more damaging than deep quakes of comparable magnitude (such as the deep M6.8 Nisqually earthquake in 2001). This is primarily because the seismic waves of deeper quakes have lost more energy by the time they reach the surface.

Aftershocks: Unlike deep earthquakes, which usually produce few or no aftershocks strong enough to be felt, a M7.2 shallow earthquake like the one in this scenario would likely be followed by many after-shocks, a few of which could be large enough to cause additional damage.

Photo: FEMA/Kevin Galvin

Figure 2. Historic buildings in Seattle's Pioneer Square damaged by the M6.8 Nisqually earthquake in 2001.

Other Earthquake Effects

Tsunamis: Some earthquakes may rupture a fault at the surface of the ground. If this offsets the floor of Puget Sound, it could generate a local tsunami. Delta failures and landslides caused by the shaking may also create or amplify 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 this scenario, the liquefaction susceptibility of the land on either side of the Green River 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.

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Hazus Results for the Seattle Fault 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 earthquake on the Seattle fault. Such an event is expected to impact fifteen counties in Washington, with the most significant effects apparent in King and Kitsap counties.

Injuries: The number of people injured is likely to be high, particularly if the earthquake occurs during or at the end of the business day. King County is expected to suffer the highest number of casualties (as many as 15,615), followed by Kitsap and Pierce counties; many of these injuries will require hospitalization and hundreds may be life-threatening if not treated promptly. Numerous fatalities are also likely, the highest number being in King and Kitsap counties (over 1,000 if the event occurs at 2:00 PM).

Damage: The earthquake will damage thousands of buildings in all of the affected counties. King and Kitsap counties account for the largest part of the total (357,789 and 68,094 respectively) and will suffer damage to the highest percentages of their building stocks. In many cases, damage will be slight to moderate, but large numbers of buildings will suffer extensive damage (over 21,000 in King County alone). Thousands of buildings are expected to collapse or to be in imminent danger of collapse (complete damage). Most of these are in King and Kitsap counties. The majority of damaged structures will be residential, commercial, and industrial, but the total includes buildings of all types and occupancy classes. Many unreinforced masonry and non-ductile concrete structures are likely 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 and Kitsap counties account for the largest portion of the estimated capital stock loss (nearly $19 billion).

Income losses, including wage losses and loss of rental income due to damaged buildings, are also highest in King County (over $4 billion) and Kitsap County (about $597 million).

Impact on Households and Schools: The number of people without power or water is highest in King and Kitsap counties. In King, 218,464 households will have no power on Day 1; over 333,000 will have no water. King and Kitsap also account for most of the displaced households and individuals in need of shelter. The quake will seriously affect the short- and long-term functionality of schools in these 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 Kitsap counties (over 7 million tons).

Estimates vs. Actual Damage: Although this M7.2 earthquake scenario was modeled using the best

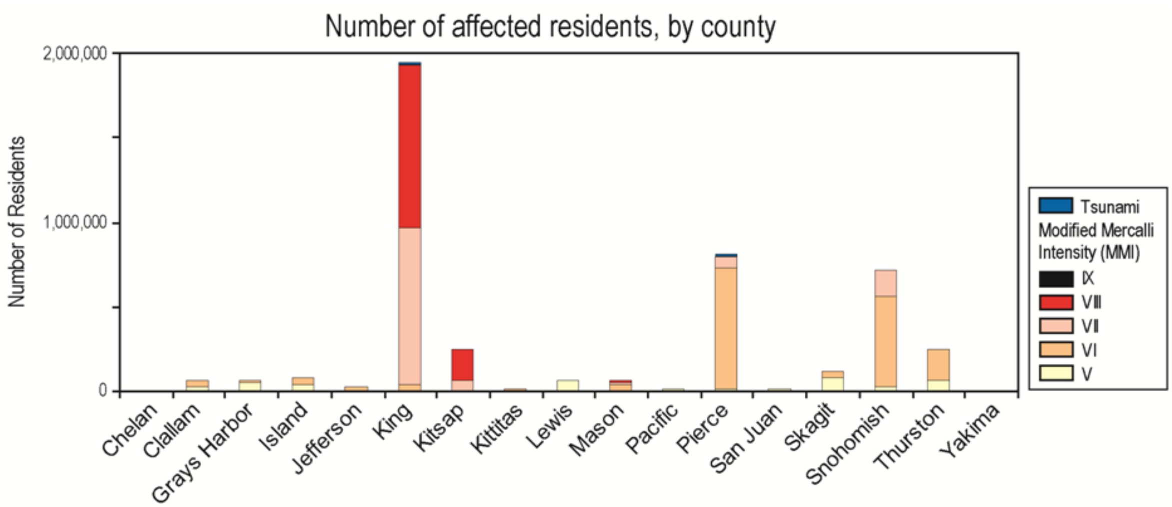
Seattle Fault Scenario Earthquake	
End-to-end length of fault (kilometers)	68
Magnitude (M) of scenario earthquake	7.2
Number of counties impacted	15
Total injuries (*severity 1, 2, 3, 4) at 2:00 PM	17,677
Total number of buildings extensively damaged	29,094
Total number of buildings completely damaged	9,062
Income losses in millions	$5,133
Displaced households	31,278
People requiring shelter (individuals)	18,193
Capital stock losses in millions	$19,868
Debris total in millions of tons	7.42
Truckloads of debris (25 tons per truckload)	296,720
People without power (Day 1)	265,583
People without potable water (Day 1)	399,991

Table 1. Summary of significant losses in the M7.2 Seattle fault earthquake scenario. Among the counties most likely to be affected are King, Kitsap, Mason, Pierce, Snohomish, and Thurston.

***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**

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 is likely to 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. Even where structural damage to buildings is slight, the shaking may be strong enough to damage furnishings and inventories.



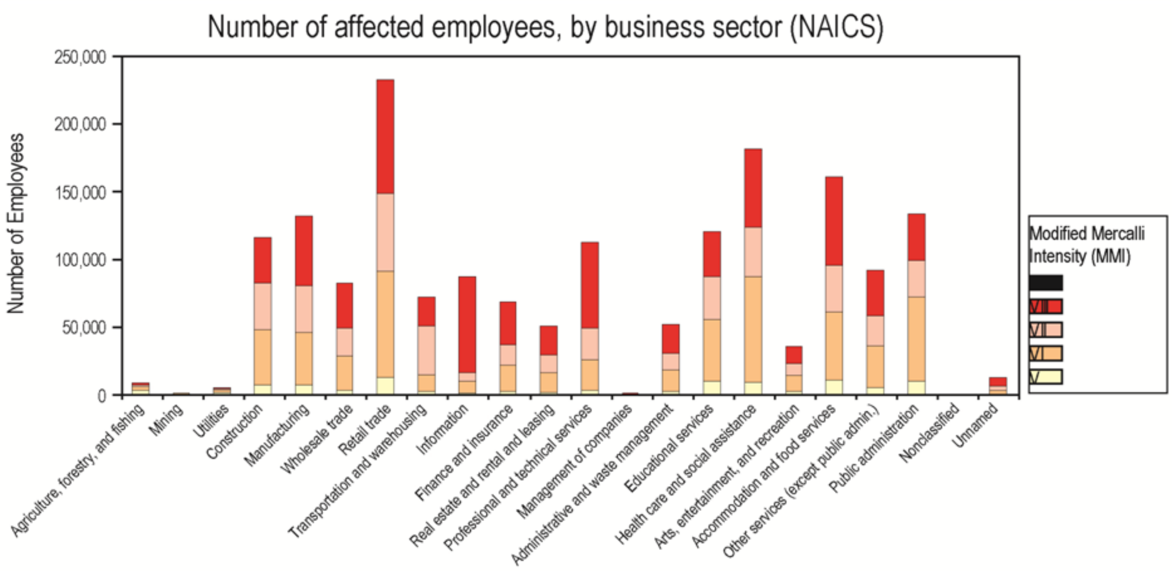


Figure 3. Number of residents and employees affected by the M7.2 earthquake projected for the Seattle fault. The Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.

V. Rather Strong (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.
VI. Strong (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.
VII. Very Strong (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.
VIII. Destructive (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.
IX. Violent (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.