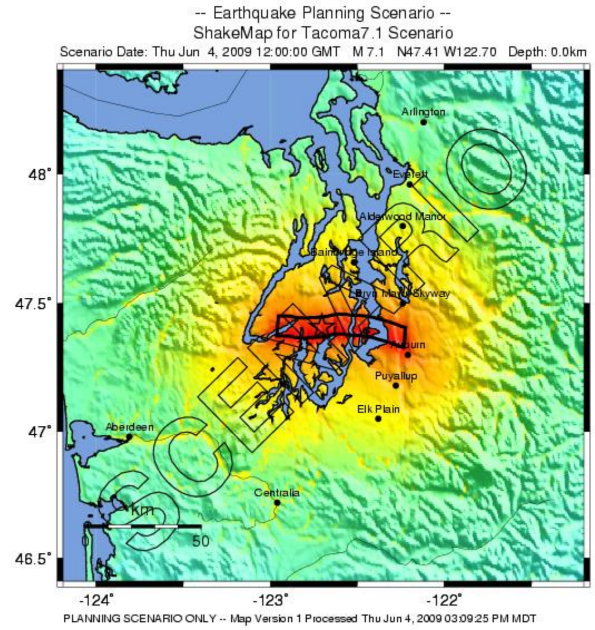
Modeling a Magnitude 7.1 Earthquake on the Tacoma Fault Zone in South-Central Puget Sound

Geologic Description

The M7.1 earthquake scenario for the Tacoma fault zone is based on a 56 kilometer (35 mile)-long rupture of the fault zone between Kent and Union. The source of this event would probably include surface rupture along a large portion of the fault zone, and the region would experience very strong ground motions.

Evidence for the Tacoma fault zone consists of several geophysical lineaments along the southern and western flanks of the Seattle uplift, with as much as 6 to 7 kilometers (~4 miles) of structural relief estimated on top of Eocene basalts. The fault may merge with the White River fault zone at Enumclaw and continue eastward through the Cascade Range, eventually merging with structures in the Yakima fold and thrust belt.

Geologic evidence for past activity of the Tacoma fault includes raised tidal-flat deposits and shorelines along Hood Canal, Case Inlet, and Carr Inlet. Radiocarbon ages of peat and delicate plant fossils suggest that freshwater peat began forming over former tide-flat muds between 900 and 1,300 years ago, indicating uplift of the tidal flats in that time period. Lidar surveys along the Tacoma fault zone revealed faults scarps near Belfair and Allyn. These scarps, as high as 4 meters (13 feet) in places, suggest that the Tacoma fault ruptured the ground surface in the recent past. Trenches across the Catfish Lake scarp showed evidence of a late Holocene earthquake that folded glacial deposits and young soils; this is associated with locally uplifted shorelines along Case Inlet and Hood Canal, which were raised as much as 4 meters (13 feet) in the late Holocene between 1,240 and 850 years ago. Additional trenches across two other scarps, both situated in the upthrown block of the Tacoma fault zone, show evidence of right-lateral



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 M7.1 earthquake on the Tacoma fault zone. The black polygon is the modeled fault rupture surface.

oblique and normal faulting between 600 and 1,300 years ago. All of these ages are consistent with a large regional earthquake on the Tacoma fault zone between 1,240 and 850 years ago.

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 earthquake, 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.

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- 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 magnitude 7.1 scenario earthquake modeled for the Tacoma fault zone is a shallow or crustal earthquake. Shallow earthquakes 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 M7.1 shallow earthquake like the one in this scenario would likely be followed by many aftershocks, a few of which could be large enough to cause additional damage.

Other Earthquake Effects

Tsunamis: Some earthquakes, such as the one in this scenario, may rupture a fault at the surface of the ground. If this earthquake 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 the Tacoma scenario, the liquefaction susceptibility of the land on either side of the Puyallup and Green rivers and their valleys 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.

Be prepared wherever you are: **Develop a plan and a disaster supply kit. When you're prepared, you feel more in control and better able to keep yourself and your family safe.**

Learn more about what you can do: **www.emd.wa.gov**

Photo: FEMA/Keven Galvin

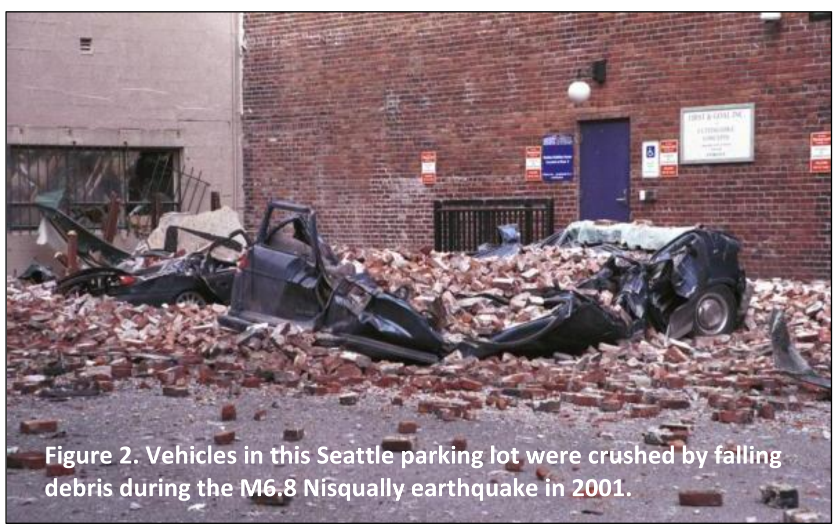


Figure 2. Vehicles in this Seattle parking lot were crushed by falling debris during the M6.8 Nisqually earthquake in 2001.

Hazus Results for the Tacoma 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 M7.1 earthquake on the Tacoma fault. Such an event is expected to impact sixteen counties in Washington, with the most significant effects apparent in King, Pierce, 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 injuries (as many as 5,151), followed by Pierce and Kitsap counties; many of these injuries will be serious enough to require hospitalization and some may be life-threatening if not treated promptly. Numerous fatalities are also likely, the highest number being in King and Pierce counties (over 300 at 2:00 PM).

Damage: The earthquake will damage thousands of buildings in all of the affected counties. The highest numbers are in King, Kitsap, Mason, Pierce, and Thurston counties. King and Pierce counties account for the largest part of the total (184,893 and 70,319 respectively). In many cases, damage will be slight to moderate, but the number of buildings likely to suffer extensive damage is very high (nearly 10,000 in King County alone). Thousands of buildings are expected to collapse or to be in imminent danger of collapse. Most of these are in King County, but Pierce, Kitsap, and Mason counties account for more than 1,500. The majority of damaged structures will be residential, commercial, or industrial, but the totals include buildings of all types and occupancy classes. Unreinforced masonry and non-ductile concrete 'tilt up' buildings are likely to experience partial to full 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 Pierce counties account for the largest portion of the capital stock loss estimate (well over $7 billion).

Income losses, including wage losses and loss of rental income due to damaged buildings, are also highest in King County (over $1.4 billion) and Pierce County (about $276 million).

Impact on Households and Schools: The number of people without power or water is highest in King, Pierce, and Kitsap counties. These three counties also account for most of the displaced households and individuals in need of shelter. The earthquake will most affect the functionality of schools in Mason, King, Kitsap, and Pierce 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 (over 2.6 million tons).

Estimates vs. Actual Damage: Although this M7.1 earthquake scenario was modeled using the best scientific information available, it represents a simplified version of expected ground motions.

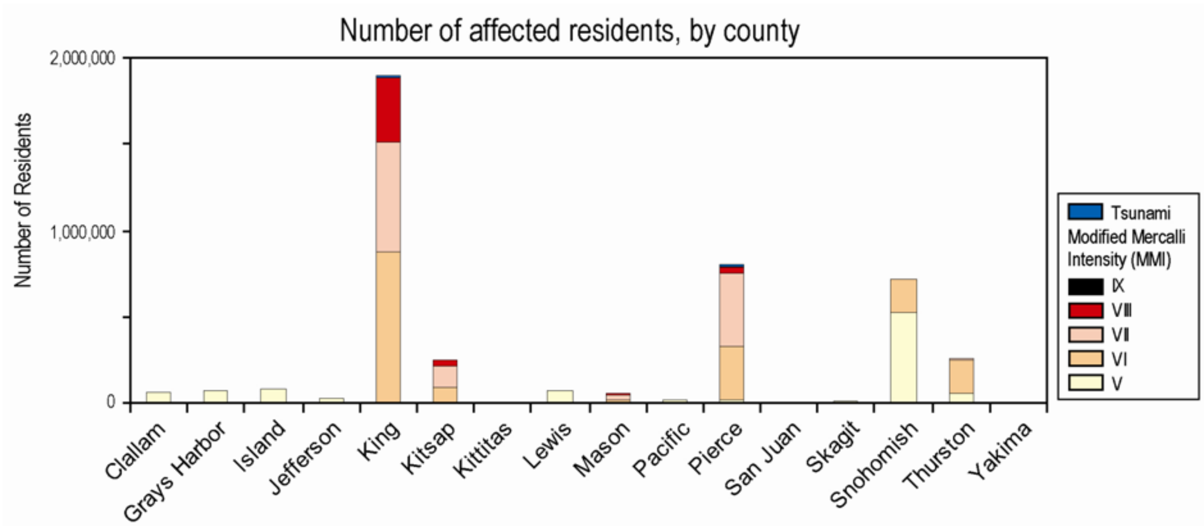
Tacoma Fault Scenario Earthquake	
End-to-end length of fault (kilometers)	68
Magnitude (M) of scenario earthquake	7.1
Number of counties impacted	16
Total injuries (*severity 1, 2, 3, 4) at 2:00 PM	6,070
Total number of buildings extensively damaged	15,410
Total number of buildings completely damaged	4,457
Income losses in millions	$1,847
Displaced households	11,576
People requiring shelter (individuals)	7,146
Capital stock losses in millions	$8,654
Debris total in millions of tons	2.95
Truckloads of debris (25 tons per truckload)	117,960
People without power (Day 1)	87,675
People without potable water (Day 1)	193,544

Table 1. Summary of significant losses in the M7.1 Tacoma fault earthquake scenario. Among the counties most likely to be affected are Grays Harbor, Jefferson, King, Kitsap, Mason, Pierce, 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**

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.



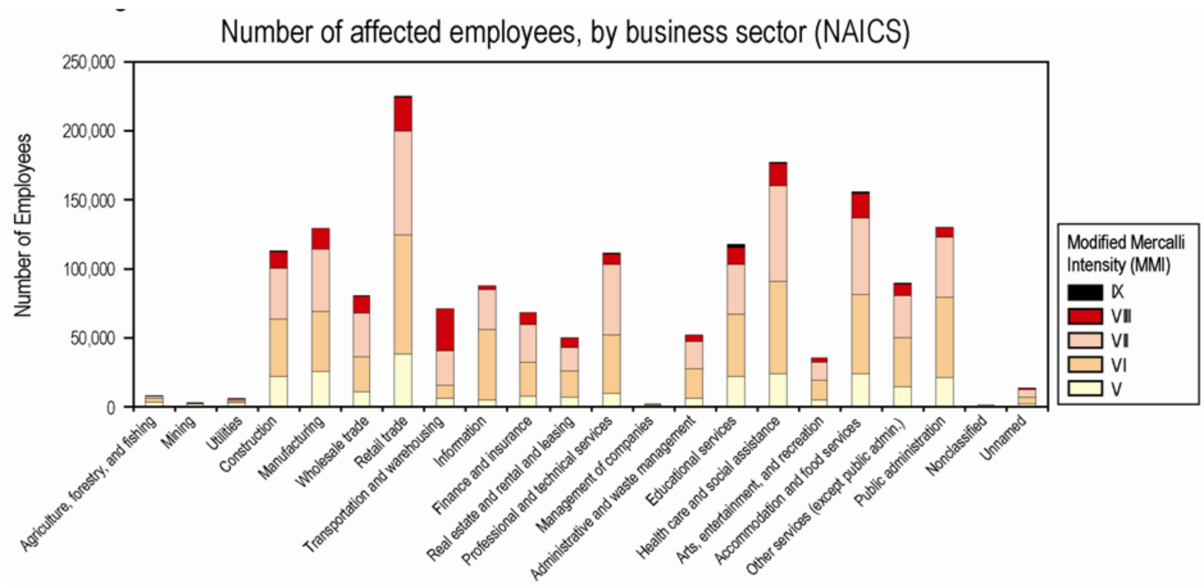


Figure 3. Number of residents and employees affected by the M7.1 earthquake projected for the Tacoma fault. The Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.

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.