

UNDERSTANDING EARTHQUAKE HAZARDS IN WASHINGTON STATE

Modeling a Magnitude 7.1 Earthquake on the Mill Creek Fault Zone in Yakima County

Geologic Description

The M7.1 Mill Creek earthquake scenario is based on a 57 kilometer (35 mile)-long rupture of the fault along the northern flank of Toppenish Ridge. Toppenish Ridge is an anticline in the southern part of the Yakima fold and thrust belt, an east–west-trending set of anticlinal ridges and synclinal valleys with associated thrust faults that deform late Miocene and younger rocks. The Mill Creek fault—mapped as a thrust fault—follows the northern flank of Toppenish Ridge for 65 kilometers (40 miles). A young fault scarp is associated with the Mill Creek fault, and numerous normal faults near the crest of the ridge are associated with bending-moment folding and faulting.

Paleoseismology of natural exposures and trenches show that the Mill Creek thrust along the northern flank of Toppenish Ridge dips between 9° and 15° to the south. Fault scarp excavations exposed a gently dipping thrust fault that places late Miocene volcanic rocks of the Columbia River Basalt Group over late Pleistocene sand and gravels. Ages of soils that are overridden by the Mill Creek fault limit the youngest earthquake to between 7,490 ±70 and 5,690 ±390 C¹⁴ years BP. The USGS Fault and Fold Database lists the Mill Creek fault as having a slip rate of less than 0.2 millimeters/year.

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 earth

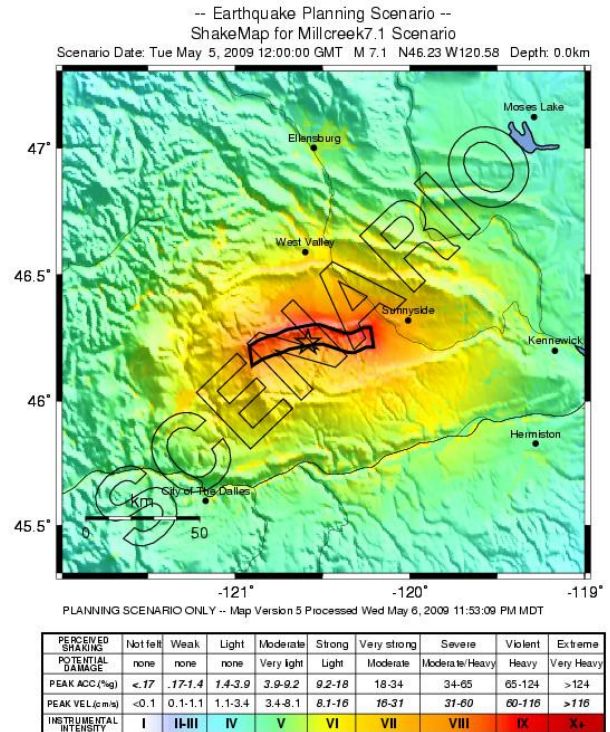


Figure 1. ShakeMap for a M7.1 earthquake on the Mill Creek fault. The black polygon is the modeled fault rupture surface.

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.



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- How close the rupture is to the surface of the ground.

Deep vs. Shallow: The M7.1 scenario earthquake modeled for the Mill Creek fault zone is a shallow or crustal earthquake. Shallow earthquakes tend to be much more damaging than deep quakes of comparable magnitude (such as the deep M6.8 Nisqually earthquake in 2001). This is primarily because in deeper quakes, the seismic waves 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

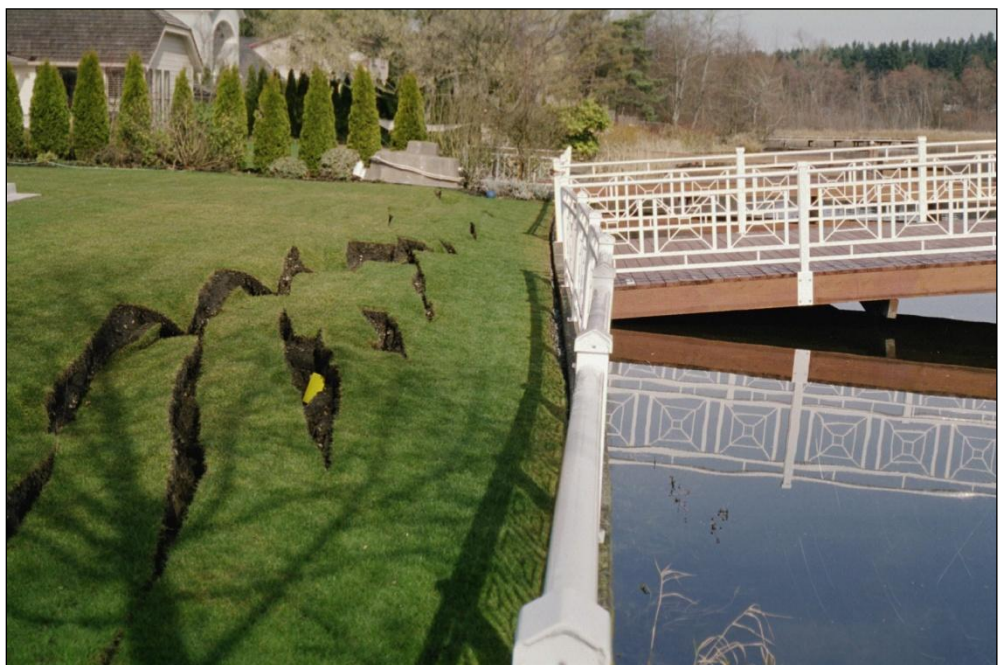
Liquefaction: If sediments (loose soils consisting of silt, sand, or gravel) are water-saturated, strong shaking can disrupt the grain-to-grain contacts, causing the sediment to lose its strength. Increased pressure on the water between the grains can sometimes produce small geyser-like eruptions of 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 Mill Creek scenario, the liquefaction susceptibility of the land on either side of the Yakima 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.

Figure 2. A lateral spread on Long Lake east of Lacey resulting from the 2001 Nisqually quake. It occurred in a manmade fill that is superimposed on peat and lacustrine sediments. (Photo: WADNR/ Bill Lingley)



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Hazus Results for the Mill Creek 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 scenario earthquake on the Mill Creek fault zone in Yakima County. Such an event is expected to impact sixteen counties in Washington, with the most significant effects apparent in Yakima County, followed by Benton and Klickitat counties.

Injuries: The number of people injured in this scenario will be highest in Yakima County. While most of these injuries will not be life-threatening, some more serious injuries and fatalities are expected, especially if the earthquake occurs during the business day. Residents of Benton and Klickitat counties are also likely to experience injuries, but few of these are expected to require hospitalization.

Damage: The earthquake will damage buildings in all of the affected counties. For many, only a few dozen or a few hundred buildings will be affected, and the damage is expected to be slight to moderate. In Yakima County, however, thousands of buildings will suffer damage; the damage to over 1,700 buildings may be extensive. Hundreds of buildings will collapse or be in danger of collapsing. After Yakima, the extent of damage will be greatest in Benton County. Commercial and industrial buildings account for a large part of the total, but damaged residential structures will also be numerous. Unreinforced masonry buildings in particular may experience 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. Yakima County accounts for the largest portion of the capital stock loss estimate (nearly \$314 million), followed by Benton County (over \$23.5 million).

MILL CREEK SCENARIO EARTHQUAKE	
End-to-end length of fault (kilometers)	55
Magnitude (M) of scenario earthquake	7.1
Number of counties impacted	16
Total injuries (*severity 1, 2, 3, 4) at 2:00 PM	191
Total number of buildings extensively damaged	1,678
Total number of buildings completely damaged	297
Income losses in millions	\$102
Displaced households	287
People requiring shelter (individuals)	325
Capital stock losses in millions	\$339
Debris total in millions of tons	0.17
Truckloads of debris (25 tons per truckload)	6,880
People without power (Day 1)	1,135
People without potable water (Day 1)	9,440

Table 1. Summary of significant losses in the M7.1 Mill Creek earthquake scenario. The counties most likely to be affected are Benton, Franklin, Grant, Lewis, Skamania, Yakima, and Klickitat.

***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**

Income losses, including wage losses and loss of rental income due to damaged buildings, are also highest in Yakima County (over \$99 million) and Benton County (about \$3 million).

Impact on Households and Schools: The number of people without power or water will be highest in Yakima County. This county also accounts for most of the displaced households and individuals in need of shelter. Schools in Yakima County will be only 81% functional on Day 1 following the earthquake.

Debris Removal: Following an earthquake, debris consisting of brick, wood, concrete, and steel will have to be removed and disposed of. Much of this will come from Yakima County (169,000 tons) and Benton County (4,000 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. 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.

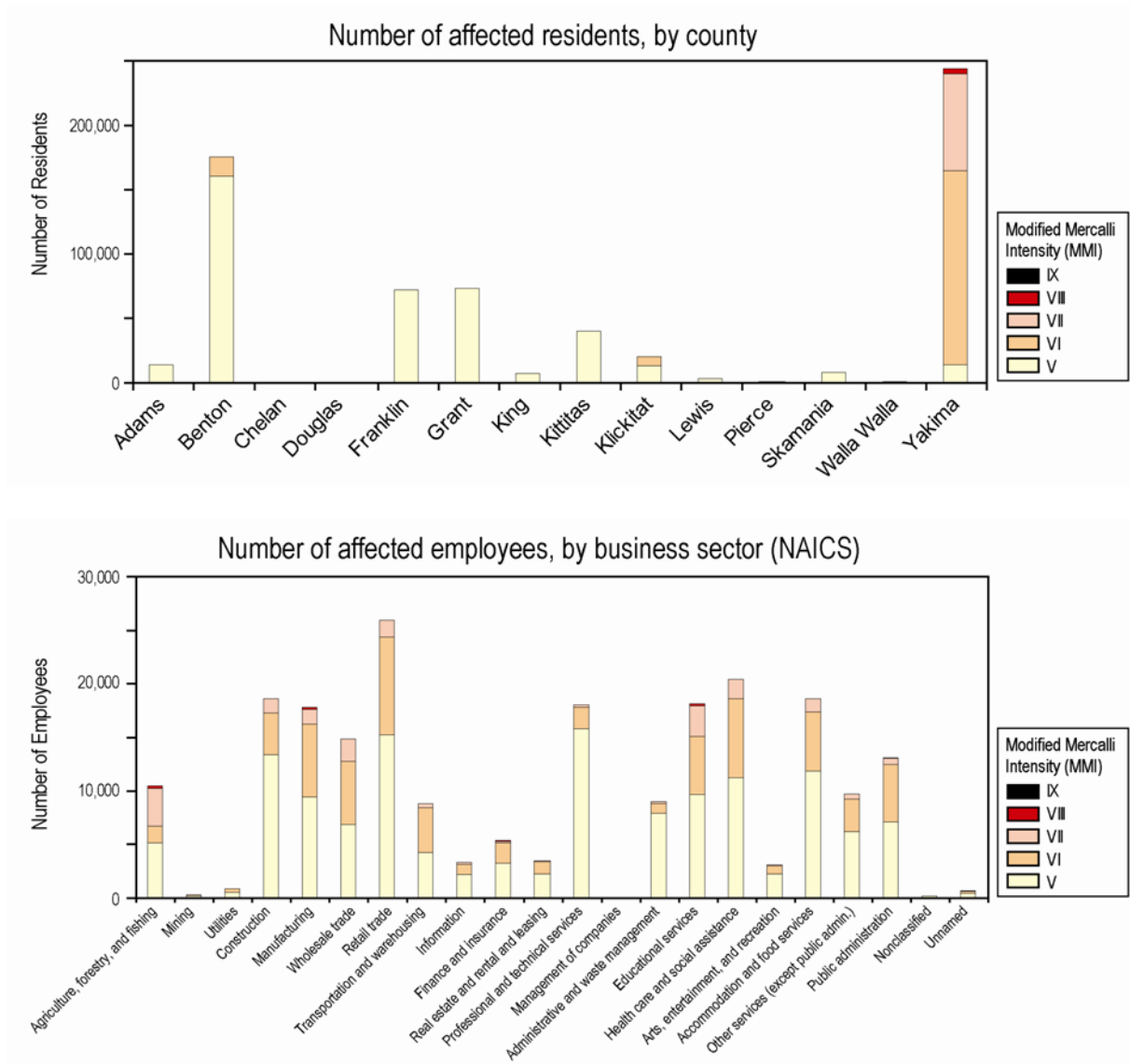


Figure 3. Number of residents and employees affected by the M7.1 earthquake projected for the Mill Creek fault. The Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.

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.