UNDERSTANDING EARTHQUAKE HAZARDS IN WASHINGTON STATE

Modeling a Magnitude 6.8 Earthquake on the Cle Elum Seismic Zone in Southern Kittitas and Northern Yakima Counties

Geologic Description

The Cle Elum scenario is a M6.8 earthquake based on a hypothetical 30 kilometer (19 mile)-long rupture along a set of faults following Manastash Ridge and Cle Elum Ridge. The modeled rupture assumes slip on a fault running along the northern flank of Manastash Ridge just south of Ellensburg, and continuing to the northwest along a concealed thrust fault beneath Cle Elum Ridge. The geologic basis for this rupture is a set of thrust faults along the northern flank of Manastash Ridge. One of the thrusts turns and follows Manastash Creek westward while another turns northward and becomes a right-lateral strike-slip fault beneath the Taneum mono-cline just south of Cle Elum. No paleoseismology or slip-rate data is available for these faults.

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.

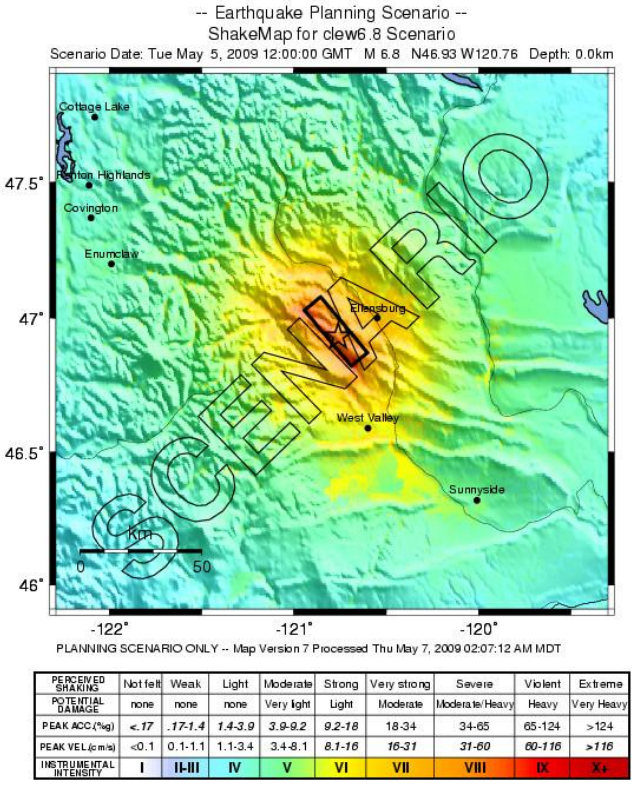

Figure 1. ShakeMap for a M6.8 earthquake on the faults running along Manastash Ridge and Cle Elum Ridge. The black polygon is the modeled fault rupture for this scenario.

Deep vs. Shallow: The M6.8 scenario earthquake modeled for the Cle Elum seismic zone is a shallow or crustal earthquake. Shallow quakes 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 earthquakes, the seismic waves have lost more energy by the time they reach the surface.

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Aftershocks: Unlike deep earthquakes, which usually produce few or no aftershocks strong enough to be felt, a M6.8 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 upward 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 Cle Elum seismic zone scenario, the liquefaction susceptibility of the land on either side of the Yakima River approaching Ellensburg 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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Figure 2. A lateral spread in a yard on Long Lake east of Lacey resulting from the 2001 Nisqually quake. This lateral spread occurred in a manmade fill that is superimposed on peat and lacustrine sediments. (Photo: WADNR/ Bill Lingley)

Hazus Results for the Cle Elum 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 M6.8 scenario earthquake on the Cle Elum seismic zone in Kittitas and Yakima counties. This event is expected to impact ten counties in Washington, with the most significant effects apparent in Yakima and Kittitas counties.

Injuries: The estimated number of people injured in this scenario is low for all counties except Yakima and Kittitas. Although most of the injuries are not expected to be serious enough to require hospitalization, potentially life-threatening injuries are anticipated, particularly in Kittitas County. Several fatalities are also possible, particularly if the event occurs during the evening commute.

Damage: Buildings in all counties will sustain some damage; in most cases, the level of damage is expected to range from slight to moderate. Yakima and Kittitas counties will have the greatest number of damaged buildings. Most of these will be residential, although the damage estimates include many commercial and industrial buildings, especially unreinforced masonry structures. About 550 buildings are likely to be extensively damaged, and at least 74 are projected to collapse or to be in danger of collapse (complete damage). Kittitas County accounts for most of these.

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 (over $106 million), followed by Kittitas County ($94 million) and King County (about $9 million).

Income losses, including wage losses and loss of rental income due to damaged buildings, are also highest in Kittitas County ($23.4 million) and Yakima County (about $22.4 million).

Cle Elum Scenario Earthquake	
End-to-end length of fault (kilometers)	30
Magnitude (M) of scenario earthquake	6.8
Number of counties impacted	10
Total injuries (*severity 1, 2, 3, 4) at 2:00 PM	55
Total number of buildings extensively damaged	550
Total number of buildings completely damaged	75
Income losses in millions	$47
Displaced households	138
People requiring shelter (individuals)	110
Capital stock losses in millions	$215
Debris total in millions of tons	0.07
Truckloads of debris (25 tons per truckload)	2,600
People without power (Day 1)	1,516
People without potable water (Day 1)	1,058

Table 1. Summary of significant losses in the M6.8 Cle Elum earthquake scenario. The counties most likely to be affected are Benton, Chelan, Douglas, Grant, King, Kittitas, and Yakima.

***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**

Impact on Households and Schools: Displaced households occur primarily in Kittitas and Yakima counties—the majority in Kittitas, which also has the highest number of households without power or water following the earthquake. These two counties will have the highest numbers of individuals in need of shelter; and in Kittitas County, the earthquake is expected to affect the functionality of some schools.

Debris Removal: Following an earthquake, debris consisting of brick, wood, concrete, and steel will have to be removed and disposed of. In this scenario Kittitas, Yakima, and King counties will account for most of the debris (30,600 tons or 2,520 truckloads).

Estimates vs. Actual Damage: Although this M6.8 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 possible impacts on different services and business sectors. Note that in King County, a greater number of residents will be exposed to less severe shaking, whereas Yakima and Kittitas counties, although less populated, will experience more intense ground motions.

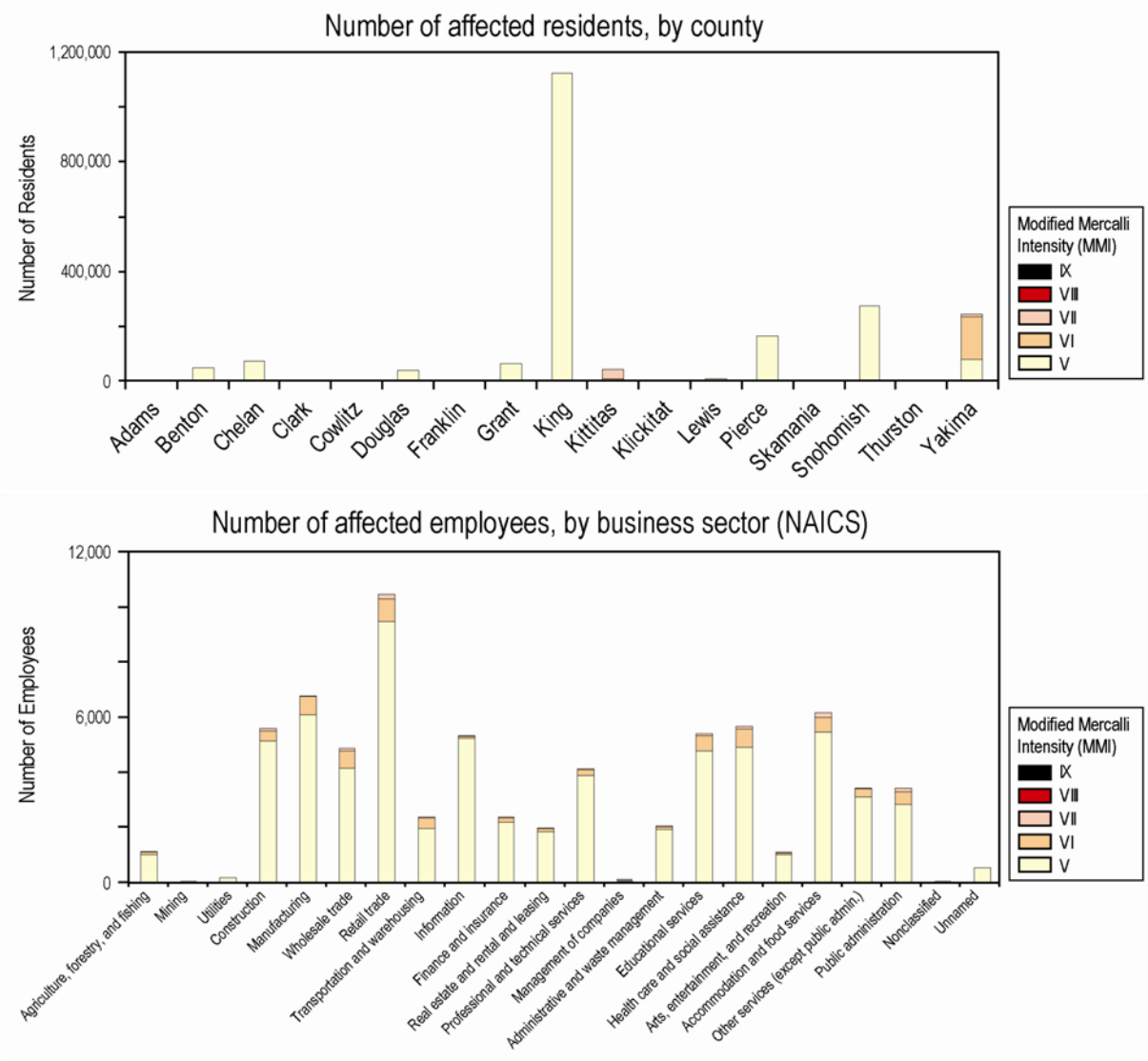

Figure 3. Number of residents and employees affected by the M6.8 quake projected for the Cle Elum seismic zone. Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.

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.