UNDERSTANDING EARTHQUAKE HAZARDS IN WASHINGTON STATE

Modeling a Magnitude 7.2 Earthquake on the Chelan Fault Zone in Douglas County

Geologic Description

The Chelan earthquake scenario is based on a hypothetical fault rupture in the Chelan fault zone near Waterville in Douglas County. The scenario earthquake approximates a large earthquake that occurred in the Chelan region in 1872. The 1872 earthquake is the largest upper plate earthquake to occur historically in the state of Washington. Early workers placed the earthquake anywhere from southern British Columbia to central Washington, but after an analysis of shaking reports following the 1872 earthquake, seismologists concluded that it most likely occurred near Lake Chelan, Washington. They estimated the 1872 earthquake at M6.5 to 7.0. In the seismic event modeled for the Chelan scenario, a north-northeast trending fault experiences a 56 kilometer (35 mile)-long rupture, resulting in a M7.2 earthquake. The modeled rupture area (Fig. 1) incorporates the epicentral region of the 1872 quake and also covers the Chelan fault zone, an area of intense microseismicity near Entiat, Washington. No paleoseismology or slip rate information exists for this modeled fault.

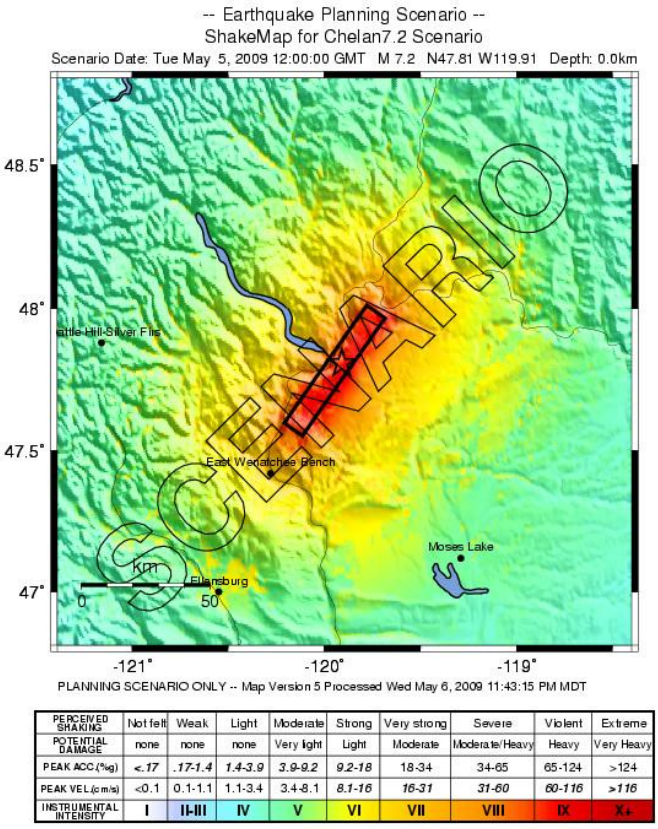

Figure 1. ShakeMap for a M7.2 earthquake on the Chelan seismic zone near Waterville. The black polygon is the modeled fault rupture for this scenario.

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 magnitude 7.2 earthquake modeled for the Chelan scenario is a shallow or crustal earthquake. Shallow earthquakes tend to be

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much more damaging than deep earthquakes 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 a significant number of 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 Chelan scenario, the liquefaction susceptibility of the land alongside the Columbia River near Wenatchee and in the flood plain south of Monument Hill in Grant County 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. The Cathedral of the Blessed Sacrament in Christchurch, New Zealand, damaged by a M6.1 aftershock on February 21, 2011. This quake was part of the aftershock sequence of the M7.0 Darfield earthquake in September 2010.

Photo: NOAA/NGDC, Steve Taylor (Ray White)

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Hazus Results for the Chelan 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 scenario earthquake on the Chelan fault in Douglas County. Such an event is expected to impact nine counties in Washington, with the most significant effects apparent in Chelan, Douglas, and Okanogan counties.

Injuries: For most of the affected counties, the estimated number of people injured in this scenario is moderately low and most injuries will not be severe enough to require hospitalization. People in Chelan and Douglas counties, however, will experience both the greatest number of injuries and the most serious. Depending on what time of day the earthquake occurs, several fatalities are also likely.

Damage: The largest number of damaged buildings will be found in Douglas and Chelan counties. While much of this damage will be slight to moderate, hundreds of buildings will be extensively damaged (the majority in Douglas County). Some cases of extensive and complete damage are also expected in Grant and Okanogan counties. Although the majority of damaged buildings will be residential, commercial and industrial buildings are also expected to account for a large part of the total.

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. Chelan County accounts for the largest portion of the capital stock loss estimate (more than $69.5 million), followed by Douglas County (about $55.4 million) and Grant County (nearly $13 million).

Income losses, including wage losses and loss of rental income due to damaged buildings, are also highest in Douglas County (more than $14 million) and Chelan County (about $11.5 million).

CHELAN FAULT SCENARIO EARTHQUAKE	
End-to-end length of fault (kilometers)	56
Magnitude (M) of scenario earthquake	7.2
Number of counties impacted	9
Total injuries (*severity 1, 2, 3, 4) at 2:00 PM	31
Total number of buildings extensively damaged	375
Total number of buildings completely damaged	11
Income losses in millions	$30
Displaced households	33
Capital stock losses in millions	$151
Debris total in millions of tons	0.05
Truckloads of debris (25 tons per truckload)	1,680
People without power (Day 1)	0
People without potable water (Day 1)	466

Table 1. Summary of significant losses in the M7.2 Chelan fault earthquake scenario. The counties most likely to be affected are Chelan, Douglas, Ferry, Grant, Kittitas, Lincoln, and Okanogan.

***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 Douglas and Chelan counties, most in Douglas. The number of people who will require shelter is also highest for Douglas County. Schools in Douglas County will be only 54% functional on Day 1 after the earthquake; in Chelan County, schools may be 74% functional.

Debris Removal: Following an earthquake, debris consisting of brick, wood, concrete, and steel will have to be removed and disposed of. Douglas and Chelan counties will account for most of the debris (42,000 tons or 1,680 truckloads), followed by Grant, Okanogan, and Kittitas counties.

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 possible impacts on different services and business sectors. Note that in Grant County, a greater number of residents will be exposed to strong shaking, whereas Douglas and Chelan counties, although somewhat less populated, will experience even more intense ground motions.

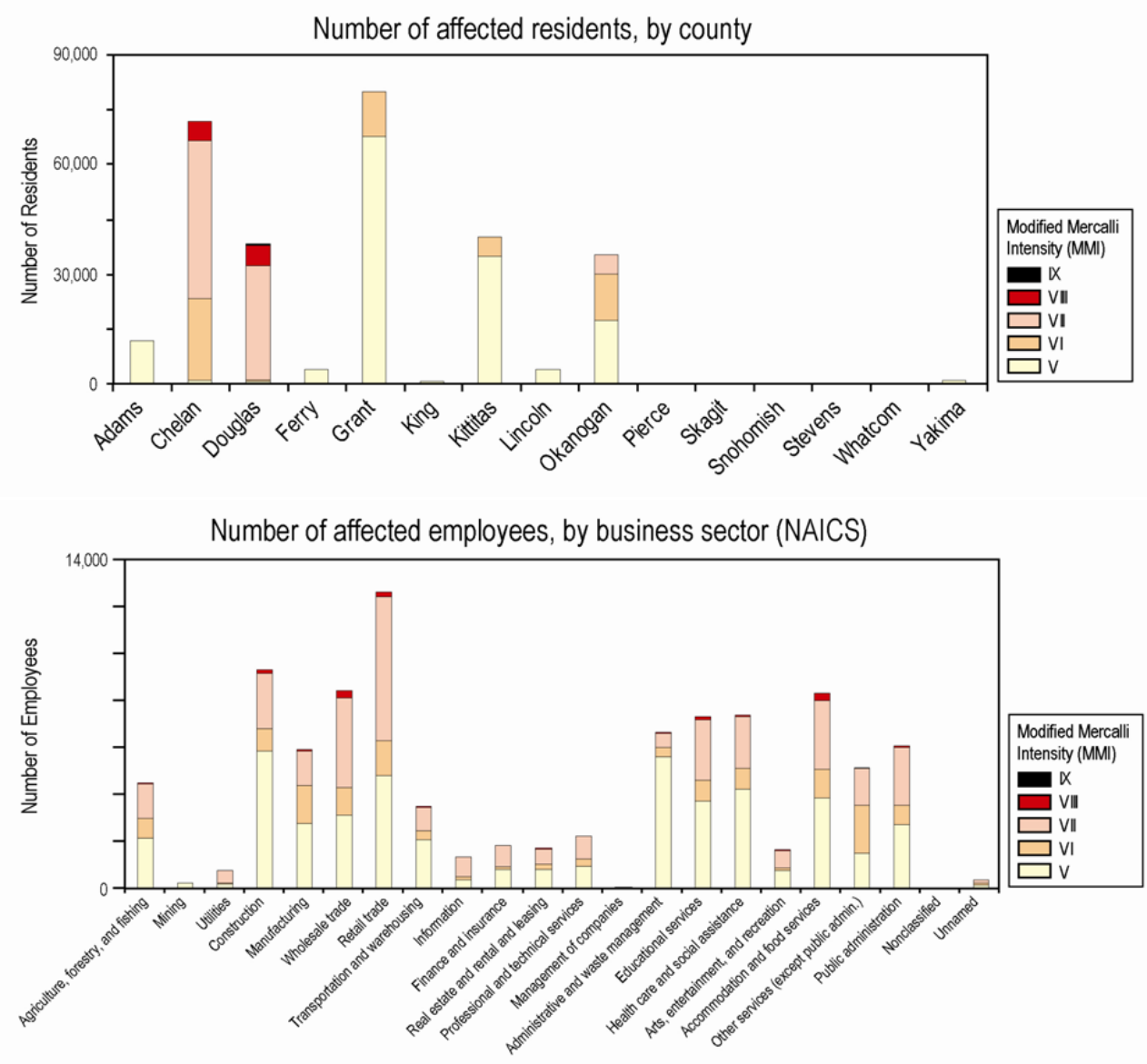

Figure 3. Number of residents and employees affected by the M7.2 earthquake projected for the Chelan fault zone. The Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.

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.