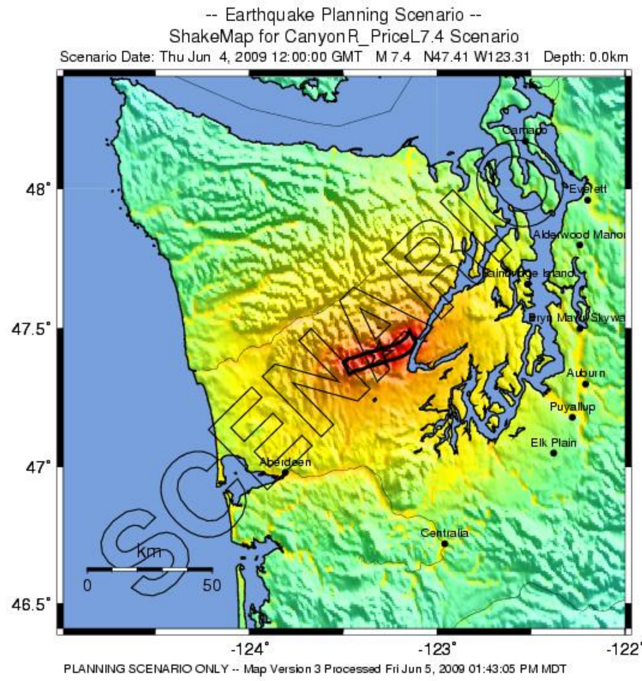
Modeling a Magnitude 7.4 Earthquake on the Canyon River–Saddle Mountain Fault Zone in Mason County

Geologic Description

The M7.4 earthquake scenario modeled for the Canyon River–Saddle Mountain fault zone (CRSM) is based on a 30 kilometer (19 mile)-long rupture of the fault zone between Lake Wynoochee and Lilliwaup. The CRSM fault zone is located along the southeastern flank of the Olympic Mountains. It roughly parallels the contact between the upper and lower members of the Paleocene Crescent Formation (basalt) near Lake Cushman. The fault zone is expressed topographically as three parallel scarps that are traced from Lilliwaup swamp, through the outfall of Price Lake, across the southern end of Lake Cushman, and on to the Canyon River near Lake Wynoochee. A detailed analysis of aeromagnetic data suggests the CRSM is a zone of deformation approximately 45 kilometers (28 miles) long that may accommodate northward shortening of crust beneath the Puget Lowland east of the Olympic Mountains.

Scarps revealed by lidar (light detection and ranging) surveys and recent paleoseismic studies demonstrate that the CRSM fault zone is active and has a recent history of large earthquakes. Trenching studies on the Canyon River fault focused on a 3 meter (10 foot)-high, north-facing scarp. Striae observed on the fault plane exposed by the trench show that past movement was oblique left-lateral-reverse faulting and was predominantly strike-slip. A single late Holocene event about 1,800 years ago had 3.7 to 7.9 meters of slip, suggesting a M6.7 to 7.8 earthquake. Trenching studies on the Saddle Mountain fault near Price Lake suggest multiple surface-rupturing earthquakes on the Saddle Mountain fault zone in the last 17,000 years. Recent trenching suggests two to four Holocene earthquakes (most likely two) on the Saddle Mountain fault zone.



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 M7.4 earthquake on the Canyon River–Saddle Mountain fault zone. The black polygon is the modeled fault rupture surface.

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 M7.4 scenario earthquake modeled for the Canyon River–Saddle Mountain fault 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 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 M7.4 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

Seiches and Local Tsunamis: Large earthquakes such as the one in this scenario may create waves (known as seiches) in enclosed or partially enclosed bodies of water. The effect is similar to water sloshing up the sides of a bathtub. Delta failures and landslides caused by the shaking could also create local 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.

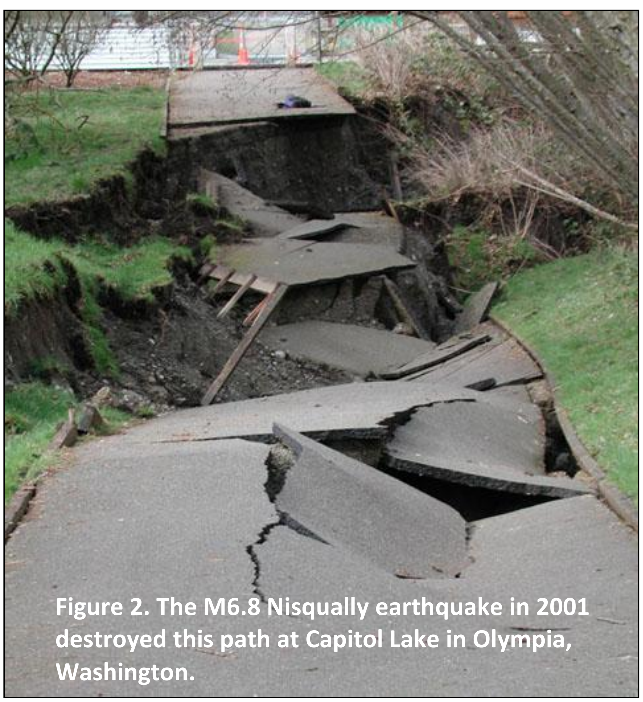

Figure 2. The M6.8 Nisqually earthquake in 2001 destroyed this path at Capitol Lake in Olympia, Washington.

(Photo: Karl Wegmann, Washington State Dept. of Natural Resources)

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 Canyon River–Saddle Mountain scenario, the liquefaction susceptibility of the land on either side of the Skokomish 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 Canyon River–Saddle Mountain Earthquake 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 M7.4 earthquake on the Canyon River–Price Lake fault zone in Mason County. Such an event is expected to impact eight counties, with the most significant effects apparent in Mason, King, Pierce, Kitsap, and Thurston counties.

Injuries: Most of those who are injured will need medical attention but not hospitalization. A few, more serious cases are estimated for Mason, King, Pierce, Kitsap, and Thurston counties. The majority of these injuries will not be life-threatening; however, numerous fatalities are possible.

Damage: More than 37,000 buildings in Mason, King, Kitsap, Pierce, Thurston, Grays Harbor, and Pacific counties are expected to incur damage, although in most cases, the damage will be slight to moderate. Several hundred buildings will be extensively or completely damaged, the majority in Mason County. Most of the damaged structures will be residential, commercial, and industrial.

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 County accounts for the largest portion of the capital stock loss estimate (about $271 million), followed by Pierce (about $119 million), Mason (just under $87 million), and Kitsap (about $85 million).

Income losses, including wage losses and loss of rental income due to damaged buildings, are highest in King County (about $27 million) and Mason County (nearly $15 million).

Impact on Households and Schools: The majority of people without power on Day 1 are in Mason County. Those without potable water are in Mason and Kitsap counties. The highest number of displaced households will be in Kitsap County, followed by King and Mason counties. The estimated number of individuals who will require shelter after the earthquake is also highest in Kitsap County. The earthquake may impact the functionality of some schools on Day 1, particularly in Mason County; but for most counties, this impact is not expected to be significant.

Debris Removal: Following an earthquake, debris consisting of brick, wood, concrete, and steel will have to be removed and disposed of. Most of the estimated number of truckloads will come from King, Mason, and Pierce counties.

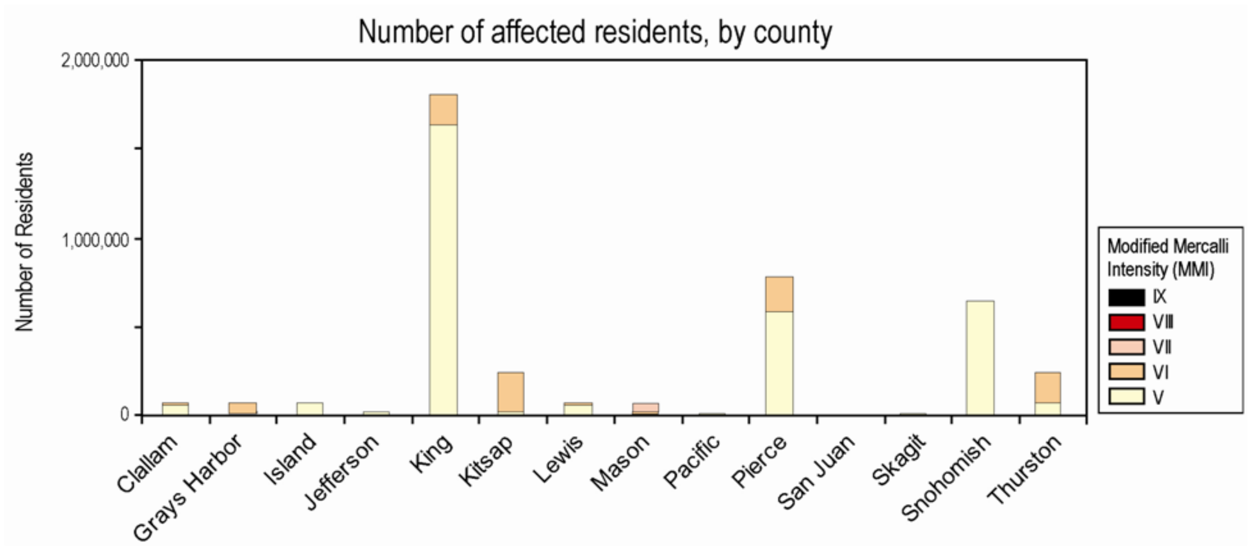
Estimates vs. Actual Damage: Although this M7.4 earthquake scenario was modeled using the best scientific information available, it represents a simplified version of expected ground motions. The damage resulting from an actual earthquake of similar magnitude is likely to be even more variable and will depend on the specific characteristics and environment of each affected structure.

CANYON RIVER–SADDLE MOUNTAIN SCENARIO EARTHQUAKE	
End-to-end length of fault (kilometers)	30
Magnitude (M) of scenario earthquake	7.4
Number of counties impacted	12
Total injuries (*severity 1, 2, 3, 4) at 2:00 PM	117
Total number of buildings extensively damaged	511
Total number of buildings completely damaged	26
Income losses in millions	$79
Capital stock losses in millions	$719
Debris total in millions of tons	0.12
Truckloads of debris (25 tons per truckload)	4,520
People without power (Day 1)	166
People without potable water (Day 1)	1,185

Table 1. Summary of significant losses in the M7.4 Canyon River–Saddle Mountain earthquake scenario. The counties likely to be most affected are Mason, King, Pierce, Grays Harbor, Kitsap, Thurston, and Pacific.

***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**

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 possible impacts on different services and business sectors. Note that even where structural damage to buildings is slight, the shaking may be strong enough to damage furnishings and inventories.



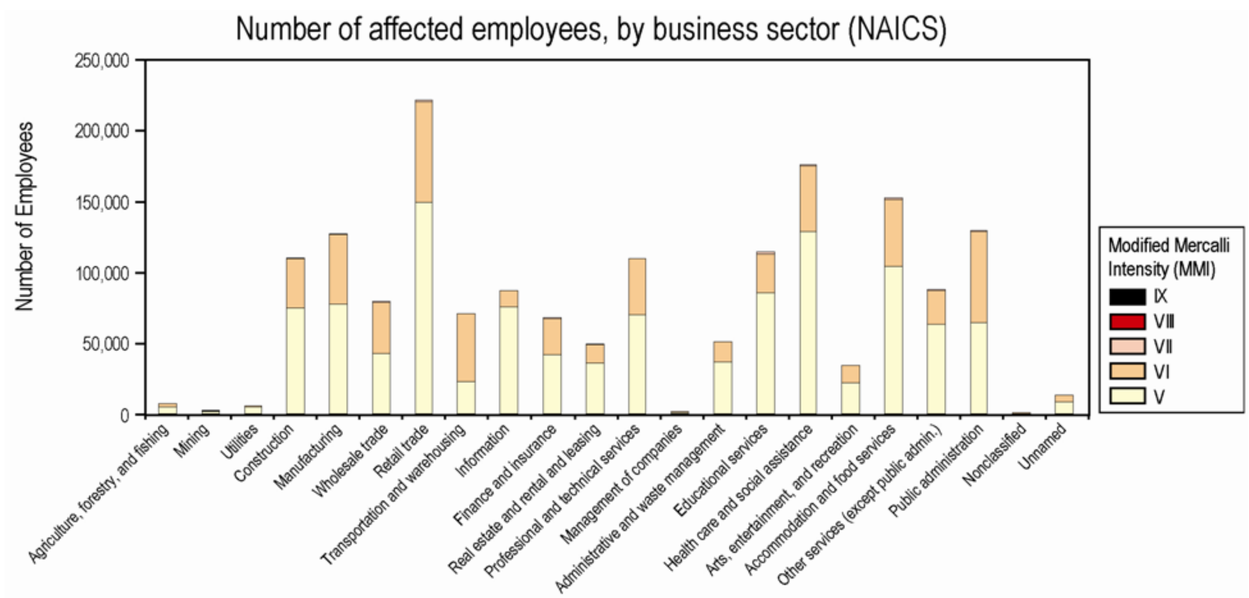


Figure 3. Number of residents and employees affected by the M7.4 quake projected for the Canyon River–Saddle Mountain fault. Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of shaking.

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.