WASHINGTON STATE HAS ONE OF THE HIGHEST EARTHQUAKE RISKS IN THE COUNTRY. PREPARATION BEFORE A MAJOR EARTHQUAKE MAY SAVE YOUR LIFE AND MAY ALSO SAVE YOU MONEY.
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Knowledge of earthquake hazards improves with scientific discovery of active faults and from case studies of seismic events. Updates to building codes accommodate the latest understanding of seismic hazard and advancements in earthquake engineering. The building code used during the construction of your house may no longer be sufficient for currently known earthquake hazards.

Timeline of Seismic Building Code Updates

First building code adopted by Washington State **1975**
Publication of Uniform Building Code with seismic changes **1997**
Publication of International Building Code **2000**
First inclusion of Seattle Fault and Cascadia subduction zone in Washington Building Code **2005**

**2011** Tohoku, Japan earthquake M9.1 and tsunami
**2005** Saddle Mountain fault (eastern Washington) key finding
**2004** Indian Ocean earthquake M9.1 and tsunami
**2001** Nisqually earthquake M6.8
**2001** Tacoma fault key finding
**1996** Southern Whidbey Island fault key finding
**1992** Seattle Fault key finding
**1987** Cascadia subduction zone & tsunami risk key finding
**1965** Puget Sound earthquake M6.5–6.7
**1964** Great Alaska earthquake M9.2 and tsunami
**1960** Great Chilean earthquake M9.5 and tsunami
**1949** Olympia earthquake M6.8–7.0
**1946** Olympia earthquake M5.8
**1945** North Bend earthquake M5.7
**1939** Bremerton earthquake M5.8–6.2
**1936** State Line earthquake M6.1
**1909** San Juan Islands earthquake M6.0
**1896** Salish Sea earthquake M5.7
**1882** Puget Sound earthquake M5.8–6.2
**1872** Entiat/Chelan earthquake M7.0

Timeline of earthquake building code changes (left) compared against significant earthquakes, key fault discoveries, and key publications (right).

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INTENT OF THIS BOOKLET

This booklet provides homeowners with some guidance regarding earthquake hazards as they pertain to the home. It is meant to:

- introduce the types of earthquake hazards in Washington.
- point to maps and resources to assess the risks an earthquake may pose to your home.
- demonstrate that the structural and nonstructural components of your home can be fortified to withstand earthquake hazards.
- suggest ways to better prepare yourself, your family, and your property for an earthquake.

LIMITATIONS OF THIS BOOKLET

This booklet focuses on one- or two-family homes. Structures larger than two-family homes or taller than three stories are larger, heavier, more complex, and more vulnerable than single-family homes.

A professional engineer, licensed contractor, architect, and (or) local building official/permitting department can provide guidance on retrofits.

Preparation is your greatest defense against earthquake hazards and damage. Though seismic retrofits address the main causes of collapse and life safety in a home, they do not ensure that a home will be undamaged. Damage to the interior of a home in a major earthquake may still occur, even with proper seismic retrofitting.
**Consider Purchasing Earthquake Insurance**

Check if your homeowner’s insurance policy covers damage from earthquakes. If not, it might be worth the additional cost of an earthquake and (or) flood insurance policy. More information at: insurance.wa.gov/earthquake-insurance

**Consider Hiring a Professional**

While some people can do some seismic retrofits on their own, it may be preferable to hire a professional with experience. You may also want to contact a licensed geotechnical engineer and (or) engineering geologist to assess the potential for landslides, liquefaction, or earthquake ground shaking to affect your property.

The following resources may help in your decision to hire professionals to assess your property’s seismic risk and the best methods to address that risk.

- Washington State Department of Labor & Industries
  lni.wa.gov/licensing-permits/contractors/hiring-a-contractor
- Washington State Department of Licensing
  dol.wa.gov/business/professionals.html
- Seattle Department of Construction & Inspections
  seattle.gov/documents/Departments/SDCI/Forms/
  EarthquakeHomeRetrofitPlanset.pdf
- Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings
  fema.gov/media-library/assets/documents/92229
- Homebuilder’s Guide to Earthquake-Resistant Design and Construction
  fema.gov/media-library/assets/documents/6015
- Reducing the Risks of Nonstructural Earthquake Damage
  fema.gov/media-library/assets/documents/21405
Why Earthquakes Happen in Washington

Just off the Washington coast is the Cascadia subduction zone (CSZ), a major tectonic plate boundary where oceanic crust is pulled beneath the North American continent. Subduction involves friction between tectonic plates. Right now, the CSZ is stuck, building up stress until the next big earthquake happens and releases it. As the subducting oceanic plate descends, it also bends and tears, which generates deep earthquakes like the 2001 Nisqually earthquake.

Near the surface of Washington State, shallow earthquakes occur along faults in the crust such as the Seattle and Entiat faults.

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Once an earthquake occurs, damage to a home depends on factors such as: the earthquake magnitude, its distance from your home, the rock/soil beneath your home, and your home’s structural and nonstructural characteristics.
The map to the right shows the maximum shaking intensity that has a significant chance of happening in the next 50 years.

- **tsunami hazard area**
- **potentially active fault**
- **damaging earthquake since 1871**

The shaking intensity scale ranges from higher to lower.
**Ground Shaking**

The closer you are to the fault along which an earthquake occurs, the more intense the shaking may be. Most of the known active faults in Washington lie close to population centers.

Ground shaking intensity depends partly on rock/soil type. Soft materials and loose soils common near bodies of water and formerly glaciated areas (for example, the Puget Sound region) amplify the shaking, whereas hard rocks shake less severely.
**Liquefaction**

When ground shaking occurs in water-saturated sediment, the sediment can behave like a liquid (much like quicksand) which could cause damage to your home.

**Landslides and Ground Failures**

Ground shaking can also cause landslides and ground ruptures. Homes built on slopes or bluffs are at risk for earthquake-induced landslides. This is especially true if soils are saturated from rain.

Other ground failures can occur on gentle slopes due to soil liquefaction. Even small ground movements can disrupt utilities or make your home uninhabitable.
Find out what type of material sits beneath your home and its liquefaction potential. Check the Geologic Information Portal for maps showing liquefaction potential: [https://geologyportal.dnr.wa.gov/#natural_hazards](https://geologyportal.dnr.wa.gov/#natural_hazards)

Artificial fill, beach sand, dunes, river deposits, and relatively young sediment are especially susceptible to liquefaction.

**Tsunamis**

Following a large earthquake, areas along the outer coast, the lower Columbia River, and Puget Sound are at risk for tsunamis. Local earthquakes can produce tsunamis within a short period of time. A distant earthquake will not produce ground shaking but may produce a tsunami. If you feel the ground shake, drop, cover, and hold on. If you are near the water, evacuate to higher ground or inland immediately once the shaking stops.
WHAT COULD MAKE YOUR HOME UNSAFE DURING AN EARTHQUAKE?

- Steep hillside
- Soft story
- House not anchored to foundation
- Unreinforced masonry
- Unsecured water heater
- Unsecured chimney
- Masonry foundation
- Falling hazards inside house
- Steep hillside
- Damaged utility connections

SEISMIC IMPROVEMENTS BEFORE AN EARTHQUAKE ARE MUCH CHEAPER THAN REPAIRS AFTER AN EARTHQUAKE. THIS IS THE BEST PROTECTION YOU CAN PROVIDE FOR YOUR HOME.
Unreinforced construction will not fare well during an earthquake, possibly causing flooding, fire, or structural damage.

Seismic improvements before an earthquake are much cheaper than repairs after an earthquake. This is the best protection you can provide for your home.

Home Siting and Construction

Unsecured water heater and unbraced posts can lead to falling hazards inside the house.

Propane tank and utility connections can be unsecured, posing a risk during an earthquake.

Falling hazards inside the house, such as unanchored deck and pier & post, can lead to structural damage.

Rigid gas line and unreinforced masonry foundation can contribute to structural instability.

Unsecured pier & post, parapet, exterior deck not anchored to house, and unbraced posts can lead to additional hazards.

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**Water Heaters**

**Weakness:**
Your free-standing and unsecured water heater is one of the most unstable appliances in your home. During ground shaking it is apt to topple, causing broken gas and water lines, flooding, and (or) fire.

**Reinforcement:**
Ensure your water heater stays put with a water-heater bracing kit, available at your local hardware store. Or build your own. **Make sure all family members know how to turn gas and water off** in the event of a leak. A heater that remains upright can be a potable water source should utilities be interrupted.

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If you build your own:
- **Heavy-gauge metal strap wrapped around tank 1.5 times (do not use plumber’s tape).**
- **Braces or mounts must be anchored to wall stud with long lag screws.**
- Consider **zip-tying an appropriately sized wrench for emergency gas leaks.**
- **Flexible gas and water line connectors and piping.**
- **Place braces around top and bottom of tank, not in the middle.**
**Propane Tanks Weakness:**

During an earthquake, unsecured propane tanks with rigid supply lines may tip over and break their connections, causing fire. You might want to purchase and install an automatic gas shut-off valve.

**Reinforcement:**

Keep your propane tank stable and connected by: 1 using flexible gas supply lines, 2 placing the tank on a concrete slab, 3 bolting the tank footings to the slab, 4 ensuring large objects nearby will not fall on the tank, and for large tanks, you may consider 5 installing bollards around the tank for further stability. If you don’t own your tank, consult your tank provider.

- Four bollards around tank:
  - steel pipe filled with concrete extending above center line of tank
- Center line of tank
- Concrete slab
- Expansion bolts
- Flexible gas line
- Rigid gas line
**Wood Stoves**

**Weakness:**
Another cause of fire after earthquakes are free-standing wood stoves that are not anchored to the ground.

**Reinforcement:**
There are several inexpensive ways to make your wood stove more secure:

1. Secure straps to the flue using a radiation shield and affix to wood wall stud with lag bolt,

2. Attach flue sections, making sure not to penetrate the inner wall of the pipe, and either

3. Bolt legs of stove through an added brick that is grouted to the floor,

OR

4. Anchor the legs using grout placed in a pocket in brick.
**Tall and Heavy Equipment**

**Weakness:**
Unsecured tall, heavy equipment such as compressed gas cylinders may topple or become projectiles during an earthquake. These can also be punctured causing explosions and fires.

**Reinforcement:**
To secure one gas cylinder, use steel eye screws, connectors, and chain to hold the cylinder against a wall, making sure to connect to a wall stud. This type of fastening is insufficient to secure two or more cylinders. Instead, use a prefabricated gas cylinder rack that will hold several cylinders and ensure that it is bolted to the floor and wall, if possible.
**Small Items: Furniture and Valuables**

**Weakness:**
Damage or injury from unsecured belongings, especially those that may fall from inside cabinets/shelves.

**Reinforcement:**
Many items in the home can be secured to prevent toppling during an earthquake, which may block exits or cause injury. Securing these items also prevents them from breaking and needing to be replaced. The following methods are possible solutions using materials that can be obtained at your local hardware store.

**Televisions**
- Sheet metal screws attached to braced wall studs

**Computers**
- Nylon straps and buckles

**Small Objects**
- Earthquake putty

(Also works on refrigerators)
**CABINETS & DRAWERS**

- Child-proof latches
- Closed hook
- Earthquake putty
- Wire
- Eyebolt attached to wall stud

**WALL HANGINGS**

- Child-proof latches
- Rubber mats on shelves

**CABINETS & DRAWERS (also works on refrigerators)**

- Small objects
- Computers
- Nylon straps and buckles
- Sheet metal screws attached to braced wall studs

**BOOKCASES**

- Velcro
- Angle brackets

**Hazardous Objects**

- Rubber mats on shelves
- Child-proof latches
- Wire
- Eyebolt attached to wall stud
FOUNDATIONS

Foundations are the critical connection between your living space and the ground, and during an earthquake the type of foundation may determine if your home remains standing. For this reason, it’s important to know exactly what kind of foundation you have beneath your home and what condition it is in.

CONCRETE SLABS AND BASEMENTS

Slab foundations and basements usually consist of a masonry or concrete structure upon which the house is directly placed. As long as the slab is in good condition (no cracks or sagging) and the house is adequately bolted or strapped to the slab, houses with these types of foundations generally perform well during earthquakes.

UNREINFORCED MASONRY

Foundations built from bricks, concrete blocks, or mortared stone often fail during earthquakes. Have a licensed engineer check to see if your masonry has been reinforced. Options for reinforcement include strengthening or replacing with a concrete foundation.
Post & Pier

Though not common, post and pier foundations are extremely vulnerable to collapse during earthquakes if not properly braced. Contact a professional engineer to evaluate your home if you have this type of foundation. Some homes may be made safer by bracing the posts and using pier bolts, but you may be better served by adding a brand new foundation.

Caissons

This type of foundation involves all or part of a house elevated above concrete piers embedded in the ground. If the piers reach bedrock, they pose little hazard. But if the piers rest in unconsolidated material, earthquake movement may seriously compromise the structure of the home.

Contact a professional engineer to evaluate your home if you have this type of foundation. Some homes may be made safer by bracing the posts.

Soft Stories

Soft stories are floors in a multi-story building that are largely unsupported by shear walls that prevent horizontal shaking. Garages, large bay windows, and wide doors are all good examples of this type of structural weakness. Houses with soft stories are vulnerable to collapse.

Soft stories may be made more rigid by structural reinforcement. Contact a professional engineer to evaluate the best retrofit method for your home’s design and your budget.

more foundations on the next page

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**Weakness:**
These foundations consist of short walls made of poured concrete on which the wood frame of the house rests. The only weakness of concern with these types of foundations is that the wood frame of the house must be bolted or anchored to the stem walls. Otherwise, during an earthquake, the house could shake right off its foundation. Many older houses are not bolted to their foundations.

**Reinforcement:**
The good news is that a handy homeowner could retrofit this type of foundation on their own, and it’s MUCH cheaper to have the stem wall anchored to the house than to have to replace the foundation after an earthquake moves it. It’s possible to do these retrofits yourself, but a professional engineer and (or) contractor can navigate other issues inherent in older construction.
Weakness:
Cripple walls are vertical wood frames that rest on the stem wall and lie beneath the floor of the house. These exterior foundations support the weight of the house. Without proper reinforcement, however, these walls buckle or collapse during horizontal shaking during earthquakes. Older houses may not have the required shear walls installed to protect against collapse.

Reinforcement:
Reinforcing cripple walls involves installing plywood or Oriented Strand Board (OSB) shear walls. Reinforcement is likely too advanced for most homeowners. A professional engineer and (or) contractor with experience doing this type of work is recommended.
**Chimneys**

**Weakness:** Unreinforced masonry chimneys may crumble or topple during an earthquake, posing a hazard to roofs, people, and nearby vehicles. These chimneys tend to break at the roofline or peel away from the house, and the likelihood of breakage increases with chimney height. Check the grout between the brick or stones by picking at it with a knife. It should not crumble.

**Reinforcement:**
- Replace masonry chimneys above the roofline with lighter metal flues that may be veneered to match the lower brickwork.
- Add plywood above the ceiling joists in the attic or layer additional plywood directly beneath the roof shingles near the chimney to prevent any collapsing brickwork from damaging the interior of the home.
- Reinforce the masonry with additional anchorage at each floor, roof, and ceiling to meet design standards.

**Parapets**

**Weakness:** Parapets are low walls along the edges of roofs or balconies. Older unreinforced masonry designs are typically unbraced—during an earthquake they can fall apart, damaging the house and possibly causing injury.

**Reinforcement:** The materials used to construct the parapet determine the method used to brace them. Contact a professional engineer to evaluate your parapet.
Steep hillsides either uphill or downhill from your home may fail during an earthquake.

Retaining walls, groundwater control, or regrading can provide extra stability to soil and control excess water flow.

See our homeowner’s guide to landslides for more on slope stability. There are also numerous types of retaining walls (a few are shown below). Contact a professional engineer to design retaining walls to fit your slope and your budget.
WHAT TO DO

BEFORE AN EARTHQUAKE

Prepare emergency kits for your home, automobile, and work

- Two-week kit
- Three-day kits

home  car  work

DURING AN EARTHQUAKE

DROP TO THE FLOOR, AWAY FROM OBJECTS THAT MAY TOPPLE

COVER! TAKE COVER BENEATH LARGE, STURDY FURNITURE

HOLD ON UNTIL THE SHAKING SUBSIDES

There are instructions for what to do during an earthquake for persons with limited mobility: shakeout.org/graphics/index.html#dcho

If you are outside during an earthquake, move out into the open and avoid anything that might fall on you, including buildings, chimneys, trees, light posts, and power lines.

AFTER THE SHAKING SUBSIDES

- If you are near water, grab your go bag and move to high ground or inland immediately!
- Check yourself and others for injuries, and apply basic first-aid if needed
- Move away from unsafe areas
- Follow your family/business/agency/organization emergency plan/instructions
- Expect aftershocks

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WHAT SHOULD I HAVE IN MY EMERGENCY KIT?

You should prepare an emergency kit with a two-week supply of necessary items for each member of your family, including pets. The kit should be adapted to your needs. Have a go-bag ready for immediate evacuation. Develop a plan with your family and practice it. Possible supplies include:

- Non-perishable food and cooking and eating utensils, including can opener
- Water and a water purification kit
- First-aid kit, medication, and glasses
- Important documents
- Cash, cell phone, and portable chargers
- Plastic bags for storage & waste
- Maps showing safe routes to high ground
- Baby supplies and diapers
- Pet food and supplies
- Clothes and shoes
- Sleeping bag & tent
- Radio, headlamp/flashlight, and batteries
- Pocket knife
- Whistle
- Gloves
- Soap
WASHINGTON GEOLOGICAL SURVEY
Earthquakes and Faults
http://www.dnr.wa.gov/earthquake

The geology beneath your home:
Geologic Information Portal
https://www.dnr.wa.gov/geologyportal

INSTITUTE FOR BUSINESS & HOME SAFETY
A Homeowner’s Guide to Earthquake Retrofit

CENTERS FOR DISEASE CONTROL & PREVENTION
Earthquakes
https://www.cdc.gov/disasters/earthquakes/

FEDERAL EMERGENCY MANAGEMENT AGENCY
Earthquake Safety at Home
https://www.fema.gov/earthquake-safety-home

READY.GOV
Earthquakes
https://www.ready.gov/earthquakes

WHO CAN I CONTACT FOR MORE INFORMATION?

WASHINGTON GEOLOGICAL SURVEY
360.902.1450
www.dnr.wa.gov/geology

WASHINGTON MILITARY DEPARTMENT
1.800.562.6108
http://www.mil.wa.gov/earthquake