Seismic Risks and Hazards for Fairfield and Victoria on Southern Vancouver Island

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Earthquakes don't kill people, buildings do!

We live in Canada's most active urbanized seismic zone in a region geologists refer to as Cascadia. The Cascadia subduction zone runs from the Brooks Peninsula of Northern Vancouver Island to Cape Mendocino ~700 km south in Northern California. Last year within the Canadian portion of this 300 km by 200 km region, there were about 300 earthquakes, or about one per day. Most of these were below a Richter magnitude of 1 and unfelt. So can we rest easy and ignore the whole issue? This is probably not the best course of action.

Here on the west coast we live near convergent and transform plate boundaries that have been responsible for many of Canada's largest earthquakes. Beneath our feet, down to about 45 km depth, the North America plate is moving to the SW. Even deeper than this, the Juan de Fuca Plate is moving to the NE. These two plates are converging at a about 4 cm a year causing stress across the subducting plate margin which builds up until rocks exceed their breaking strength. They break along a fault and jump to a new position. The larger the jump, the bigger the earthquake.

In this setting we experience 3 types of earthquakes.

1. **The so-called "Big-one" is when the entire ~700 subduction zone thrust fault moves about 5-15 meters over the duration of a few seconds. This can generate a megathrust earthquake as big as is possible for anywhere on the planet, namely about a magnitude 9 event wherein the outer coast might drop down a few metres and the shaking could last for several minutes as it did on January 26, 1700.**
2. **The second type of earthquake is due to stresses in the top of the subducting ocean lithosphere and these can be up to about a magnitude 7.5.**

3. The third type occurs between 2 and 30 km depth within the over-riding North America Plate. The magnitude scale is logarithmic and increases by a factor of 31.6 for each digit as from a magnitude 7 to an 8.

All 3 types of earthquakes are of concern but recent studies of crustal deformation monitored by GPS arrays and very low level episodic seismic tremors may provide a means of predicting the most likely times for the next Megathrust event. An Episodic Tremor and Slip (ETS), appears to recur about every 15 months beneath Victoria. Over a 2 week period very low frequency tremors cause a few millimetres of slip back to the west. At these times, the load is being transferred to the locked zone of the Cascadia Megathrust fault between North America and the Juan de Fuca Plates. These periodic loading events are thought to be capable of triggering the big one!

The last of these ETS events was in late May to early June, so the next worrisome ETS loading time is likely to be around August-September 2010. That gives us about a year to earthquake proof our buildings and prepare the necessities of life without hydro, gas, telecommunications, shelter and sustenance.

These 3 kinds of earthquakes are unequal not only in magnitudes, but in their locations and their recurrence intervals. The Megathrust events are centered beneath the West Coast, right along the locked zone between the 2 converging plates. They are as big as it gets anywhere on the planet, but they are relatively far away from Victoria, (think of the drive to Bamfield or Tofino). That distance diminishes the shaking, so that even during a big one, wherein we might experience ~5 minutes of shaking, the effect of that shaking is likely to be less than about 0.2 g or +/- 20% of the gravity or weight you or a building might ordinarily feel. This is like slowly driving over a small speed bump. Megathrust events only occur every several hundred years and it is 309 years and counting since the last big one.

The second type, crustal earthquakes, tend to occur between Sooke and Bellingham and with shallow crustal hypocentres. At less than 30 km deep, these are getting pretty close to home. This means for a magnitude 5 quake like we get every 5 years or so, everybody feels it, but other than a bit of tongue wagging there is relatively little effect or damage. Larger crustal quakes are more infrequent like the 7.3 Vancouver Island Quake of June 23, 1946 centered between Campbell River and Port Alberni or the magnitude 7 quake north of Tofino on December 6, 1918 (Cassidy et. al. 1988). These occur

more often somewhere beneath Vancouver Island and as the historical records attest they can damage buildings, roads and considerably affect infrastructure. These crustal earthquakes are truly the most dangerous because they are the closest and most capable of imparting strong shaking.

The 3rd type of quake occurs in the Juan de Fuca oceanic plate. When these are offshore, it is no big deal to us here, however when it is 45 km directly beneath our feet that is close enough to be in the near field and experience large acceleration. Our poster child earthquake of this type is the 6.8 magnitude, February 28, 2001 Nisqually quake beneath Seattle. Seattle experienced considerable damage but here we only felt a few seconds of shaking as the long period surface waves passed by.

An earthquake is the wave-like motion of the earth in response to the passing seismic waves. This feels rather like bouncing on a trampoline or hitting air pockets while on an aircraft flight. You alternately feel lighter and heavier in response to the changing accelerations or earth motions that move you up and down or back and forth in the earth's gravity field. The things that increase these local motions during a quake are:

1) **to be closer to the hypocentre,**
2) **having a bigger earthquake that lasts longer and moves the earth more and**
3) **being located on thick underlying soft sediments which slows the waves and manages to match their frequency such that each successive wave in the train adds to the amplitude of motion you already experience.**

This is similar to pushing a child on a swing. The motions for a person might be noticeable, alarming or, in extreme cases, make it hard to stand up. This is more of an issue for the aged and infirm in a local rest home than for healthy rambunctious kids on a playground. For buildings and other infrastructure: pipelines, wiring, bridges, steep cliffs and other things that are stable in a static load, the motions and changing accelerations add stresses that can exceed their strength, or that of the underlying slope or soils.

Generally modern wood framed buildings fare well as they have 3-dimensional interlocking and overlapping strength. Unreinforced masonry structures: brick walls, cinderblock strip malls, older chimneys and overhanging concrete balconies fare poorly as does tip up warehouse style construction favoured for large box stores. Even highway bridges and overpasses can shear off their foundations and collapse or fall, if not properly

designed and constructed to resist earthquakes. The key issue is how was the building built and when. Prior to ~1964 there was no building code that pertained to earthquakes.

It was not required that buildings be bolted to their foundations. Modern construction requires earthquake engineering, but older construction practices and municipal inspection standards were less rigorous. Large construction cranes and incomplete buildings are particularly risky sites as they rely on uniform gravity for their tenuous grasp on stability. The massive loss of life in other countries with even moderate 6.0-7.4 quakes is always associated with poor quality and unreinforced stone and brick construction. Contrary to the moral of the familiar children's story, in the case the "Big Bad Wolf Earthquake" the "third little pig" fares the worst!

The best locations are on bedrock or with very shallow bedrock overlain by a thin layer of compacted fill. Damp sand is stronger than either dry or water saturated sand which can liquefy (quicksand). Wet mud is also a weak substrate and peat is horrible. Recall what the intersection of Vancouver and View streets used to be like before its multi million dollar reconstruction.

The sum of these effects means that your foundation strength vary with the underlying geology and that even at one location, your seismic vulnerability changes seasonally as the water table rises and falls. Consequently the summer and fall are safer while winter and spring are weaker for the same substrate. The most vulnerable sites are buildings on slopes or with thick unconsolidated sediments (greater than a few metres). The sediments are especially failure prone during the wet part of the year with high water tables or high pore water saturation, as this makes the sediments heavier and internally lubricated. This is when slumps and landslides naturally occur without added shaking.

When shaking is added, these unstable building sites on unconsolidated and unloaded fill incur the greatest damage. The Marina District in San Francisco suffered the worst in the 1906 quake and it was all built on artificial fill. The most prevalent geohazards in urban areas across B.C., Washington, and Oregon are landslides, and slope failures, given the abundance of steep slopes in unconsolidated and uncompacted sediments, the high rainfall and active seismicity. Fortunately the capital region has few of these kinds of slopes and most are outside of Fairfield. A glance at Monahan and Levson's (2000) geohazards map for Victoria shows that Beacon Hill Park and the dense

housing areas back from the Dallas Road cliffs present higher risk to buildings than the area from Moss Rock Park northwards or from the eastern edge of Ross Bay eastwards into Oak Bay, simply due to the thickness of underlying sediments versus lack thereof. The biggest risk areas are on clays thicker than 3 meters or unconsolidated fill in former foreshore, wetland or marshy areas where the amplification of seismic motion and risk is uniformly high. The height of the building also matters as the period of the waves from the earthquake can match the natural period of buildings, causing them to sway more. This is not just rule of thumb information but the results of how different areas behaved during the Nisqually earthquake as felt reports or measured by strong motion seismometers in the Victoria area (Molnar, 2003, 2004).

So what does this mean in practical terms? Anywhere in the greater Victoria region we might experience an infrequent magnitude 7 earthquake, which may shake things up for 1 minute or so. The top of a 4 storey walk up apartment sited on 6 meters of clayey glacial deposits will tend to sway 5-6 times more than a single storey home build on bedrock. Most of our wood framed buildings irrespective of age will not collapse in a large earthquake. This is not to say all of the walls will be straight and all of the doors will still close!

From the Nisqually earthquake, the Victoria, Fairfield and Saanich areas experienced shaking of VI on the Modified Mercalli Index scale including a few broken windows, shaking houses, jumping fridges and swaying lampposts. For any location around here, it might not be the best place in the world to hang a mirror on the ceiling over your waterbed! Joking aside, older chimneys without liners or exterior strapping to wooden frames might sway and fall, overhanging balconies might shear off, brick or stone facades might shear off or fall, and masonry or rock retaining walls could fail.

According to Molnar (2003, 2004) our high to very high risk areas include the 2 biggest commercial centres of the Fairfield Plaza and the Cook Street Village. While the actual risk varies on a building by building and site by site basis, still this seems a fragile basket within which to hold our services and supplies be it beer or batteries in case of a major local earthquake. Even our roadways are at risk as most are built on fill which can settle or shift due to traffic loads and shallow groundwater motions. This is especially an issue for the stretch of Dallas road below the Ross Bay Cemetery. Water mains, sewer lines, gas mains

and power lines could all break and are prone to do so where they cross or underlie roadways.

For each of these structures there is a practical solution ranging from removal to reinforcement. It is obviously too big of a problem to fix everything all at once. But nonetheless, the longer we wait and the more infrastructure we build or install, the greater the risk and expense will be. Pause to think for a minute how undeveloped Vancouver Island was in 1918 or even 1946 compared to now. How many older, poorly designed buildings are still in use? The damage from the same sized earthquakes would be commensurately greater if they were to recur today. We only need to look at the effects of floods, hurricanes and fires to see the rising costs of insurance. This is not because the apocalypse is approaching but because more and more of what we do is building in harm's way.

Victoria is no different than New Orleans in this regard. What you can do ranges from inspecting and cleaning up your own "back yard" to hiring a contractor and applying some form of earthquake proofing or buying earthquake insurance. Check the net for free downloadable information on provincial and federal websites or even check the Yellow Pages for local companies that specialize in retrofitting buildings. For home and apartment owners, there is the CMHC Residential Guide to Earthquake Resistance. Better to put in some critical thought, consultation, planning and to pay and fix it now rather than pray and clean it up if you are still able and not buried under the rubble! On both a personal scale and a community scale these sorts of potential risks require some preparation and re-thinking of how we do things. The intermittent nature of earthquakes kindly affords us some time to set about making the necessary changes.

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