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FOURTH-GENERATION SEISMIC HAZARD MAPS FOR THE 2005 NATIONAL BUILDING CODE OF CANADA

John ADAMS[1] and Stephen HALCHUK[1]

SUMMARY

The Geological Survey of Canada's new seismic hazard model for Canada will form the basis for the seismic design provisions of the 2005 National Building Code of Canada (NBCC). As such it represents Canada's fourth generation of seismic hazard maps (previous ones were in 1953, 1970, and 1985). The Cornell-McGuire method is used with two complete earthquake source models - historical and regional/geological - to represent the uncertainty in where (and why) earthquakes will happen in the future. Ground motions for a deterministic Cascadia subduction earthquake are computed for southwestern Canada, and probabilistic seismic hazard for the nearly aseismic central part of Canada is assessed based on a global model. A 'robust' method is used to combine the probabilistic hazard estimates (at a probability of 2%/50 years or 0.000404 p.a.) from the four source models: the mapped value is the largest of the values. Products will include seismic hazard maps, tabulated values, uniform hazard spectra (UHS), plots of deaggregated hazard and documentation. For the seismic provisions of the 2005 National Building Code of Canada the median ground motion on firm soil sites for spectral acceleration at periods of 0.2, 0.5, 1.0 and 2.0 seconds and peak acceleration will be used. The four spectral parameters will allow the construction of approximate UHS for each locality, and hence improve earthquake-resistant design.

INTRODUCTION

A national seismic hazard map forms the fundamental basis of the most effective way that we can reduce deaths and economic losses from future earthquakes. To be useful, a national map must estimate hazard fairly across the country, so future protection can be distributed equitably according to the hazard. This clearly requires a good assessment of the earthquakes sources, but it also needs the selection of the probability level for the assessment and a wise choice of earthquake parameters. As the knowledge of, and sophistication in, probabilistic seismic hazard have grown, Canada's national mapping efforts have moved from qualitative assessment in 1953, to probabilistic assessment at 0.01 p.a. using peak horizontal ground acceleration (PGA) in 1970, to probabilistic assessment at 0.0021 p.a. using both PGA and peak horizontal ground velocity (PGV) in 1985, and to the 4th Generation assessment at 0.000404 p.a. using spectral acceleration parameters which will be the basis for the 2005 edition of the National Building Code of Canada (NBCC2005).

In this paper we lay out the new features of the 4th Generation hazard mapping and discuss some of their

[1]Earthquakes Canada, Geological Survey of Canada, 7 Observatory Crescent, Ottawa, K1A 0Y3 Canada. Email: adams@seismo.nrcan.gc.ca

consequences. The new hazard model incorporates a significant increment of earthquake data, recent research on source zones and earthquake occurrence, together with complementary research on strong ground motion relations [1]. Further detailed information on the model's parameters is given by Adams and Halchuk [2], and an overview is provided by Adams and Atkinson [3]. The April 2003 special issue of the Canadian Journal of Civil Engineering also contains 12 papers related to NBCC2005.

METHOD

We apply the same Cornell-McGuire methodology [4] as was adopted by Basham et al. [5,6] for Canada's 3rd generation maps and NBCC1995 [7], but we used a customized version of the FRISK88 hazard code (FRISK88 is a proprietary software product of Risk Engineering Inc.) in order to incorporate uncertainty. The new seismic hazard model for Canada considers two types of uncertainty – aleatory uncertainty due to randomness in process and epistemic uncertainty due to uncertainty in knowledge; the former cannot be reduced by collecting additional information, but the latter can be [3]. The treatment of uncertainty is detailed in Adams and Halchuk [2].

Regionalization of Canada

Of necessity, eastern and western Canada must be treated slightly differently because of the different properties of the crust. Figure 1 shows the earthquakes and the regionalization used and identifies in a

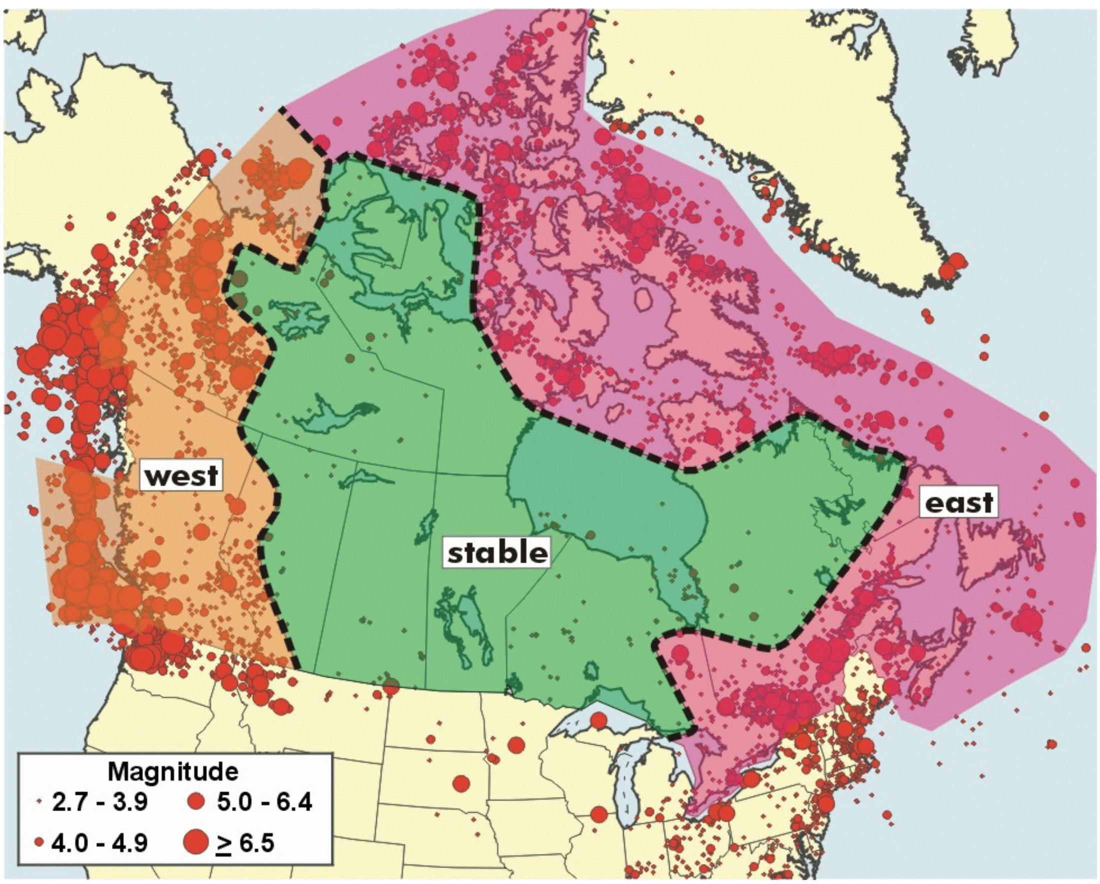


Figure 1. Map of Canada showing the earthquake catalog used for the 4th Generation model together with dashed lines delimiting the eastern and western seismic regions and the "stable Canada" central region.

general way the low-seismicity central part of Canada we discuss later as “stable Canada”. Seismic hazard to the west of the leftmost dashed line on Figure 1 has been calculated using western strong ground motion relations; eastern relations are used for the remaining regions.

Ground Motion Parameters

In contrast to the 1985 maps used in NBCC1995, which gave values for PGA and PGV, we present 5% damped horizontal spectral acceleration values for the 0.2, 0.5, 1.0, and 2.0 second periods that will be used in NBCC 2005. The spectral acceleration parameters are denoted by Sa(T), where T is the period. We also present PGA values, which are only used for liquefaction analyses. We express the values in units of g and report them to 2 significant figures (an appropriate level of precision), except for some small 2.0 s values for which one significant figure is appropriate.

Probability Level

We recommended the 2% chance of non-exceedence in 50 years (written subsequently as 2%/50 year), equivalent to an annual probability of 0.000404, for the new seismic hazard maps and this was adopted for NBCC2005. The lower probability was required by the need to assess seismic hazard fairly across the country for the target building performance [8]. For backward comparability, Adams and Halchuk [2] give some 10%/50 year values computed using the new hazard model.

Choice of Confidence Level

The 4th Generation model provides an assessment of uncertainty, and so instead of presenting just the value for a given probability level (representing the result of our best estimates of the input parameters) it provides the percentiles of the distribution. While typical choices include the mean (which is the expected value given the uncertainty) and the 84th percentile (which uses the uncertainty to provide a higher confidence that the specified ground motion will not be exceeded), we recommended the 50th percentile - the median - ground motions for NBCC2005 as it is less sensitive to the exact amount of uncertainty included in the model. For typical seismic hazard computations in Canada the mean hazard value typically lies between the 65th and 75th percentiles of the hazard distribution.

The Four Seismicity Models - H, R, F, and C

To capture epistemic uncertainty in source, two complete probabilistic seismic hazard models were created for Canada, a “H” model that uses relatively small source zones drawn around historical seismicity clusters, and a “R” model that establishes larger, regional zones reflecting seismotectonic units. Both models are composed chiefly of areal sources, with only the Queen Charlotte Fault being modeled as a fault source. Standard methods were applied to define the source zone boundaries, select the earthquakes that pass completeness, choose upper bound magnitudes, and fit the magnitude-recurrence curves. Details of the method and listing of the parameters chosen are given in Adams and Halchuk [2]. For the relatively aseismic central part of Canada a “stable Canada” probabilistic “F” model with arbitrary boundaries was used to integrate knowledge about earthquake activity rates in similar parts of the world’s continents. The F model provides a “floor” value to seismic hazard for all parts of Canada. A great earthquake occurred off Vancouver Island on the Cascadia subduction zone in 1700 A.D. We chose to adopt a realistic scenario for this earthquake involving a line source with magnitude 8.2 [2, Fig. 6], and so provide a deterministic (“C” model), rather than probabilistic, estimate of its ground motions.

Strong Ground Motion Relations

The different physical properties of the crust in eastern and western Canada and the different nature of the earthquake sources in southwestern Canada required the use of four separate strong ground motion relations. For eastern and central Canada, east of the leftmost dashed line on Figure 2, we used the relations of Atkinson and Boore [9] adjusted to represent the ground motions on “firm ground” (see below). For the western Canadian shallow source zones, including the subcrustal transition zones west of Vancouver Island as well as the Queen Charlotte Fault, we adapted the ground motion relations from Boore et al. [10] to include a period-dependent anelastic attenuation term for distances beyond 100 km. For subcrustal, normal-mechanism earthquakes within the subducting slab under Puget Sound we used the Youngs et al. [11] intraslab relations adjusted to “firm soil” with a representative depth of 50 km. For the Cascadia subduction earthquake scenario we used Youngs et al. [11] interface relations with a magnitude of 8.2 and depth of 25 km, and with the closest approach of the rupture zone to establish distances to each site.

Reference Ground Condition for Canada

For the preparation of national hazard maps it is essential to present seismic hazard levels on the same ground condition. Thus a "reference" ground condition is needed in order to make the 2005 hazard values both numerically comparable between east and west, and roughly comparable in intent to the past (1985) hazard maps. NBCC2005 has adopted "Site Class C", defined by a 360 to 750 m/s average shear wave velocity in the uppermost 30 m [12] for the Canada-wide reference ground condition because it: represents the larger number of strong motion recordings in well-instrumented places like California; is in the mid-range between very hard and very soft ground (thus minimizing uncertainty in the amplification or deamplification factors); and is close to the ground conditions that were implied by the strong ground motion relationships used in for the 1985 maps. The strong ground motion equations we use, such as the hard-rock relations of Atkinson and Boore [9], have been modified to Site Class C.

Combining Hazard Results from Various Seismicity Models

For NBCC 2005 the results from the four seismicity models are combined using the method termed "robust" by Adams et al. [13]. The "robust" model is just choosing the highest value from the four models for each grid point across Canada. The actual procedure is to compare the H, R and F models for the east and choose the higher value, compare the H, R and F models for the west and choose the higher value, compare these eastern and western value sets and choose the higher value (this ensures a robust join in Saskatchewan and the western Arctic), then lastly compare the Canadian H+R+F values for southwestern Canada with the values from the C model.

RESULTS

Adams and Halchuk [2] give the NBCC2005 values for over 650 localities across Canada, of which Table 1 is a summary for selected cities. Seismic hazard values were calculated for a grid extending over Canada and used to create national contour maps such as Figure 2 and maps to demonstrate the pattern of seismic

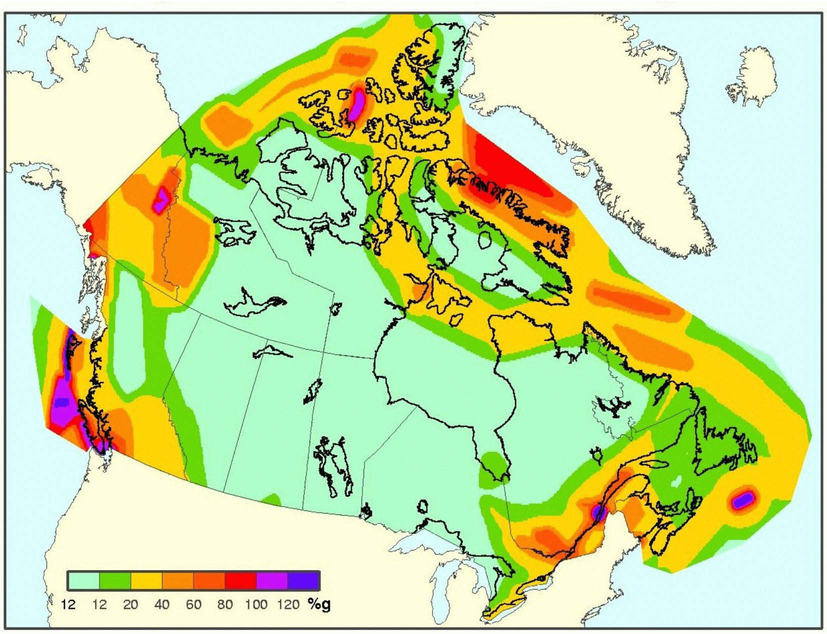


Figure 2. Sa(0.2) for Canada (median values of 5% damped spectral acceleration for Site Class C and a probability of 2%/50 years).

Table 1. NBCC 2005 design values for selected Canadian cities (lefthand side) and comparison of 1985 with 2005 Peak Ground Acceleration, 10%/50 year values on firm-ground (units=g).

	Median (50th percentile) Robust Values										Comparison 1985 to 2005			
City	$S_a(0.2)$		$S_a(0.5)$		$S_a(1.0)$		$S_a(2.0)$		PGA		1985*	2005	change	chief reasons
St. John's	0.18	R	0.11	R	0.060	R	0.016	R	0.090	R	0.054	0.036	down	1 and 2
Halifax	0.23	R	0.13	R	0.070	R	0.019	R	0.12	R	0.056	0.057	slight	--
Moncton	0.30	H	0.16	H	0.068	H	0.021	H	0.21	H	0.085	0.072	down	2
Fredericton	0.39	R	0.20	R	0.086	H	0.027	H	0.27	R	0.096	0.094	slight	--
La Malbaie	2.3	H	1.2	H	0.60	H	0.19	H	1.1	H	0.70	0.59	down	2
Québec	0.59	R	0.29	H	0.14	H	0.048	H	0.37	R	0.19	0.16	down	2
Trois-Rivières	0.64	R	0.31	R	0.12	R	0.043	R	0.40	R	0.12	0.18	up	3
Montréal	0.69	R	0.34	R	0.14	R	0.048	R	0.43	R	0.18	0.20	slight	--
Ottawa	0.67	R	0.32	R	0.14	R	0.045	R	0.42	R	0.20	0.20	--	--
Niagara Falls	0.41	H	0.20	H	0.073	H	0.021	H	0.30	H	0.084	0.12	up	4 and 5
Toronto	0.28	H	0.14	H	0.055	R	0.016	H	0.20	H	0.056	0.080	up	4 and 5
Windsor	0.18	R	0.087	R	0.040	R	0.011	R	0.12	R	0.029	0.040	up	3 and 5
Winnipeg	0.12	F	0.056	F	0.023	F	0.006	F	0.059	F	0.0	0.021	up	6
Calgary	0.15	H	0.084	H	0.041	H	0.023	H	0.088	H	0.019	0.040	up	5
Kelowna	0.28	H	0.17	H	0.089	R	0.053	R	0.14	H	0.054	0.071	up	5
Kamloops	0.28	H	0.17	H	0.10	R	0.060	R	0.14	H	0.056	0.071	up	5
Prince George	0.13	H	0.080	H	0.041	R	0.026	R	0.071	H	0.034	0.033	slight	--
Vancouver	0.96	H	0.66	R	0.34	R	0.18	R	0.48	H	0.21	0.26	up	4
Victoria	1.2	H	0.83	H	0.38	H	0.19	R	0.62	H	0.28	0.34	up	7
Tofino	1.2	C	0.93	C	0.47	C	0.21	C	0.52	C	0.35	0.27	down	4 and 8
Prince Rupert	0.38	R	0.25	R	0.17	R	0.096	R	0.18	R	0.13	0.095	down	2
Queen Charlotte	0.66	R	0.63	R	0.50	R	0.26	R	0.36	R	0.57	0.22	down	2
Inuvik	0.12	F	0.067	H	0.039	R	0.025	R	0.060	H	0.060	0.032	down	2

The second column for each parameter indicates which of the four models provides the "robust" or largest values - H: H model probabilistic, R: R model probabilistic, C: deterministic Cascadia scenario, F: Floor level probabilistic. Peak and spectral acceleration values are in g. All values are reported to 2 significant figures.

* 1985 values are from the 1985 NBCC Commentary where possible. Other values from the 1985 seismic hazard model. See text for reasons numbered.

hazard across selected urban areas (Figure 3). The four spectral values used by NBCC2005 (together with values at a few other periods) were used to construct Uniform Hazard Spectra (UHS) for a few major cities to illustrate the range and period dependence of seismic hazard across Canada (Figure 4). Other UHS are given by Adams and Halchuk [2] and yet more can be constructed from the tabulated values therein. The UHS for Winnipeg is representative of many localities in low-seismicity parts of Canada where the F model dominates. The UHS shown are for Site Class C, while Figure 5 shows the design UHS for Montreal on various Site Classes to be used for NBCC2005.

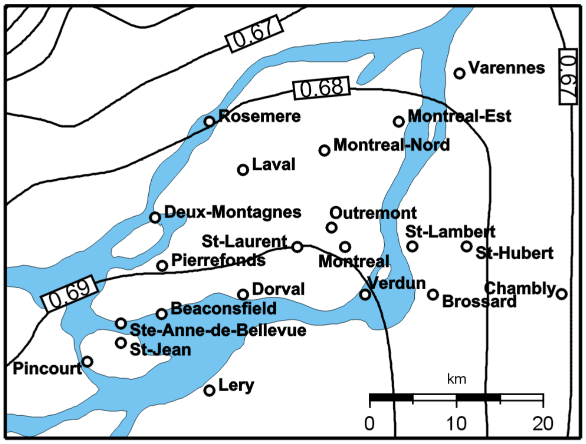
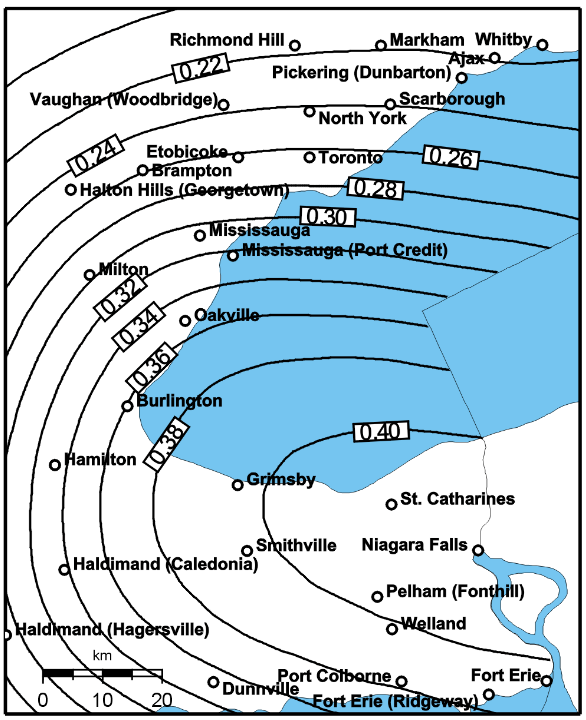


Figure 3. Detailed maps of Sa(0.2) hazard in the vicinity of Montreal, Toronto-Niagara, and Vancouver-Victoria (units = g)



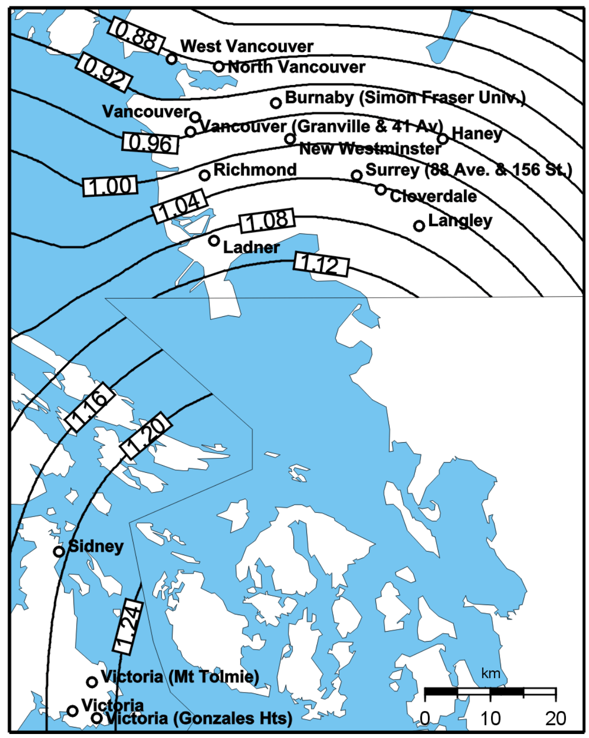
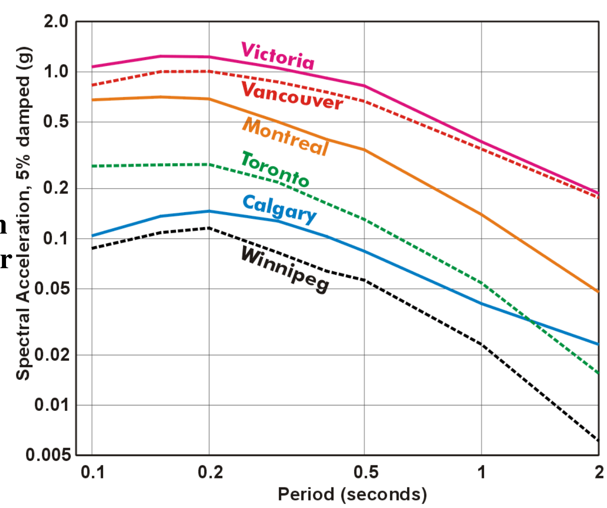


Figure 4. Uniform Hazard Spectra for median 2%/50 year ground motions on Site Class C for key cities.



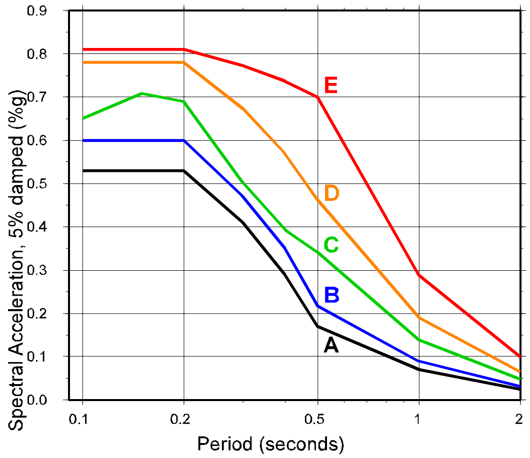


Figure 5. Seismic hazard for Montréal depicted as Uniform Hazard Spectra on various ground conditions (site classes A-E as defined by Finn [12]). Class C represents the actual UHS, the remainder are design spectra.

The change of Sa(0.2) hazard as a function of probability ("hazard curve") for selected cities is illustrated in Figure 6. Other hazard curves are given in Adams and Halchuk [14]. The slope of the curves between probabilities of 10%/50 years and 2%/50 years is of especial interest because national multiplicative factors have sometimes been mis-applied to values at one probability level to estimate hazard at a different level considered more appropriate for design (Figure 7 shows why this does not have the intended effect). Figure 8 shows that the slopes of the hazard curves also vary considerably within one geographic area. A companion paper at this conference [15] discusses the deaggregation of Canadian seismic hazard and illustrates the magnitudes and distances of the earthquakes making the largest contribution to the seismic hazard for selected cities.

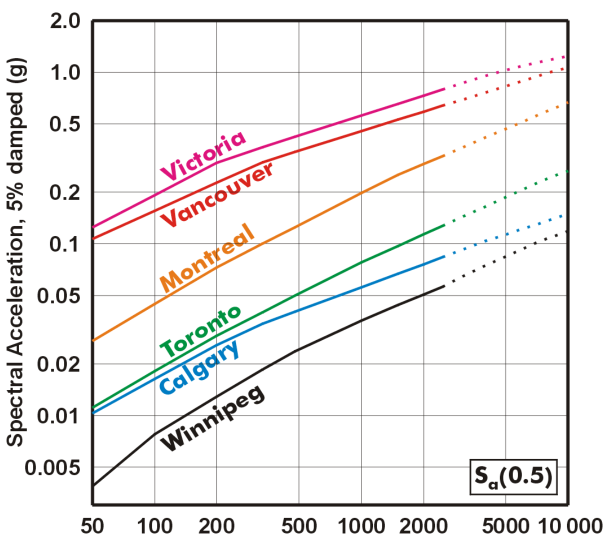


Figure 6. Sa(0.5) hazard curves for key cities.

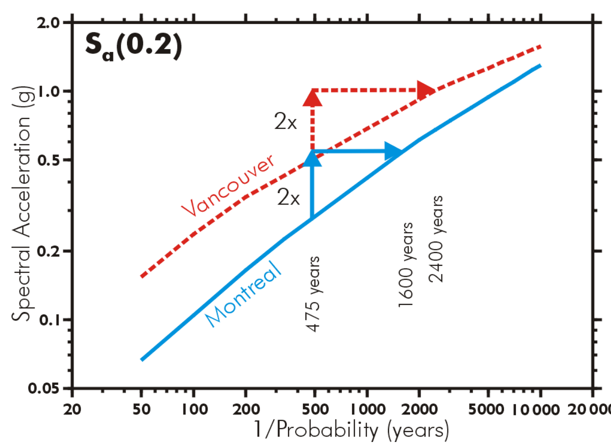


Figure 7. Sa(0.2) hazard curves for Vancouver and Montréal, showing how increasing the 10%/50 year hazard by a factor of two produces different increases in safety [1].

DISCUSSION

Changes in estimated hazard within Canada

Improved understanding of seismicity patterns, their cause and recurrence rates, and increased knowledge of strong ground motion has led to significant changes in estimated hazard relative to those of the 1985 maps. The changes depend on the period of the ground motion measures, so not all changes are apparent

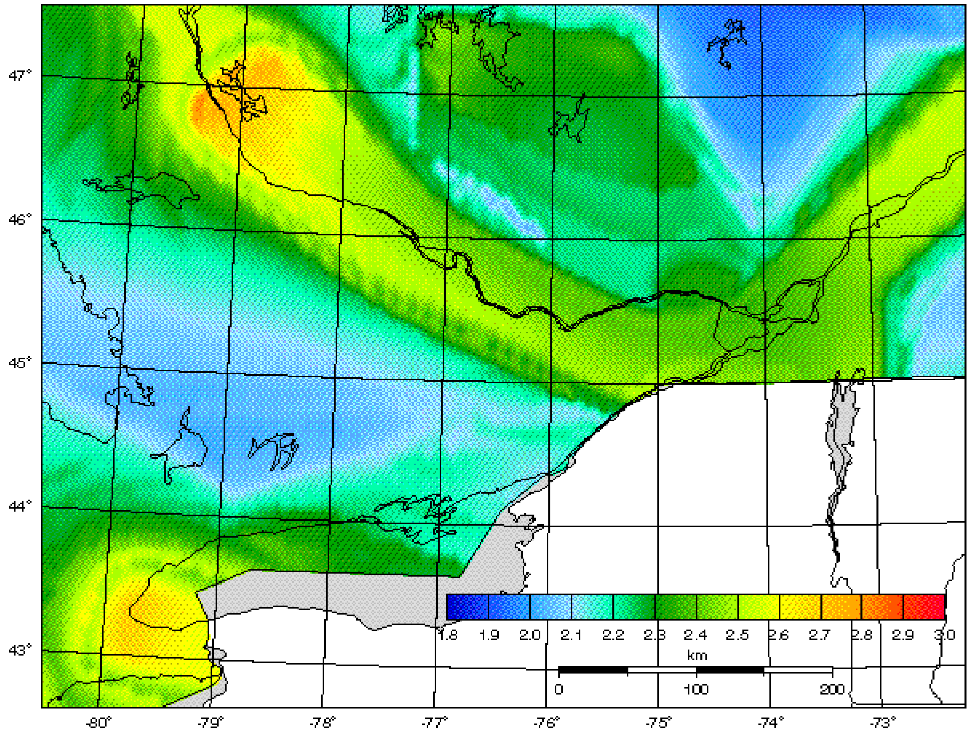


Figure 8. Ratio of 2%/50 year to 10%/50 year robust hazard for Sa(0.2) in southeastern Canada.

from the values in Table 1 which presents a comparison of 1985 and 2005 seismic hazard value. The 2005 spectral parameters can not be compared directly with the 1985 PGA and PGV parameters, for they differ in both type and probability level. Hence we compare PGA at 10%/50 year from both 1985 and 2005 models. The comparison is not ideal because PGA is a short-period measure that captures the damage potential of ground motions much more poorly than spectral acceleration at short or long periods. Brief reasons for the changes in our estimate of PGA hazard are summarized in the last column of the Table 1 [The chief reasons are: 1. less impact of 1929 Grand Banks earthquake; 2. new strong ground motion relations used; 3. effect of **R** model; 4. change in source zone boundary position; 5. larger upper bound magnitudes used; 6. effect of stable Canada model; 7. Coordinates corrected to downtown (in 1995); 8. Less impact of 1946 Vancouver Island-type earthquakes]. The stated reasons necessarily over-simplify the sum effect of many changes, some acting to increase and some to decrease the estimated hazard. For particular sites, the NBCC2005 ground motion design values may have changed in very different ways because of the effects of the improvements detailed below.

Improved distribution of estimated hazard because of new knowledge about earthquake distribution
While the general pattern of earthquakes in the two decades since the 1985 maps were compiled has not changed, there have been a few significant earthquakes that have caused re-evaluation of the earthquake sources together with an upward revision of many upper bound magnitudes. Two completely new components have been added to the 1985 maps: the Cascadia subduction earthquake, and the occurrence of earthquakes in the "stable" part of Canada. These two additions have increased the estimated hazard along the Pacific edge of Vancouver Island and throughout many areas of Canada hitherto thought to be aseismic. While only a small increment of earthquakes has been added to the 1985 active zones, the approach used for the R model has increased estimated seismic hazard at places that lie near potentially-seismogenic features with few historical earthquakes, such as the St. Lawrence valley near Trois-Rivières.

Improved distribution of estimated hazard because of change in probability level
The lowering of the probability level from 10%/50 year to 2%/50 years increases the ground motions by a factor of 1.7-2.6 times. The increase differs across Canada, being generally larger in the east and lower in

the west, and being related to both the size and proximity of large earthquakes and to the ground motion relations being used. Even within one region, the amount of increase may differ considerably (Figure 8). This redistribution is intended, and corrects the poorer distribution in 1985 that was based on the 10%/50 year values. The general increase, that is by a factor of 2 +/- 0.3, is taken into account in the building design process, through the use of new R_o factors that explicitly quantify overstrength [8]. Thus in a general way the large changes in ground motions due the change in probability level do not lead to an overall proportional increase in building "strength" or robustness.

Improved distribution of estimated hazard because of change from zones to contours

NBCC1995 used seven zones to quantize seismic hazard and then used zonal values to represent each zone. This led to underdesign for sites just on the low side of a zone boundary, overdesign for sites just on the other side, and a step jump in design across the boundary that had no basis in fact. The use of contours greatly reduces these effects. The only step transitions in NBCC2005 are at the trigger levels for the "special provisions" [8]. Certain large urban areas, especially in regions of steep seismic hazard gradient, exhibit a range of hazard values, as can be seen in Figure 3. For example values for Sa(0.2) across greater Toronto range from 0.31 g (Mississauga) to 0.24 g (Scarborough). Similar ranges were present in the 1985 seismic hazard maps, but were not evident to the engineer because zone values were used for design, and in almost every case each urban area fell into just one zone. The use of contours places large municipalities that lie in areas of steep hazard gradients (e.g., City of Toronto) in a quandary, because the short period hazard changes by a factor of 30% across the city and adopting a single value for regulatory convenience would result in a safety or economic penalty.

Improved distribution of estimated hazard because of change to site-specific spectrum

NBCC2005 uses a site-specific spectrum based on tabulated values of Sa(T) at T= 0.2, 0.5, 1.0 and 2.0 seconds. The tabulated values represent robust hazard, and in some places the values at different periods come from different seismicity models (e.g., Table 1). Using four spectral values provides a good approximation to the complete UHS and is a significant improvement to NBCC1995, which scaled a standard spectrum by peak ground velocity with a partial adjustment to accommodate estimated PGA. Ground motions at short periods will now reflect the estimated value rather than being capped at a lesser value (as occurred for Ottawa in the past code).

Improved distribution of estimated hazard because of change in soil classification

More explicit definitions for the soil types and the amplification thereof has resulted in changes. Design values on rock sites have fallen relative to firm ground, while values on soft soils at longer periods have not changed much. The range in design ground motions on defined soil classes was a factor of 2 in NBCC1995, but for the low intensity shaking becomes a factor of 3 for short periods and a factor of 4 for long periods in NBCC2005. A further change recognizes non-linear soil effects. This change reduces the penalty for short period structures on soft sites in high hazard areas, where the soil acts to weaken the ground motion [12].

Some unresolved consequences

Consistency of other standards with the new, lower NBCC2005 probability level

Some existing codes and standards were written in the context of NBCC1995, i.e. seismic hazard estimated for common buildings at 10%/50 years. For example, CSA Z289-01 [16] defines the "safe shutdown earthquake" for Liquefied Natural Gas (LNG) plants to be 5%/50 years, and so required design to a hazard probability half that required for common buildings in 2001. However this now seem out of step, in that common buildings in 2005 will be designed for hazard levels half the probability of the CSA standard for these critical structures. As many common buildings may be as reliable under NBCC2005 as under NBCC1995 (because of the inclusion of R_o factors to reflect actual building performance), it appears that although the CSA standard intended LNG plants to be designed to be safer than common buildings, that might not have been the outcome. The equivalent U.S. code, NFPA 59A [17] bases the SSE on the 1%/50 year hazard (with some exceptions that may mean that the effective SSE would be circa 2.7%/50 years for a moderate seismicity site in eastern Canada). A SSE at 1%/50 year (without the exceptions) would seems to appropriate for Canadian LNG plants and would address the public perception of relative hazard.

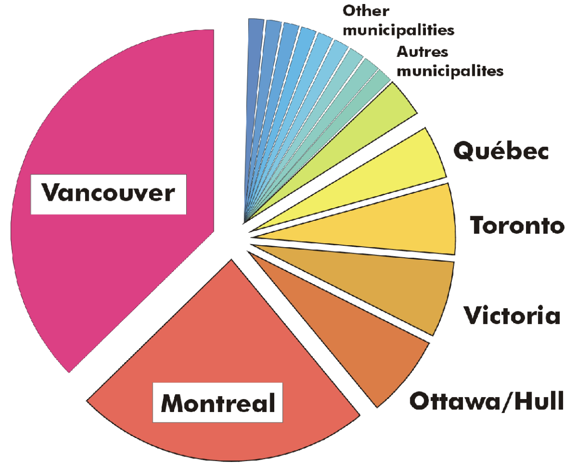
Parameters for liquefaction design
NBCC1995 was based on the philosophy that the foundation should not fail before the structure that it supports. Resistance to soil liquefaction was often based on Seed's criteria which uses the site NBCC PGA together with a representative magnitude. The move to 2%/50 year hazard has had two effects that result in more conservative anti-liquefaction designs than NBCC1995. Firstly the firm ground 2%/50 year ground motions are about twice the 10%/50 year motions. Secondly, deaggregation of hazard at the 2%/50 year probability level [15] reveals that more of the hazard is coming from the larger earthquakes than before, thus leading to larger modal (or mean) magnitudes (which may be those chosen for the liquefaction assessment). These increases are only partially offset by the smaller amplification of surface ground motions on soft soil sites in high-seismic regions. The net effect is a design increase of about 30% in the high-seismicity Vancouver/Richmond area (A. Wightman, pers. comm., 2004), but an increase of 60% or more for eastern sites in areas of low seismicity. The problem is compounded by basing liquefaction analysis on the PGA ground motion parameter. Eastern earthquakes generate shaking that is rich in short-period motions that control the amplitude of PGA, and the crust of eastern Canada attenuates them slowly. Hence PGA values that in California represent strong earthquakes capable of causing liquefaction can be produced in eastern Canada by moderate earthquakes that lack the shaking duration needed to induce liquefaction. Clearly a thoughtful analysis of the problem is required to ensure that application of California rules to eastern NBCC2005 ground motions does not produce unduly conservative designs. Site specific analyses (or model solutions for certain cities) appear to be appropriate.

Applicability of 4th Generation results for design of high-reliability structures
Past NBCC seismic provisions have formed a guide for the seismic design of "non-buildings" that require reliable performance. For example, the Canadian Dam Association Safety Guidelines [18] suggest dams be designed for one of three levels of safety, dependant on consequences, and associated with probability levels of 0.01-0.001 p.a., 0.001-0.0001 p.a., and 0.0001 p.a. As the first and perhaps often the second are above the NBCC2005 probability level of 0.000404 p.a., one might ask if the 4th Generation model provides sufficiently reliable estimates for the design of low-risk dams. The answer is "maybe", since while the hazard can be estimated at the correct probability level, there is no certainty that all the factors relevant to the specific dam have been considered by the national model. Chief among these factors are the choices made in associating relevant earthquakes into source zones and in the position of nearby source-zone boundaries. The site value for a short-period structure close to a high-seismicity zone is often sensitive to the position of the zone boundaries because of the rapid attenuation of short-period motion with distance. A shift of 10 km in the boundary could change the ground motions for Sa(0.2) by 30%. While the 4th Generation model could also be run to produce lower probability estimates (i.e., less than 2%/50 years), including the 0.0001 p.a. estimates that are often specified for the design of critical plants, we strongly caution that the national scope of the model means it cannot adequately address all uncertainties at all sites. Hence site-specific evaluation becomes essential for critical designs.

Seismic risk in Canada
A new suite of national seismic hazard maps provides an opportunity to re-assess seismic risk in Canada, where seismic risk is defined in terms of *seismic hazard * vulnerability*. A full assessment of seismic risk in Canada involves much non-seismological data, knowledge and skills to translate the effects of seismic hazard shaking into likely losses. It is thus beyond the scope of this paper, and beyond the current mandate of the Geological Survey of Canada. However, a first approximation is extremely useful for allocating resources to those places where the benefits will be largest. Adams et al. [19] assessed the distribution of urban seismic risk in Canada from $\sum$*probability of damaging ground motion * city population*. For the probability, they used the more-likely of two damage thresholds to capture the different hazard to short (1-2

storey) and tall (circa 10 storey) buildings, and to eastern and western Canada. Choosing different thresholds or ground motion parameters would produce results that differ in detail, but substantially mimic the risk distribution shown in Figure 9. Between them, greater Vancouver and Montreal account for more than half of the urban seismic risk. Canada's six largest cities at risk account for over three-quarters of the risk.

Figure 9. Approximate distribution of seismic risk among Canada's urban population [19].



CONCLUSIONS

We have summarized the basis for the new seismic provisions of NBCC2005 and shown how they result in a better distribution of estimated hazard across Canada. The improved seismicity model developed, the new ground motions adopted, the revised probability level chosen, and the use of spectral parameters will permit site-specific uniform hazard spectra to be constructed for each site, and hence allow improved earthquake-resistant design. That in turn should lead to more earthquake resistant buildings and safer communities.

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