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**GEOLOGICAL SURVEY OF CANADA  
OPEN FILE 8629**

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seismic-hazard values for selected localities**

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**M. Kolaj<sup>1</sup>, S. Halchuk<sup>1</sup>, J. Adams<sup>1</sup>, and T.I. Allen<sup>2</sup>**

<sup>1</sup>Canadian Hazards Information Service, 7 Observatory Crescent, Ottawa, Ontario K1A 0Y3

<sup>2</sup>Place, Space and Communities Division, Geoscience Australia, GPO Box 380 Canberra ACT 2601 Australia

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## **ABSTRACT**

The preliminary 6<sup>th</sup> Generation seismic hazard model of Canada (CanadaSHM6-trial) provides the basis for design values proposed for the 2020 edition of the National Building Code of Canada (NBCC2020). Seismic hazard values at a probability level of 2% in 50 years for 679 Canadian localities are provided in an accompanying spreadsheet to supplement the public review of the seismic hazard portion of NBCC2020 scheduled from January to March 2020. The spreadsheet tool provides the ability to select a Canadian locality and visualize seismic hazard values for any value of  $V_{S30}$  (140 – 3000 m/s) and Site Class (E-A). In this document we provide detailed instructions on the use of this spreadsheet. This work will be superseded by a forthcoming Open File, once NBCC2020 is finalized to reflect the final seismic hazard values calculated using CanadaSHM6.

## **INTRODUCTION**

This Open File contains an early release of the seismic hazard values calculated using the preliminary 6<sup>th</sup> Generation seismic hazard model of Canada (CanadaSHM6-trial) for a suite of 679 Canadian localities. The CanadaSHM6-trial model provides the basis for design values proposed for the 2020 edition of the National Building Code of Canada (NBCC2020). The intent of this Open File is to provide additional background information and a spreadsheet-based tool to supplement the information available in the public review documents of the seismic hazard portion of NBCC2020 (Earthquake Design, Part 4) scheduled to begin in January 2020 (NRC 2020). This Open File will be updated prior to the release of NBCC2020 to reflect the final seismic hazard values calculated using CanadaSHM6.

The 6<sup>th</sup> Generation model inputs are provided in Kolaj et al. (2020) and a general overview of the model, results and ground motion models (GMMs) are discussed in Adams et al. (2019) and Kolaj et al. (2019). The hazard values are accessible through an Excel spreadsheet tool which allows the user to select a locality, obtain the proposed CanadaSHM6-trial values, and compare them to the 5<sup>th</sup> Generation seismic hazard model values that are the basis for NBCC2015 (NRC, 2015).

## **METHOD**

The present method for calculating seismic hazard builds upon the work of Adams et al. (2015) which established the 5<sup>th</sup> Generation of seismic hazard maps for Canada. We apply the same Cornell-McGuire methodology (e.g., McGuire, 2004) using the OpenQuake software (Pagani et al., 2014) version 3.3.2. Validation relative to the GSCFRISK computational code used for the 5<sup>th</sup> Generation results is documented by Allen et al. (2020). A description of the CanadaSHM6 update is available in Adams et al. (2019) for updates to earthquake source models, Kolaj et al. (2019) for updates to ground motion models, and Halchuk et al. (2019) for addition of the Leech River Valley - Devil's Mountain fault system.

## ***Adjusting for Ground Condition***

NBCC2015 adopted "Site Class C", defined by a 450 m/s time-averaged shear wave velocity ( $V_S$ ) in the uppermost 30 m ( $V_{S30}$ ), as the Canada-wide reference ground condition. The Class C values were used together with period-dependent foundations factors, F(T), in NBCC2015 to calculate design spectral accelerations. For NBCC2020, seismic hazard is provided directly for a range of site designations which may be one of: 1)  $V_{S30}$  calculated from *in-situ* measurements of  $V_S$  (preferred approach), or 2) Site Class (acceptable under certain circumstances). As such, the CanadaSHM6-trial provides seismic hazard values for  $V_{S30}$  values ranging from 140 m/s – 3000 m/s and for Site Classes A-E.

The adoption of site-designation-specific hazard maps will fundamentally simplify the way end users determine seismic design values for a given location and site designation, and has numerous other technical advantages as discussed in Kolaj et al. (2019) and Adams et al. (2019). However, it should be noted that at the time of publishing Kolaj et al. (2019), the decision to provide hazard for a range of  $V_{S30}$  values (in addition to Site Classes) was not yet finalized. With the CanadaSHM6-trial model, hazard for the user-specified  $V_{S30}$  is calculated through linear interpolation of shaking measures precomputed at fifteen  $V_{S30}$  values. Also, the definition of Site Classes between Kolaj et al. (2019) and the CanadaSHM6-trial has changed. In Kolaj et al. (2019), Site Classes were defined based on the NBCC 2015 "V-bar" approach (NBCC 2015 Commentary J-76) whereas the values contained here (and proposed for NBCC 2020) are based on the largest hazard value within each Site Class'  $V_{S30}$  bounds. For example, to determine the Site Class value for Site Class C, the largest value between 360 m/s and 760 m/s would be used. Note that the  $V_{S30}$  of the maximum spectral acceleration often varies with response spectral period. The calculation of the maximum value is performed within the attached spreadsheet.

## ***Accuracy and precision in this report***

Seismic hazard values should be reported to two significant figures (in our view, an appropriate level of precision). While the raw data in some of the computed tabs (e.g., tab <CanadaSHM6-trial Vs30 140-3000>) retains four places after the decimal, only two significant figures (one significant figure where the value is less than 0.001) are reported in the Search Location tabs that provide the 2020/2015 values.

## **RESULTS**

Roughly 122,000 hazard values are provided in this Open File, representing 15 values of  $V_{S30}$  and 5 Site Classes for 9 shaking measures ( $Sa(T)$ , with T ranging from 0.1 to 10 s, plus PGA) at 679 localities. Because of the very large number of values it is inconvenient to provide all of them in an inline table. Instead, the spreadsheet (CanadaSHM6-trial\_SeismicHazardLocalities\_OF\_8629.xlsx) included provides the hazard values on tabs <CanadaSHM6-trial Vs30 140-3000> (values tabulated for a range of  $V_{S30}$  values) and <CanadaSHM6-trial Class E-A> (values tabulated for each Site Class) for each locality. As an example, Table 1 summarizes the values for Vancouver (city hall) from those two tabs.

**Table 1.** Summary of hazard values calculated using CanadaSHM6-trial at the Vancouver (city hall) location (latitude 49.25, longitude -123.12). Values are provided for a suite of 15  $V_{S30}$  values and 5 Site Classes, and for 9 shaking measures (PGA plus Sa(T)). All values are provided for the probability of 2%/50 years (0.000404 per annum), are mean values, and are given in units of g. Values for all 679 localities can be found in the spreadsheet under tabs: <CanadaSHM6-trial Vs30 140-3000> and <CanadaSHM6-trial Class E-A>.

$V_{S30}$ (m/s)	PGA	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1)	Sa(2)	Sa(5)	Sa(10)
140	0.56	0.98	1.18	1.33	1.31	1.01	0.61	0.18	0.066
160	0.56	0.98	1.19	1.32	1.29	0.98	0.58	0.17	0.061
180	0.55	0.99	1.20	1.32	1.26	0.89	0.52	0.15	0.057
250	0.54	1.02	1.21	1.31	1.17	0.68	0.41	0.12	0.046
300	0.53	1.03	1.20	1.25	1.06	0.61	0.36	0.10	0.041
360	0.52	1.04	1.18	1.19	0.95	0.54	0.32	0.089	0.037
450	0.49	1.03	1.15	1.10	0.82	0.47	0.28	0.075	0.032
580	0.45	1.00	1.04	0.94	0.68	0.39	0.23	0.063	0.028
760	0.41	0.94	0.91	0.78	0.56	0.32	0.19	0.052	0.024
910	0.37	0.89	0.83	0.70	0.50	0.28	0.18	0.049	0.023
1100	0.34	0.84	0.77	0.64	0.46	0.26	0.16	0.047	0.023
1500	0.35	0.84	0.74	0.61	0.44	0.25	0.16	0.047	0.023
1600	0.35	0.83	0.74	0.61	0.43	0.24	0.16	0.047	0.023
2000	0.35	0.83	0.73	0.59	0.42	0.24	0.16	0.046	0.023
3000	0.35	0.83	0.73	0.59	0.42	0.24	0.16	0.046	0.023
<b>Site Class</b>									
E	0.56	0.99	1.20	1.33	1.31	1.01	0.61	0.18	0.066
D	0.55	1.04	1.21	1.32	1.26	0.89	0.52	0.15	0.057
C	0.52	1.04	1.18	1.19	0.95	0.54	0.32	0.089	0.037
B	0.41	0.94	0.91	0.78	0.56	0.32	0.19	0.052	0.024
A	0.35	0.84	0.74	0.61	0.44	0.25	0.16	0.047	0.023

## USE OF THE EXCEL HAZARD PLOTTING TOOLS

This spreadsheet contains two tools for examining the 2%/50 year probability locality values calculated using the CanadaSHM6-trial model as proposed for use in the 2020 edition of the National Building Code of Canada. Its intent is to be a guide for the types of output that may be made available to the user on the future EarthquakesCanada website once the NBCC2020 has been published.

At first, the user may need to [see yellow bar near top of open worksheet] *enable editing* (most of the spreadsheet is locked, however) and *enable content*.

The user can choose to query results for any of the 679 localities based on either the desired  $V_{S30}$  value (in the range of 140 m/s to 3000 m/s) or the desired Site Class (A, B, C, D or E). Choose

the appropriate tab <Search Location  $V_{S30}$ > or <Search Location Site Class> to begin your search. Instructions are highlighted in yellow on each tab. Provinces/Territories, Locations and Site Class can be selected from the drop down lists.  $V_{S30}$  values must be typed in. For comparison, the NBCC2015 values for the corresponding Site Class can also be turned on (or off).

### **Search Location $V_{S30}$ tab**

When the location and  $V_{S30}$ /Site Class values are chosen, it will take the spreadsheet a moment to update. The hazard values for the requested location using CanadaSHM6-trial (as proposed for NBCC 2020) and NBCC2015 values (if selected) are tabulated immediately below the search tool (e.g., Table 2). Although a high degree of precision is provided, only two significant digits should be used.

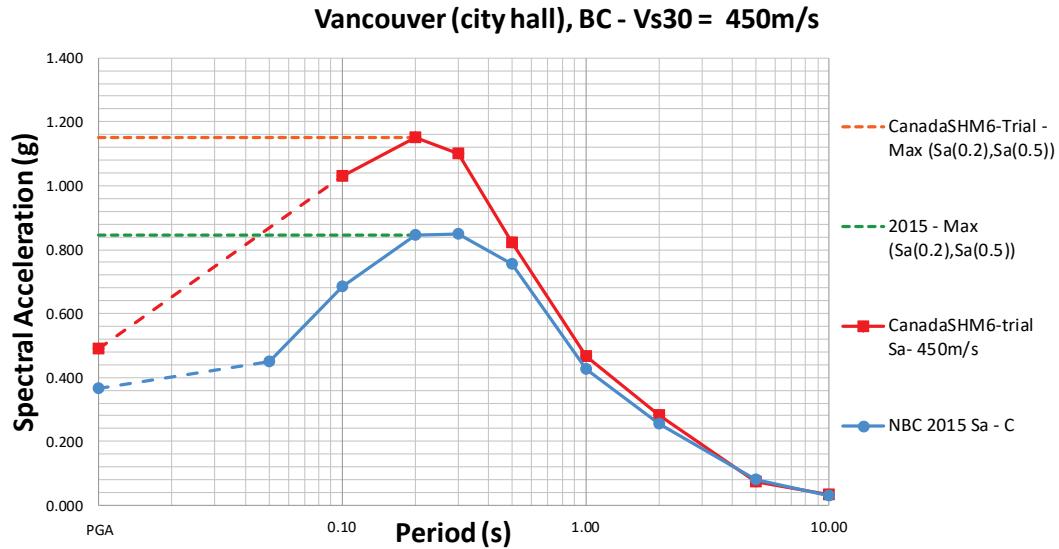
**Table 2.** Sample 2%/50 year probability peak and spectral acceleration values for a chosen locality and site designation. Values are given in units of g.

**Proposed NBCC 2020 values for : Vancouver (city hall), BC**

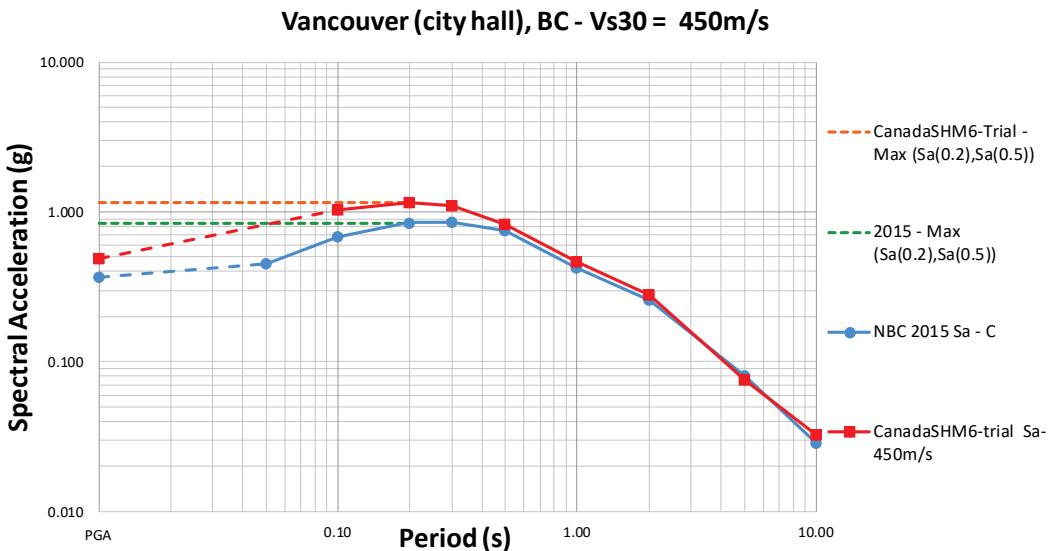
	Chosen Site Designation: 450m/s	Equivalent Site Class: C
Parameter	NBC 2020	NBC 2015
PGA	0.4906	0.367
Sa(0.1)	1.0314	0.685
Sa(0.2)	1.1495	0.846
Sa(0.3)	1.1016	0.850
Sa(0.5)	0.8222	0.754
Sa(1)	0.4657	0.425
Sa(2)	0.2813	0.256
Sa(5)	0.0752	0.081
Sa(10)	0.0323	0.029

The output is also displayed in a series of plots. Three plots are displayed on the Search Location  $V_{S30}$  tab. From left to right, these are:

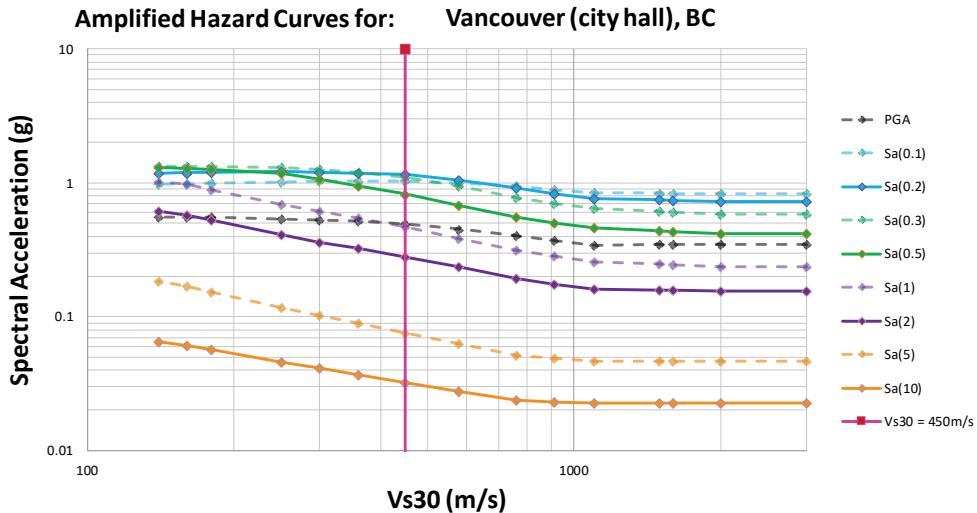
1. Uniform Hazard Spectra (UHS) for the requested location on a log-linear plot. PGA has been plotted at a spectral acceleration of 0.01 seconds for convenience. The larger of Sa(0.2) and Sa(0.5) following NBCC clause 4.1.8.4-9 is included as a dashed line for  $T \leq 0.2$  s. (Figure 1)
2. Uniform Hazard Spectra for the requested location on a log-log plot. The data on the plotted curves is the same as the log-linear plot. (Figure 2)
3. Amplified Hazard Curves (AHC) for the requested location on a log-log plot. The variation in hazard value with  $V_{S30}$  is shown for each of the response spectral parameters along with PGA. The location of the requested  $V_{S30}$  value is shown as a vertical magenta line on the plot. (Figure 3)



**Figure 1.** Sample Uniform Hazard Spectra, showing the variation in hazard with spectral period based on the CanadaSHM6-trial and 2015 hazard models. The user has chosen a  $V_{S30}$  value of 450 m/s. PGA is plotted at 0.01 seconds for convenience. The period and spectral acceleration are shown on logarithmic and linear axes respectively.



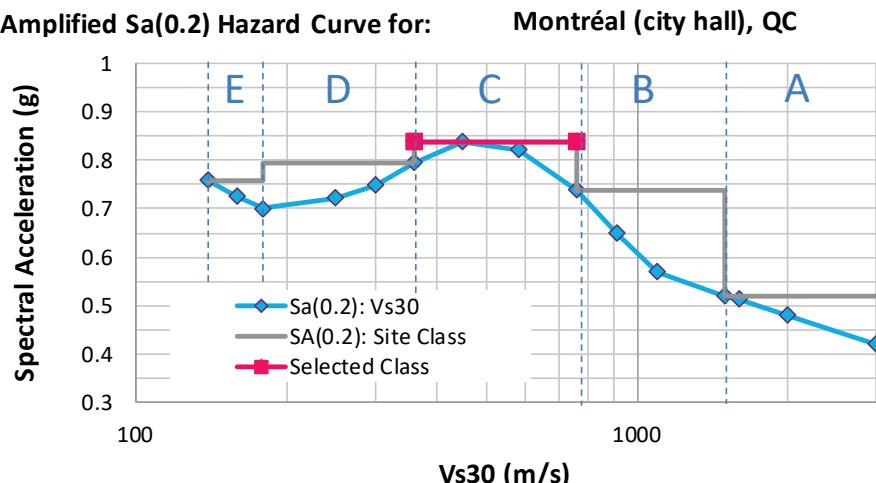
**Figure 2.** Sample Uniform Hazard Spectra like Figure 1 but with logarithmic-logarithmic axes.



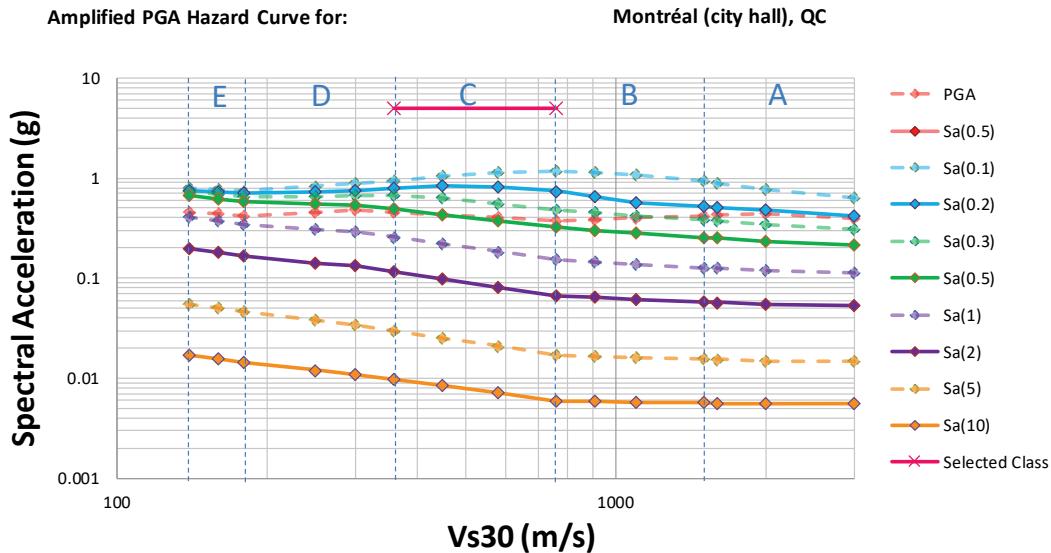
**Figure 3.** Sample Amplified Hazard Curves plot, showing the variation in hazard with  $V_{S30}$  value for all parameters.

### Search Location Site Class tab

When the “Search Location Site Class” tool is chosen, several additional plots are provided. The UHS plot formats are similar to those provided in the  $V_{S30}$  tab, with the exception that the proposed NBCC2020 Site Class maximum values are plotted. A suite of AHCs, one for each spectral parameter in addition to a separate plot for PGA, is provided (scroll down the worksheet tab to see all of them). On each plot, the AHC for that period is shown as a coloured line. The maximum value within the  $V_{S30}$  bounds of each Site Class (i.e., the Site Class values using the approach proposed for NBCC2020) appears as a grey stepped line. The user's selected Site Class is shown as a heavy magenta line (Figure 4). Additionally, a plot showing AHCs for all parameters is given for the selected location. The user selected Site Class is shown as a double-headed magenta arrow (Figure 5).



**Figure 4.** Sample AHC for  $Sa(0.2)$  at the selected site showing the variation with  $V_{S30}$  (dashed orange line) and the Site Class values (stepped grey curve). The user-selected Site Class is shown as the horizontal magenta line.



**Figure 5.** Sample Amplified Hazard Curves plot, showing the variation in hazard with  $V_{S30}$  values for all ground-motion intensity measures. The user selected Site Class is indicated as the double-headed magenta arrow.

### *CanadaSHM6-trial Vs30 140-3000 tab*

This tab contains the CanadaSHM6-trial model hazard mean values for the 679 localities at a probability of 2%/50 years. Peak and spectral results are provided for the following  $V_{S30}$  values: 140, 160, 180, 250, 300, 360, 450, 580, 760, 910, 1100, 1500, 1600, 2000, 3000 m/s.

### *CanadaSHM6-trial Class A-E tab*

This tab contains the CanadaSHM6-trial model hazard mean values for the 679 localities at a probability of 2%/50 years. Peak and spectral results are provided for the following Site Classes: A, B, C, D, and E.

### *2015 NBCC Class A-E tab*

This tab contains the 5<sup>th</sup> Generation seismic model hazard mean values for the 679 localities at a probability of 2%/50 years. Peak and spectral results are provided for the following Site Classes: A, B, C, D, and E.

## SUMMARY

Seismic hazard values calculated with the CanadaSHM6-trial model (as proposed for the 2020 edition of the National Building Code of Canada) for a suite of 679 localities are provided. An included Excel spreadsheet based tool allows the user to select their desired locality and site designation, either in terms of  $V_{S30}$  or Site Class. The included tools plot the uniform hazard spectra and the amplified hazard curves, depicting how hazard varies with site designation for each

ground-motion intensity measure. The tool also allows for comparisons to be made to the seismic hazard values within the 2015 National Building Code of Canada. Accordingly, users will be able to anticipate how hazard values are likely to change in NBCC2020. It is intended that a web-based version of the spreadsheet tools will make similar results available for any location in Canada once the NBCC2020 is released in late 2020.

## ACKNOWLEDGEMENTS

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