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2020 National Building Code of Canada Seismic Hazard Tool

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ABSTRACT

For the 2020 edition of the National Building Code of Canada (NBCC 2020), a new online seismic hazard webtool for the delivery of seismic hazard values has been released. The 2020 National Building Code of Canada Seismic Hazard Tool (SHT2020) provides seismic values for the design of buildings in Canada under Part 4 of NBCC 2020. SHT2020 returns interpolated seismic hazard values for any location in Canada and for any site designation. While location is specified with a latitude and longitude, the webtool can now assist the user in determining the coordinates of their site with added options such as a street address lookup or by using the geolocation service provided by the user's browser application. Site designation is defined either by determining a V_{s30} value between 140 and 3000 m/s or by Site Classes E to A. SHT2020 provides seismic hazard values for the NBCC2020's required parameters but also for additional parameters that may be of use (including ten exceedance probabilities). The tool also provides plots of the Uniform Hazard Spectra (UHS), the hazard curve and the implicit NBCC 2020 reference site amplification at the site. SHT2020 also includes a backend Application Programing Interface (API) through the GraphQL library which can be queried by users to programmatically obtain multiple seismic hazard values. This paper will briefly describe the NBCC 2020 seismic hazard model and explain the features of the SHT2020.

Keywords: National Building Code of Canada, seismic hazard.

INTRODUCTION

The 2020 edition of the National Building Code of Canada (NBCC 2020 [1]; released in March 2022) includes a significant update in both the design seismic hazard values but also in the manner in which the values are disseminated and obtained. In previous editions of the code, practitioners could obtain seismic hazard values for 679 localities directly from the body of the code (e.g., Appendix C-2 in NBCC 2015). The requirements in NBCC 2020 necessitate a more complex tool. As such, for NBCC 2020 seismic hazard values are no longer published within the body of the code and are instead only available through either a static online repository [2] or through the interactive NBCC 2020 Seismic Hazard Tool (SHT2020, [3]). SHT2020 offers increased flexibility compared to previous web interfaces of the seismic hazard tool and also provides multiple plots to help interpret these values. Users will have access to more than 200 individual values per probability at each site. This paper outlines how seismic hazard values for NBCC 2020 can be obtained using the SHT2020.

THE 6TH GENERATION SEISMIC HAZARD MODEL OF CANADA

The seismic hazard for NBCC 2020 is based on the 6th Generation Seismic Hazard Model of Canada (CanadaSHM6; [4,5]. The new model includes:

- updates to the geometry of deep inslab earthquakes in southwestern Canada and the recurrence of large megathrust subduction earthquakes,
- inclusion of the newly-discovered and potentially-active Leech-River Valley fault,
- adoption of new ground motion models,
- many other improvements related to the adoption of the OpenQuake software platform.

A representative map of CanadaSHM6 hazard is provided in Figure 1. Additional maps can be found in the Earthquakes Canada website [6] and in [7]. Interested readers are referred to [4,5] for further information on CanadaSHM6.

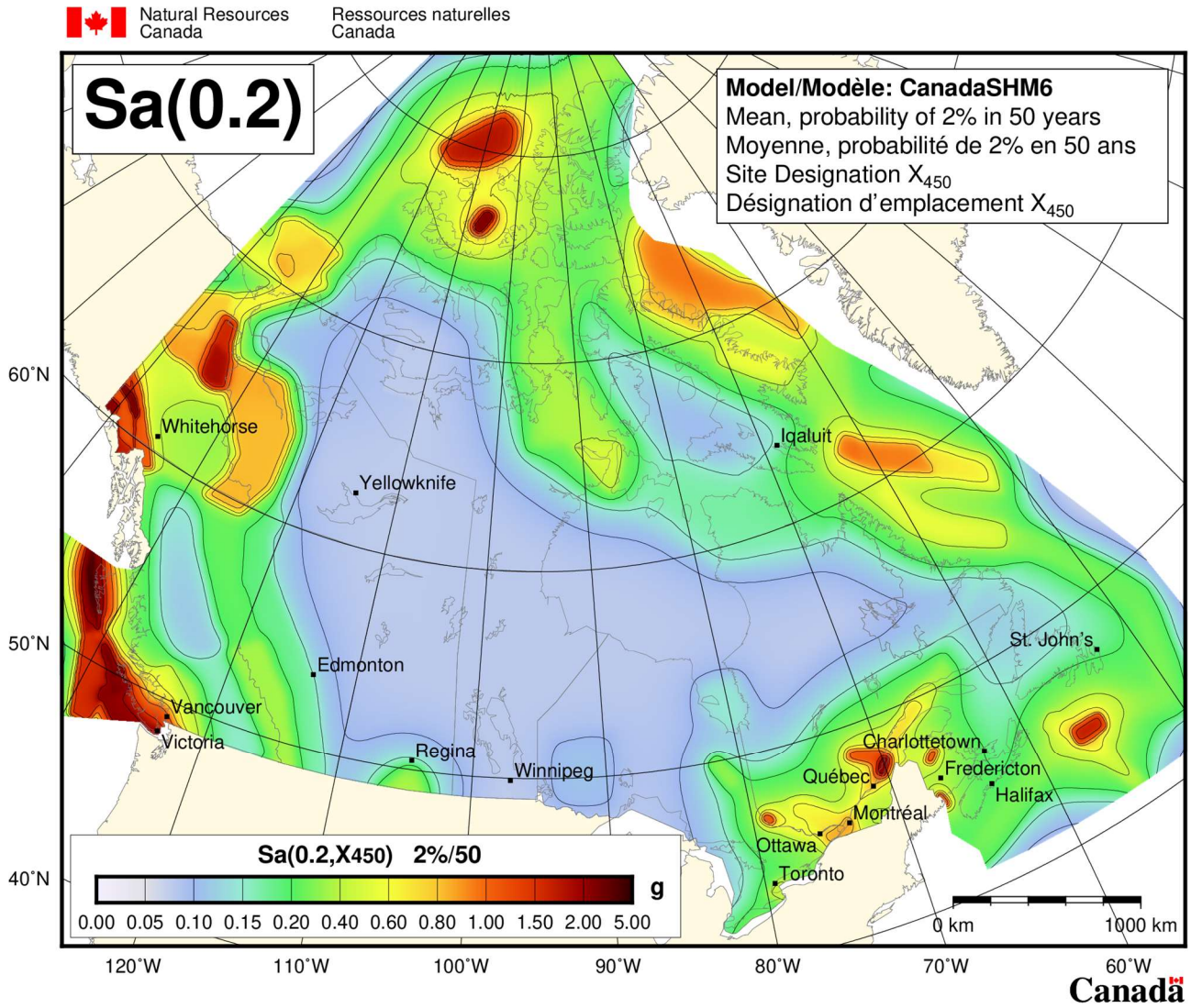


Figure 1. Sa(0.2, X_{450}) seismic hazard for Canada (mean values of 5% damped spectral acceleration for Site Designation X_{450} and a probability of 2%/50 years, units = g). Additional maps are available on the Earthquakes Canada website [6].

For the first time in Canada, the seismic hazard values are provided directly to users for specific site-conditions. That is to say that *in lieu* of tables to convert reference ground conditions to other site conditions (e.g., Foundation factors, F(T), in NBCC 2015), the seismic hazard values are provided directly to the user for their site condition. NBCC 2020 introduces the concept of "Site Designation" (X) which can be either defined via a Site Class (X_S, where S is the site class) or by a V_{s30} value (X_V, where V_{s30} is the time-averaged shear wave velocity from surface to a depth of 30 m). NBCC 2020 provides seismic hazard values for continuous values from X_{140} to X_{3000} and for X_E, X_D, X_C, X_B and X_A. It is important to note that the manner in which Site Class hazard is assigned has also changed from NBCC 2015 to NBCC 2020. In NBCC 2015, Site Class hazard was based on assigning representative V_{s30} values to each Site Class. For example, Site Class C hazard (i.e., the NBCC 2015 reference condition; corresponds to a V_{s30} between 360 and 760 m/s) was based on the seismic hazard calculated for a V_{s30} of 450 m/s. For NBCC 2020, the X_S hazard is calculated from the maximum seismic hazard value within the V_{s30} bounds of that Site Class. For example, the peak ground acceleration (PGA) for X_C is determined by determining the PGA hazard for X_{360} to X_{760} and taking the largest value.

The 5%-damped spectral acceleration values for NBCC 2020 are then denoted as $S_a(T, X)$ where T is the period (in seconds) and X is the site designation. This approach removes the need for separate site amplification look-up tables in the building code, improves the reliability of the results and simplifies the way end-users will determine seismic design values. Site

designation needs to be determined in accordance with Article 4.1.8.4 of the NBCC 2020. Further guidance is also available in the Commentary entitled Design for Seismic Effects in the Structural Commentaries (User's Guide – NBC 2020: Part 4 of Division B).

OBTAINING NBCC 2020 SEISMIC HAZARD VALUES

Figure A-1.1.3.1.(4) of NBCC 2020 describes the manner in which seismic hazard values are to be obtained. In short, values for certain coordinates (corresponding to the 679 NBCC localities) can be obtained from the NRC Publications Archive (NPARC [2]). If the site does not match one of the pre-calculated coordinates, or to obtain additional information for it, the 2020 NBCC Seismic Hazard Tool is to be used. It is important to note that seismic hazard values for the 679 localities are generated for their specific latitude and longitude coordinates. The appropriateness of the nearest pre-calculated set of values to a given site depends on the site's distance from that NPARC site and the local spatial gradient of seismic hazard. Using the SHT 2020 removes this potential issue, as it provides values specific to the user's coordinates.

NPARC

Seismic hazard values available on NPARC were generated from the NBCC SHT 2020. Values are provided for each of the 679 NBCC cities for each of the NBCC-defined seismic hazard parameters. This subset of values provides a static, archival record of SHT 2020 values. It is important to note that NPARC does not contain some of the additional values provided by the SHT.

SHT2020

The SHT2020 provides seismic values for the design of buildings in Canada under Part 4 of the National Building Code of Canada (NBCC) 2020 as prescribed in Article 1.1.3.1. of Division B of the NBCC 2020. In addition to the values required by NBCC 2020, the tool also provides additional values which may be of usefulness for specific applications. The full suite of values are:

- Site designations (X):
  - Site Classes (X_S): A, B, C, D, E
  - V_{s30} (X_V): 140 - 3000 m/s

- Ground motion intensity measures:
  - Spectral Accelerations (5% damping): 0.05, 0.1, 0.2, 0.3, 0.5, 1.0, 2.0, 5.0, 10.0 s.
  - Peak Ground Acceleration (PGA)
  - Peak Ground Velocity (PGV)

- Exceedance probabilities:
  - Probability of exceedance (%) in 50 years: 2, 2.5, 3.5, 5, 7, 10, 14, 20, 30, and 40. The probability of exceedance and return period are related via Eq. (1):

$$p(T) = 1 - e^{-\lambda T} \tag{1}$$

where p is the probability of exceedance (as a fraction; e.g., 0.02) in T years (e.g., 50), λ is the frequency (rate) of exceedance. The return period is then calculated as $1 / \lambda$.

Note that seismic hazard values provided by SHT2020 (and accepted for NBCC 2020) are generated via an interpolation (in space and in V_{s30}) of a pre-calculated set of values. The interpolation and grid are described in [8].

USING SHT2020

Web Form to request values

In order to obtain seismic hazard values for NBCC 2020, a site designation and location is required. SHT2020 guides the user in selecting these values. The tool allows for users to obtain values for either X_V or X_S. Following the selection of the user's site designation, the location for where the hazard is to be calculated is required (Figure 2). Seismic hazard values are calculated for a specific latitude and longitude. The site's location may be chosen by entering a street address, using the current location of the user's device (e.g., GPS on a smartphone), or by entering the latitude and longitude of the desired site. A map of the selected location is then provided to verify the location. The user may shift the position of the marker on the map to adjust the location.

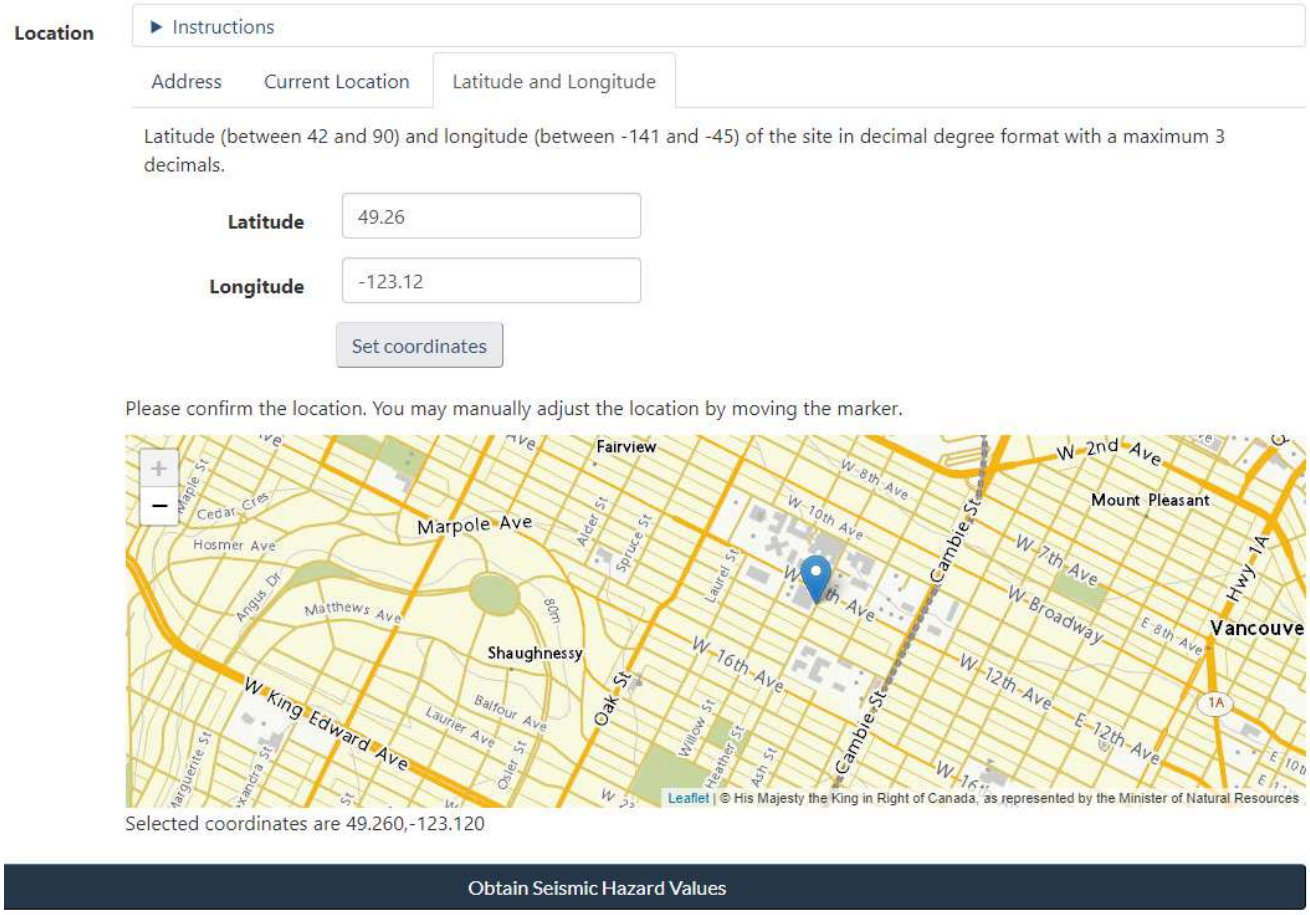


Figure 2. Example output when the user specifies a latitude and longitude coordinate.

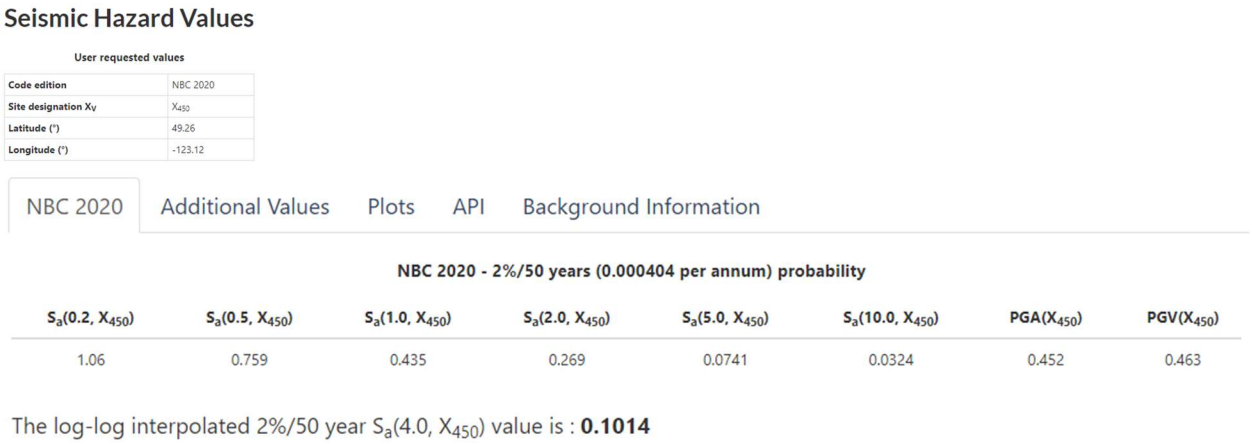
Once the user is happy with the selected location, they may select "Obtain Seismic Hazard Values" in order to generate the hazard values for their site.

Seismic hazard values

Once the values are requested a new browser tab/window will be created that contains the user's requested values. A depiction of what the user receives is shown in Figure 3 and 4, and is also described below:

- Top panel: A summary of the request to ensure that the user has not made an entry error
- Middle panel: Various tabs of information that are available:
    - NBCC 2020 (bottom panel in Figure 3): seismic design values as per NBCC 2020 for 2%, 5% and 10% in 50 years. Log-log interpolation for Sa(4.0, X) is also provided for convenience.
    - Additional values (Figure 4): Results for additional periods and an extensive range of probabilities between 2% and 40% in 50 years. The user can filter the data to the desired site designation and exceedance probability using the corresponding dropdown menu in the column head.
    - Plots: described in subsequent section
    - API: described in subsequent section
    - Background Information: largely gives references and background material on SHT2020 and CanadaSHM6

Both the "NBC 2020" and "Additional Values" tab include a "Download CSV" button which can be used to download the data as currently viewed by the user. Alternatively, the website can also be printed to a pdf.



Seismic Hazard Values

User requested values

Code edition	NBC 2020
Site designation X_V	X_{450}
Latitude (°)	49.26
Longitude (°)	-123.12

NBC 2020 | Additional Values | Plots | API | Background Information

NBC 2020 - 2%/50 years (0.000404 per annum) probability

$S_a(0.2, X_{450})$	$S_a(0.5, X_{450})$	$S_a(1.0, X_{450})$	$S_a(2.0, X_{450})$	$S_a(5.0, X_{450})$	$S_a(10.0, X_{450})$	$PGA(X_{450})$	$PGV(X_{450})$
1.06	0.759	0.435	0.269	0.0741	0.0324	0.452	0.463

The log-log interpolated 2%/50 year $S_a(4.0, X_{450})$ value is : **0.1014**

Figure 3. Default tab (NBCC 2020) when user requests seismic hazard values. Note that in all figures the additional instructions and background information have been removed for brevity in this paper.

NBC 2020 | Additional Values | Plots | API | Background Information

Site Designation	Probability	$S_a(0.05)$	$S_a(0.1)$	$S_a(0.2)$	$S_a(0.3)$	$S_a(0.5)$	$S_a(1.0)$	$S_a(2.0)$	$S_a(5.0)$	$S_a(10.0)$	PGA	PGV
X450	All											
X_{450}	2	0.658	0.955	1.06	1.02	0.759	0.435	0.269	0.0741	0.0324	0.452	0.463
X_{450}	2.5	0.603	0.876	0.975	0.931	0.696	0.397	0.241	0.0647	0.0273	0.417	0.42
X_{450}	30	0.163	0.241	0.278	0.259	0.184	0.0935	0.0429	0.01	0.00358	0.119	0.098
X_{450}	40	0.128	0.19	0.221	0.204	0.144	0.0722	0.0324	0.00744	0.00258	0.0948	0.0759

Figure 4. Results for additional periods and an extensive range of probabilities between 2% and 40% in 50 years (intermediate probabilities not shown). Values are made available for the full suite of pre-computed V_{s30} and Site Class designations.

SEISMIC HAZARD PLOTS

The "Plots" tab provides various ways of displaying and interrogating the NBCC 2020 seismic hazard data. Uniform hazard spectra, hazard curves, and site-amplification plots are provided for the NBCC and additional probabilities. By default, only the probabilities referred to in the NBCC are displayed, others can be enabled/disabled by selecting the respective item in the legend. Curves representing intermediate points are determined through either linear-linear or log-log interpolation dependent on the scale selected. For convenience, PGA is plotted on the same scale as Sa(T, X) (at T = 0.01 s). For low hazard regions, values below 0.001g for T ≤ 2.0 s and below 0.0001g for T > 2.0 s are not shown. Plot instructions and display features are described in Figure 5.

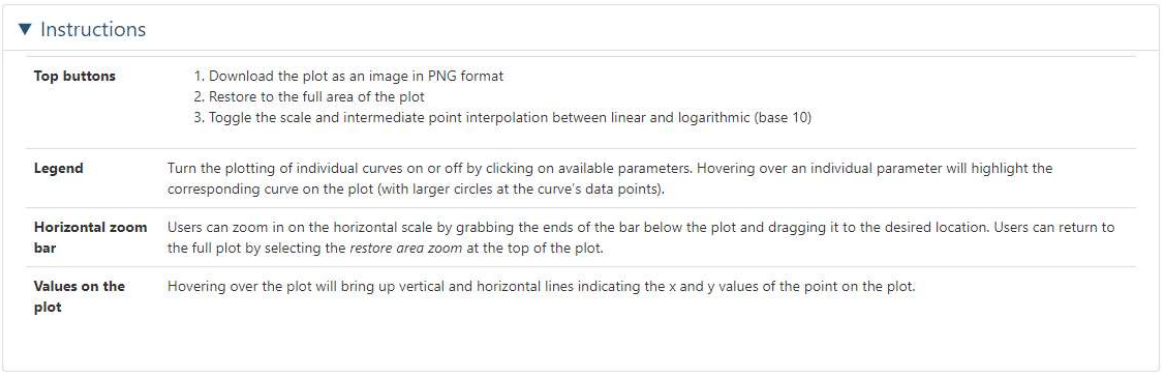


Figure 5. Features of the SHT2020 plots.

Uniform Hazard Spectra

The Uniform Hazard Spectra (UHS) contains seismic hazard values at a constant exceedance probability. By default, the plots are provided in the linear-linear scale. An example of the UHS using either the linear or log scale can be seen in Figure 6. Note that the values inherently behave in a log-manner and that the log-scale provides a better view of the relative amplitudes of the values and is (in general) a better estimate of intermediate values.

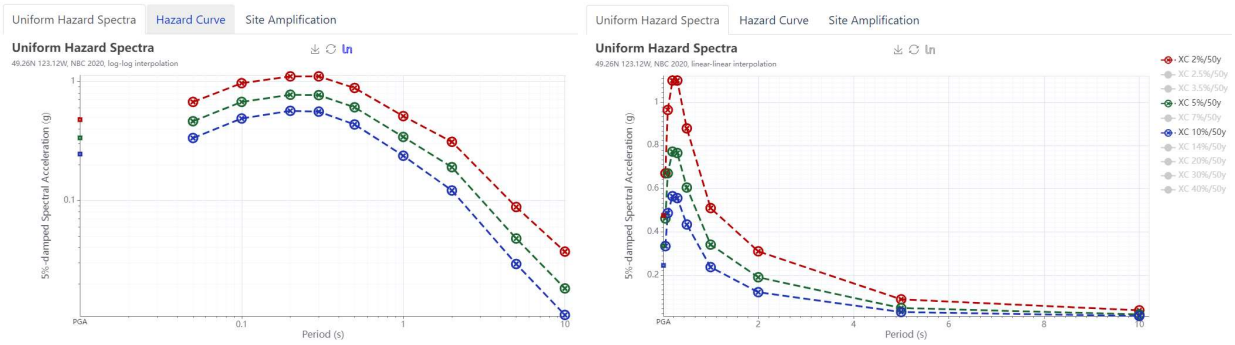


Figure 6. Uniform hazard spectra plots. The three standard NBCC probabilities – 2%, 5% and 10% in 50 years – are plotted by default. Users can turn these (and additional probabilities available in the legend) off and on by clicking on the labels. The UHS can be displayed in linear or logarithmic scales (top-centre button).

Hazard Curve

The "Hazard Curve" tab provides plots of the annual probability of exceedance versus ground motions (Figure 7). These plots are useful in understanding how seismic hazard values change for different exceedance probabilities.

In SHT2020 we provide hazard values with exceedance probabilities from 40% to 2% in 50 years. It is important to note that the high-probability ground motions (e.g., 40% in 50 year probability) may underestimate actual ground motions due to the lower-magnitude ("Mmin") cut-off used in the seismic hazard calculation (see [10] for more information). NBCC 2020 and CanadaSHM6 do not provide values for probabilities below 2% in 50 years. The determination of 1/5,000 or 1/10,000 year (i.e., 0.0002 or 0.0001 per annum) seismic hazard is normally required only for special facilities such as nuclear power plants or dams which have a large consequence if they were to fail. These low probabilities are beyond the scope of the NBCC 2020.

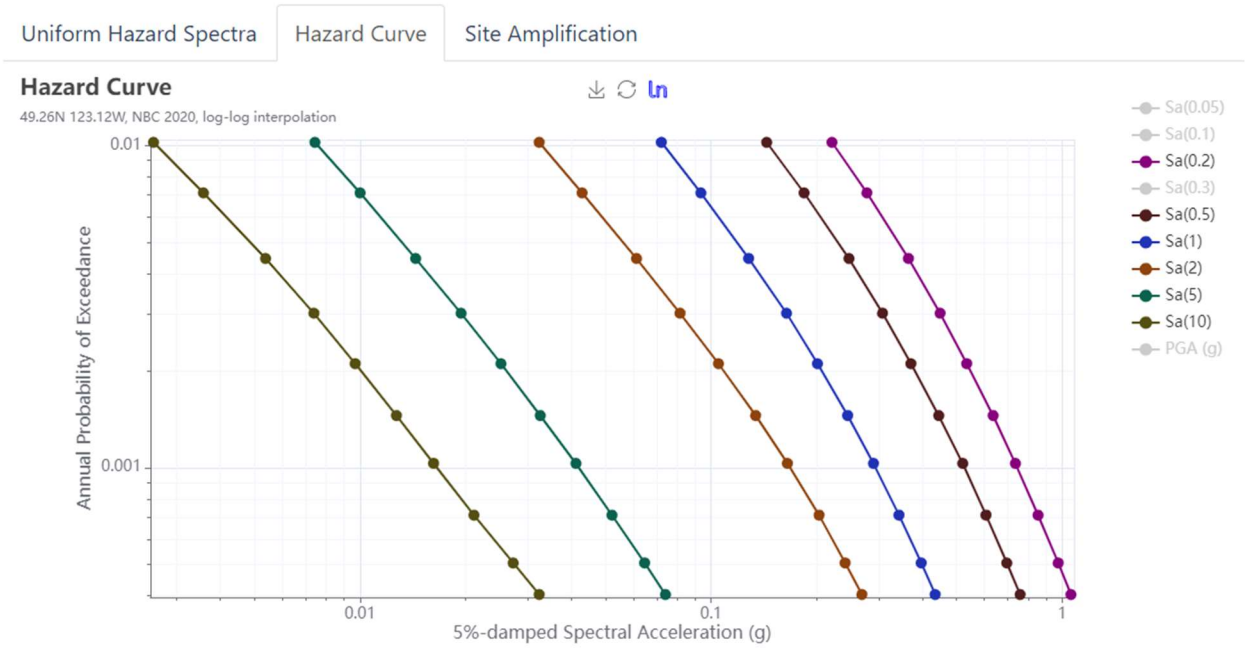


Figure 7. Hazard curves showing the variation in ground motion with probability for the range of 40 to 2% in 50 years.

Site Amplification

The "Site Amplification" tab provides a view of how the seismic hazard values at the site change with the site designation (X_V or X_S; Figure 8). The desired exceedance probability can be selected from the drop-down menu (2%/50 year is the default).

As described in [8], the user's selected site designation is interpolated from a set of pre-calculated values. The pre-calculated values are shown in these plots by the dots. Moreover, the user-selected X_V value is shown with a vertical black line; hazard for this value is interpolated (using log-log interpolation) from adjacent values (dots).

Note that the site-amplification implied by these plots is generic, does not represent a site-specific assessment, and may differ from that found by a site-specific assessment. For CanadaSHM6 (and NBC 2020), the effects of site amplification are incorporated directly in the seismic hazard calculations through V_{s30} site terms within the ground motion models [9]. With this approach, there is an inherent assumption about the applicability of generic ground profiles (used for the V_{s30} site terms) to both western and eastern Canada. If desired, the site amplification implicit in the model can be calculated as the ratio between the hazard values for the user's site designation and the hazard values for an appropriate base condition.

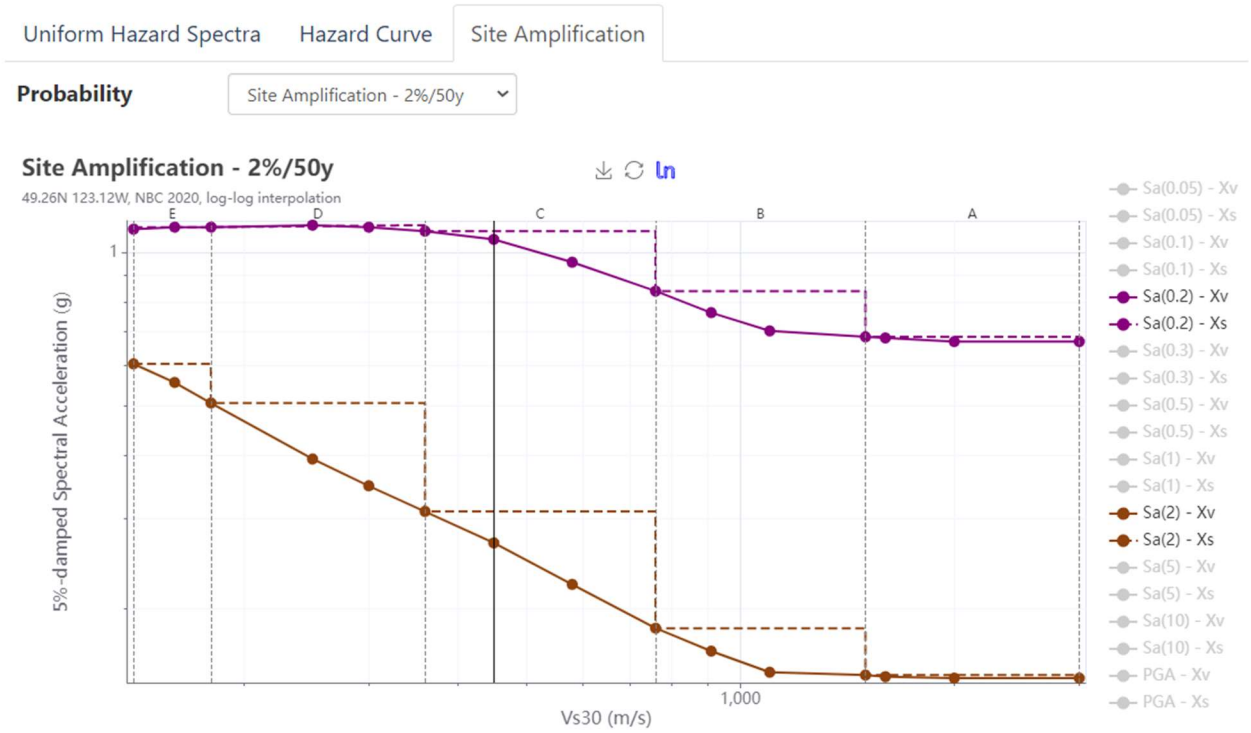


Figure 8. Site Amplification curves showing how ground motion varies with site designation. Both the V_{s30} (X_V, solid lines) and Site Class (X_S, dashed lines) amplification curves are available for each ground motion parameter. Site Classes are indicated at the top of the plot.

SHT2020 API

In lieu of using the interactive webtool, the hazard values can also be requested (in json format) through a webservice using the GraphQL Application Programming Interface (API; Figure 9). This webservice address is: https://www.earthquakescanada.nrcan.gc.ca/api/canshm/graphql. The API is suitable for those who want to incorporate NBCC 2020 seismic hazard values into software and/or for bulk requests.

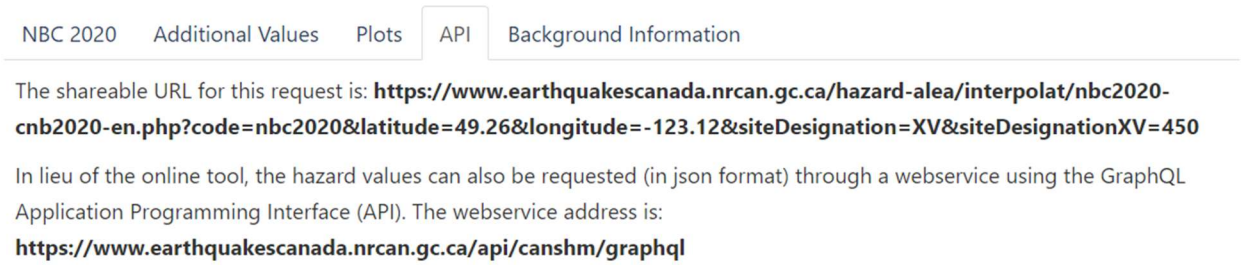


Figure 9. Application Programming Interface (API). The user can develop scripts that will allow them to obtain results directly from the tool for multiple locations, probabilities, parameters and Site conditions. API format instructions are provided.

An example of GraphQL query for Sa(0.2) and Sa(0.5) for a site designation X_{760} (V_{s30} value of 760 m/s) for probabilities of exceedance of 2%, 5% and 10% in 50 years for a site located at 45.421, -75.697:

```
query{
  NBC2020(latitude: 45.421, longitude: -75.697){
    X760: siteDesignationsXv(vs30: 760, poe50: [2.0, 5.0, 10.0]){
      sa0p2
      sa0p5
    }
  }
}
```

A more comprehensive description of the API can be found in [8].

CONCLUSIONS

A new online seismic hazard webtool delivers seismic hazard values for the 2020 edition of the National Building Code of Canada. The NBCC 2020 Seismic Hazard Tool (SHT2020) provides values for the required NBCC 2020 parameters and also for additional parameters that may be of use (including ten exceedance probabilities). The tool also provides various plots to assist the user in understanding and interrogating the data. SHT2020 also includes a backend Application Programing Interface (API) which can be queried by users to programmatically obtain multiple seismic hazard values.

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