Appendix C
Climatic and Seismic Information for Building Design in Vancouver

This Appendix is included for explanatory purposes only and does not form part of the requirements of this By-law except as referenced from Division A, Sentence 1.1.3.1.(1).

Introduction

The great diversity of climate in British Columbia has a considerable effect on the performance of buildings; consequently, building design must reflect this diversity. This Appendix briefly describes how climatic design values are computed and provides recommended design data for a number of cities, towns, and lesser populated locations. Through the use of such data, appropriate allowances can be made for climate variations in different localities of British Columbia and the By-law can be applied regionally.

The climatic design data presented in Table C-2 are based on weather observations collected by the Atmospheric Environment Service, Environment Canada. The data were researched and analyzed by Environment Canada.

Recommended climatic design values for locations not listed can be obtained by contacting the Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, (416) 739-4365. It should be noted, however, that these recommended values may differ from the legal requirements set by the City of Vancouver.

The information on seismic hazard in spectral format given in Table C-3 has been provided by the Geological Survey of Canada of Natural Resources Canada. Information for municipalities not listed can be obtained at www.earthquakescanada.nrcan.gc.ca or by writing to the Geological Survey of Canada at 7 Observatory Crescent, Ottawa, Ontario K1A 0Y3, or at P.O. Box 6000, Sidney, B.C. V8L 4B2.

General

The choice of climatic elements tabulated in this Appendix and the form in which they are expressed have been dictated largely by the requirements for specific values in several sections of this Code. These elements include the Ground Snow Loads, Wind Pressures, Design Temperatures, Heating Degree-Days, One-Day and 15-Minute Rainfalls, the Annual Total Precipitation values and Seismic Data. The following notes briefly explain the significance of these particular elements in building design, and indicate which weather observations were used and how they were analyzed to yield the required design values.

Table C-2 lists design weather recommendations and elevations for Vancouver. Elevations have been added to Table C-2 because of their potential to significantly influence climatic design values.

Since interpolation from the values in Table C-2 to other locations may not be valid due to local and other effects, Environment Canada will provide climatic design element recommendations where necessary. Local effects are particularly significant in mountainous areas, where the values apply only to populated valleys and not to the mountain slopes and high passes, where very different conditions are known to exist.

Changing and Variable Climates

Climate is not static. At any location, weather and climatic conditions vary from season to season, year to year, and over longer time periods (climate cycles). This has always been the case. In fact, evidence is mounting that the climates of Canada are changing and will continue to change significantly into future. When estimating climatic design loads, this variability can be considered using appropriate statistical analysis, data records spanning sufficient periods, and meteorological judgement. The analysis generally assumes that the past climate will be representative of the future climate.

Past and ongoing modifications to atmospheric chemistry (from greenhouse gas emissions and land use changes) are expected to alter most climatic regimes in the future despite the success of the most ambitious greenhouse gas mitigation plans.[1] Some regions could see an increase in the frequency and intensity of many weather extremes, which will accelerate weathering processes. Consequently, many buildings will need to be designed, maintained and operated to adequately withstand ever changing climatic loads.

Similar to global trends, the last decade in Canada was noted as the warmest in instrumented record. Canada has warmed, on average, at almost twice the rate of the global average increase, while the western Arctic is warming at a rate that is unprecedented over the past 400 years.[1] Mounting evidence from Arctic communities indicates that rapid changes to climate in the North have resulted in melting permafrost and impacts from other climate changes have affected nearly every type of built structure. Furthermore, analyses of Canadian precipitation data shows that many regions of the country have, on average, also been tending towards wetter conditions.[1]

In the United States, where the density of climate monitoring stations is greater, a number of studies have found an unambiguous upward trend in the frequency of heavy to extreme precipitation events, with these increases coincident with a general upward trend in the total amount of precipitation. Climate change model results, based on an ensemble of global climate models worldwide, project that future climate warming rates will be greatest in higher latitude countries such as Canada.[(2)]

In this By-law, future climatic design data projections have been provided based upon climate modelling by the Pacific Climate Impacts Consortium. Given the inherent uncertainty of making future prediction, the provided values can not necessarily be seen to be a wholly accurate prediction of future occurrences. Rather, these projections are intended to be a baseline guide for designers to wishing to consider how their building systems designs will perform in the near future. It is cautioned that complete data is not presently available for all variables, and those values related to snow and wind pressures are derived from fewer data points and are therefore less reliable.

January Design Temperatures

A building and its heating system should be designed to maintain the inside temperature at some pre-determined level. To achieve this, it is necessary to know the most severe weather conditions under which the system will be expected to function satisfactorily. Failure to maintain the inside temperature at the pre-determined level will not usually be serious if the temperature drop is not great and if the duration is not long. The outside conditions used for design should, therefore, not be the most severe in many years, but should be the somewhat less severe conditions that are occasionally but not greatly exceeded.

The January design temperatures are based on an analysis of January air temperatures only. Wind and solar radiation also affect the inside temperature of most buildings and may need to be considered for energy-efficient design.

The January design temperature is defined as the lowest temperature at or below which only a certain small percentage of the hourly outside air temperatures in January occur. In the past, a total of 158 stations with records from all or part of the period 1951-66 formed the basis for calculation of the 2.5 and 1% January temperatures. Where necessary, the data were adjusted for consistency. Since most of the temperatures were observed at airports, design values for the core areas of large cities could be 1 or 2°C milder, although the values for the outlying areas are probably about the same as for the airports. No adjustments were made for this urban island heat effect. The design values for the next 20 to 30 years will probably differ from these tabulated values due to year-to-year climate variability and global climate change resulting from the impact of human activities on atmospheric chemistry.

The design temperatures were reviewed and updated using hourly temperature observations from 480 stations for a 25-year period up to 2006 with at least 8 years of complete data. These data are consistent with data shown for Canadian locations in the 2009 Handbook of Fundamentals[(3)] published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). The most recent 25 years of record were used to provide a balance between accounting for trends in the climate and the sampling variation owing to year-to-year variation. The 1% and 2.5% values used for the design conditions represent percentiles of the cumulative frequency distribution of hourly temperatures and correspond to January temperatures that are colder for 8 and 19 hours, respectively, on average over the long term.

The 2.5% January design temperature is the value ordinarily used in the design of heating systems. In special cases, when the control of inside temperature is more critical, the 1% value may be used. Other temperature-dependent climatic design parameters may be considered for future issues of this document.

July Design Temperatures

A building and its cooling and dehumidifying system should be designed to maintain the inside temperature and humidity at certain pre-determined levels. To achieve this, it is necessary to know the most severe weather conditions under which the system is expected to function satisfactorily. Failure to maintain the inside temperature and humidity at the pre-determined levels will usually not be serious if the increases in temperature and humidity are not great and the duration is not long. The outside conditions used for design should, therefore, not be the most severe in many years, but should be the somewhat less severe conditions that are occasionally but not greatly exceeded.

The summer design temperatures in this Appendix are based on an analysis of July air temperatures and humidities. Wind and solar radiation also affect the inside temperature of most buildings and may, in some cases, be more important than the outside air temperature. More complete summer and winter design information can be obtained from Environment Canada.

The July design dry-bulb and wet-bulb temperatures were reviewed and updated using hourly temperature observations from 480 stations for a 25-year period up to 2006. These data are consistent with data shown for Canadian locations in the 2009 Handbook of Fundamentals[(3)] published by ASHRAE. As with January design temperatures, data from the most recent 25-year period were analyzed to reflect any recent climatic changes or variations. The 2.5% values used for the dry- and wet-bulb design conditions represent percentiles of the cumulative frequency distribution of hourly dry- and wet-bulb temperatures and correspond to July temperatures that are higher for 19 hours on average over the long term.

Heating Degree-Days

The rate of consumption of fuel or energy required to keep the interior of a small building at 21°C when the outside air temperature is below 18°C is roughly proportional to the difference between 18°C and the outside temperature. Wind speed, solar radiation, the extent to which the building is exposed to these elements and the internal heat sources also affect the heat required and may have to be considered for energy-efficient design. For average conditions of wind, radiation, exposure, and internal sources, however, the proportionality with the temperature difference generally still holds.

Since the fuel required is also proportional to the duration of the cold weather, a convenient method of combining these elements of temperature and time is to add the differences between 18°C and the mean temperature for every day in the year when the mean temperature is below 18°C. It is assumed that no heat is required when the mean outside air temperature for the day is 18°C or higher.

Although more sophisticated computer simulations using other forms of weather data have now almost completely replaced degree-day-based calculation methods for estimating annual heating energy consumption, degree-days remain a useful indicator of relative severity of climate and can form the basis for certain climate-related Code requirements.

The degree-days below 18°C were compiled for 1 300 stations for the 25-year period ending in 2006. This analysis period is consistent with the one used to derive the design temperatures described above and with the approach used by ASHRAE.(3)

A difference of only one Celsius degree in the mean annual temperature will cause a difference of 250 to 350 in the Celsius degree-days. Since differences of 0.5 of a Celsius degree in the mean annual temperature are quite likely to occur between two stations in the same town, heating degree-days cannot be relied on to an accuracy of less than about 100 degree-days.

Heating degree-day values for the core areas of larger cities can be 200 to 400 degree-days less (warmer) than for the surrounding fringe areas. The observed degree-days, which are based on daily temperature observations, are often most representative of rural settings or the fringe areas of cities.

Climatic Data for Energy Consumption Calculations

The climatic elements tabulated in this Appendix represent commonly used design values but do not include detailed climatic profiles, such as hourly weather data. Where hourly values of weather data are needed for the purpose of simulating the annual energy consumption of a building, they can be obtained from multiple sources, such as Environment Canada, Natural Resources Canada, the Regional Conservation Authority and other such public agencies that record this information. Hourly weather data are also available from public and private agencies that format this information for use with annual energy consumption simulation software; in some cases, these data have been incorporated into the software.

Snow Loads

The roof of a building should be able to support the greatest weight of snow that is likely to accumulate on it in many years. Some observations of snow on roofs have been made in Canada, but not enough to form the basis for estimating roof snow loads throughout the country. Similarly, observations of the weight, or water equivalent, of the snow on the ground have not been available in digital form in the past. The observations of roof loads and water equivalents are very useful, as noted below, but the measured depth of snow on the ground is used to provide the basic information for a consistent set of snow loads.

The estimation of the design snow load on a roof from snow depth observations involves the following steps:

(a) The depth of snow on the ground, which has an annual probability of exceedance of 1-in-50, is computed.

(b) The appropriate unit weight is selected and used to convert snow depth to loads, S_s.

(c) The load, S_r, which is due to rain falling on the snow, is computed.

(d) Because the accumulation of snow on roofs is often different from that on the ground, adjustments are applied to the ground snow load to provide a design snow load on a roof.

The annual maximum depth of snow on the ground has been assembled for 1 618 stations for which data has been recorded by the Atmospheric Environment Service (AES). The period of record used varied from station to station, ranging from 7 to 38 years. These data were analyzed using a Gumbel extreme value distribution fitted using the method of moments(4) as reported by Newark et al.(5) The resulting values are the snow depths, which have a probability of 1-in-50 of being exceeded in any one year.

The unit weight of old snow generally ranges from 2 to 5 kN/m^3, and it is usually assumed in Canada that 1 kN/m^3 is the average for new snow. Average unit weights of the seasonal snow pack have been derived for different regions across the country(6) and an appropriate value has been assigned to each weather station. Typically, the values average 2.01 kN/m^3 east of the continental divide (except for 2.94 kN/m^3 north of the treeline), and range from 2.55 to 4.21 kN/m^3 west of the divide. The product of the 1-in-50 snow depth and the average unit weight of the seasonal snow pack at a station is converted to the snow load (SL) in units of kilopascals (kPa).

Except for the mountainous areas of western Canada, the values of the ground snow load at AES stations were normalized assuming a linear variation of the load above sea level in order to account for the effects of topography. They were then smoothed using an uncertainty-weighted moving-area average in order to minimize the uncertainty due to snow depth sampling errors and site-specific variations. Interpolation from analyzed maps of the smooth normalized values yielded a value for each location in Table C-2, which could then be converted to the listed By-law values (S_s) by means of an equation in the form:

$$S_s = \text{smooth normalized SL} + bZ$$

where b is the assumed rate of change of SL with elevation at the location and Z is the location's elevation above mean sea level (MSL). Although they are listed in Table C-2 to the nearest tenth of a kilopascal, values of S_s typically have an uncertainty of about 20%. Areas of sparse data in northern Canada were an exception to this procedure. In these regions, an analysis was made of the basic SL values. The effects of topography, variations due to local climates, and smoothing were all subjectively assessed. The values derived in this fashion were used to modify those derived objectively.

For the mountainous areas of British Columbia, a more complex procedure was required to account for the variation of loads with terrain and elevation. Since the AES observational network often does not have sufficient coverage to detail this variability in mountainous areas, additional snow course observations were obtained from the provincial government of British Columbia. The additional data allowed detailed local analysis of ground snow loads on a valley-by-valley basis. Similar to other studies, the data indicated that snow loads above a critical or reference level increased according to either a linear or quadratic relation with elevation. The determination of whether the increase with elevation was linear or quadratic, the rate of the increase and the critical or reference elevation were found to be specific to the valley and mountain ranges considered. At valley levels below the critical elevation, the loads generally varied less significantly with elevation. Calculated valley- and range-specific regression relations were then used to describe the increase of load with elevation and to normalize the AES snow observations to a critical or reference level. These normalized values were smoothed using a weighted moving-average.

Tabulated values cannot be expected to indicate all the local differences in S_s. For this reason, especially in complex terrain areas, values should not be interpolated from Table C-2 for unlisted locations. The values of S_s in the Table apply for the elevation and the latitude and longitude of the location, as defined by the Gazetteer of Canada. Values at other locations can be obtained from Environment Canada.

The heaviest loads frequently occur when the snow is wetted by rain, thus the rain load, S_r, was estimated to the nearest 0.1 kPa and is provided in Table C-2. When values of S_r are added to S_s, this provides a 1-in-50-year estimate of the combined ground snow and rain load. The values of S_r are based on an analysis of about 2 100 weather station values of the 1-in-50-year one-day maximum rain amount. This return period is appropriate because the rain amounts correspond approximately to the joint frequency of occurrence of the one-day rain on maximum snow packs. For the purpose of estimating rain on snow, the individual observed one-day rain amounts were constrained to be less than or equal to the snow pack water equivalent, which was estimated by a snow pack accumulation model reported by Bruce and Clark.[7]

The results from surveys of snow loads on roofs indicate that average roof loads are generally less than loads on the ground. The conditions under which the design snow load on the roof may be taken as a percentage of the ground snow load are given in Subsection 4.1.6. The By-law also permits further decreases in design snow loads for steeply sloping roofs, but requires substantial increases for roofs where snow accumulation may be more rapid due to such factors as drifting. Recommended adjustments are given in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

The ground snow load values, S_s, were updated for this edition of the By-law using a similar approach to the one used for the ground snow load update in the 1990 NBC, which was the basis for the 1992 British Columbia Building Code. The Gumbel extreme value distribution was fitted to the annual maxima of daily snow depth observations made at over 1 400 weather stations, which were compiled from 1990 onward – to as recently as 2012 for some stations – to calculate the 50-year return period snow depth. The 50-year ground snow load was then calculated for each weather station by combining the 50-year snow pack depth with the assigned snow pack density. The S_s values for each location in Table C-2 were compared with the updated weather station values and revised accordingly.

Annual Total Precipitation

Total precipitation is the sum in millimetres of the measured depth of rainwater and the estimated or measured water equivalent of the snow (typically estimated as 0.1 of the measured depth of snow, since the average density of fresh snow is about 0.1 that of water).

The average annual total precipitation amounts in Table C-2 have been interpolated from an analysis of precipitation observations from 1 379 stations for the 30-year period from 1961 to 1990.

Annual Rainfall

The total amount of rain that normally falls in one year is frequently used as a general indication of the wetness of a climate, and is therefore included in this Appendix. See also Moisture Index below.

Rainfall Intensity

Roof drainage systems are designed to carry off rainwater from the most intense rainfall that is likely to occur. A certain amount of time is required for the rainwater to flow across and down the roof before it enters the gutter or drainage system. This results in the smoothing out of the most rapid changes in rainfall intensity. The drainage system, therefore, need only cope with the flow of rainwater produced by the average rainfall intensity over a period of a few minutes, which can be called the concentration time.

In Canada, it has been customary to use the 15-minute rainfall that will probably be exceeded on an average of once in 10 years. The concentration time for small roofs is much less than 15 minutes and hence the design intensity will be exceeded more frequently than once in 10 years. The safety factors in Book II (Plumbing Systems) of this By-law will probably reduce the frequency to a reasonable value and, in addition, the occasional failure of a roof drainage system will not be particularly serious in most cases.

The rainfall intensity values were updated for the 2014 edition of the By-law using observations of annual maximum 15-minute rainfall amounts from 485 stations with 10 or more years of record, including data up to 2007 for some stations. Ten-year return period values – the 15-minute rainfall having a probability of 1-in-10 of being exceeded in any year – were calculated by fitting the annual maximum values to the Gumbel extreme value distribution[4] using the method of moments. The updated values are compiled from the most recent short-duration rainfall intensity-duration-frequency (IDF) graphs and tables available from Environment Canada.

It is very difficult to estimate the pattern of rainfall intensity in mountainous areas, where precipitation is extremely variable and rainfall intensity can be much greater than in other types of areas. Many of the observations for these areas were taken at locations in valley bottoms or in extensive, fairly level areas.

One-Day Rainfall

If for any reason a roof drainage system becomes ineffective, the accumulation of rainwater may be great enough in some cases to cause a significant increase in the load on the roof. In previous editions of this information, it had been common practice to use the maximum one-day rainfall ever observed for estimating the additional load. Since the length of record for weather stations is quite variable, the maximum one-day rainfall amounts in previous editions often reflected the variable length of record at nearby stations as much as the climatology. As a result, the maximum values often differed greatly within relatively small areas where little difference should be expected. The current values have been standardized to represent the one-day rainfall amounts that have 1 chance in 50 of being exceeded in any one year or the 1-in-50-year return value one-day rainfalls.

The one-day rainfall values were updated using daily rainfall observations from more than 3 500 stations with 10 years or more of record, including data up to 2008 for some stations. The 50-year return period values were calculated by fitting the annual maximum one-day rainfall observations to the Gumbel extreme value distribution using the method of moments.[4]

Rainfall frequency observations can vary considerably over time and space. This is especially true for mountainous areas, where elevation effects can be significant. In other areas, small-scale intense storms or local influences can produce significant spatial variability in the data. As a result, the analysis incorporates some spatial smoothing.

Moisture Index (MI)

Moisture index (MI) values were developed through the work of a consortium that included representatives from industry and researchers from NRC.[1] The MI is an indicator of the moisture load imposed on a building by the climate and is used in Part 9 to define the minimum levels of protection from precipitation to be provided by cladding assemblies on exterior walls.

It must be noted, in using MI values to determine the appropriate levels of protection from precipitation, that weather conditions can vary markedly within a relatively small geographical area. Although the values provided in the Table give a good indication of the average conditions within a particular region, some caution must be exercised when applying them to a locality that is outside the region where the weather station is located.

MI is calculated from a wetting index (WI) and a drying index (DI).

Wetting Index (WI)

To define, quantitatively, the rainwater load on a wall, wind speed and wind direction have to be taken into consideration in addition to rainfall, along with factors that can affect exposure, such as nearby buildings, vegetation and topography. Quantitative determination of load, including wind speed and wind direction, can be done. However, due to limited weather data, it is not currently possible to provide this information for most of the locations identified in the Table.

This lack of information, however, has been shown to be non-critical for the purpose of classifying locations in terms of severity of rain load. The results of the research indicated that simple annual rainfall is as good an indicator as any for describing rainwater load. That is to say, for Canadian locations, and especially once drying is accounted for, the additional sensitivity provided by hourly directional rainfall values does not have a significant effect on the order in which locations appear when listed from wet to dry.

Consequently, the wetting index (WI) is based on annual rainfall and is normalized based on 1 000 mm.

Drying Index (DI)

Temperature and relative humidity together define the drying capacity of ambient air. Based on simple psychrometrics, values were derived for the locations listed in the Table using annual average drying capacity normalized based on the drying capacity at Lytton, B.C. The resultant values are referred to as drying indices (DI).

Determination of Moisture Index (MI)

The relationship between WI and DI to correctly define moisture loading on a wall is not known. The MI values provided in the Table are based on the root mean square values of WI and 1-DI, with those values equally weighted. This is illustrated in Figure C-1. The resultant MI values are sufficiently consistent with industry's understanding of climate severity with respect to moisture loading as to allow limits to be identified for the purpose of specifying where additional protection from precipitation is required.

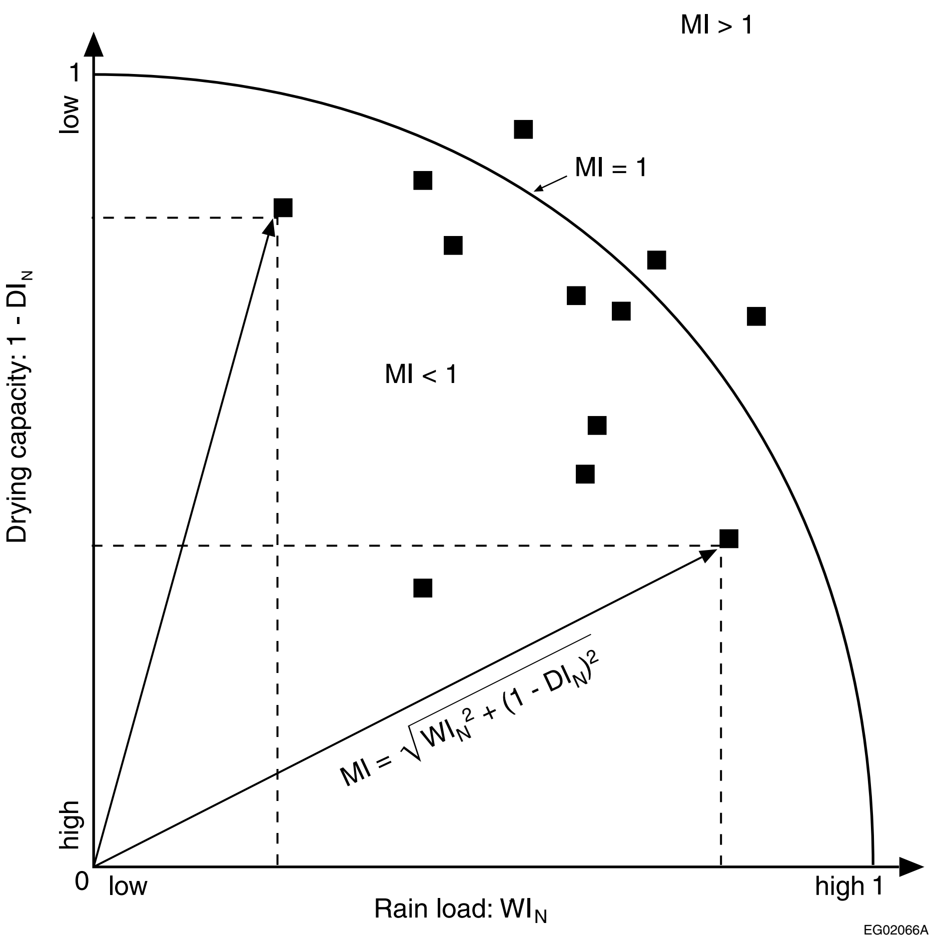

Figure C-1 Derivation of moisture index (MI) based on normalized values for wetting index (WI) and drying index (DI)

Note to Figure C-1:

(1) MI equals the hypotenuse of the triangle defined by W_{IN} and $1\text{-}D_{IN}$

Driving Rain Wind Pressure (DRWP)

The presence of rainwater on the face of a building, with or without wind, must be addressed in the design and construction of the building envelope so as to minimize the entry of water into the assembly. Wind pressure on the windward faces of a building will promote the flow of water through any open joints or cracks in the facade.

Driving rain wind pressure (DRWP) is the wind load that is coincident with rain, measured or calculated at a height of 10 m. The values provided in the Table represent the loads for which there is 1 chance in 5 of being reached or exceeded in any one year, or a probability of 20% within any one year. Approximate adjustments for height can be made using the values for C_e given in Sentence 4.1.7.3.(5) as a multiplier.

Because of inaccuracies in developing the DRWP values related to the averaging of extreme wind pressures, the actual heights of recording anemometers, and the use of estimated rather than measured rainfall values, the values are considered to be higher than actual loads.[(8)(9)] Thus the actual probability of reaching or exceeding the DRWP in a particular location is less than 20% per year and these values can be considered to be conservative.

DRWP can be used to determine the height to which wind will drive rainwater up enclosed vertical conduits. This provides a conservative estimate of the height needed for fins in window extrusions and end dams on flashings to control water ingress. This height can be calculated as:

$$\text{height of water, mm} = \text{DRWP} / 10, \text{Pa}$$

Note that the pressure difference across the building envelope may be augmented by internal pressures induced in the building interior by the wind. These additional pressures can be estimated using the information provided in the Commentary entitled Wind Load and Effects of the “User’s Guide – NBC 2015, Structural Commentaries (Part 4 of Division B).”

Wind Effects

All structures need to be designed to ensure that the main structural system and all secondary components, such as cladding and appurtenances, will withstand the pressures and suctions caused by the strongest wind likely to blow at that location in many years. Some flexible structures, such as tall buildings, slender towers and bridges, also need to be designed to minimize excessive wind-induced oscillations or vibrations.

At any time, the wind acting upon a structure can be treated as a mean or time-averaged component and as a gust or unsteady component. For a small structure, which is completely enveloped by wind gusts, it is only the peak gust velocity that needs to be considered. For a large structure, the wind gusts are not well correlated over its different parts and the effects of individual gusts become less significant. The “User’s Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)” evaluates the mean pressure acting on a structure, provide appropriate adjustments for building height and exposure and for the influence of the surrounding terrain and topography (including wind speed-up for hills), and then incorporate the effects of wind gusts by means of the gust factor, which varies according to the type of structure and the size of the area over which the pressure acts.

The wind speeds and corresponding velocity pressures used in the By-law are regionally representative or reference values. The reference wind speeds are nominal one-hour averages of wind speeds representative of the 10 m height in flat open terrain corresponding to Exposure A or open terrain in the terminology of the “User’s Guide – NBC 2015, Structural Commentaries (Part 4 of Division B).” The reference wind speeds and wind velocity pressures are based on long-term wind records observed at a large number of weather stations across Canada.

Reference wind velocity pressures in previous versions of the By-law since 1961 were based mostly on records of hourly averaged wind speeds (i.e. the number of miles of wind passing an anemometer in an hour) from over 100 stations with 10 to 22 years of observations ending in the 1950s. The wind pressure values derived from these measurements represented true hourly wind pressures.

The reference wind velocity pressures were reviewed and updated for the 2014 edition of the By-law. The primary data set used for the analysis comprised wind records compiled from about 135 stations with hourly averaged wind speeds and from 465 stations with aviation (one- or two-minute average) speeds or surface weather (ten-minute average) speeds observed once per hour at the top of the hour; the periods of record used ranged from 10 to 54 years. In addition, peak wind gust records from 400 stations with periods of record ranging from 10 to 43 years were used. Peak wind gusts (gust durations of approximately 3 to 7 seconds) were used to supplement the primary once-per-hour observations in the analysis.

Several steps were involved in updating the reference wind values. Where needed, speeds were adjusted to represent the standard anemometer height above ground of 10 m. The data from years when the anemometer at a station was installed on the top of a lighthouse or building were eliminated from the analysis since it is impractical to adjust for the effects of wind flow over the structure. (Most anemometers were moved to 10 m towers by the 1960s.) Wind speeds of the various observation types – hourly averaged, aviation, surface weather and peak wind gust – were adjusted to account for different measure durations to represent a one-hour averaging period and to account for differences in the surface roughness of flat open terrain at observing stations.

The annual maximum wind speed data was fitted to the Gumbel distribution using the method of moments[(4)] to calculate hourly wind speeds having the annual probability of occurrence of 1-in-10 and 1-in-50 (10-year and 50-year return periods). The values were plotted on maps, then analyzed and abstracted for the locations in Table C-2.

The wind velocity pressures, q, were calculated in Pascals using the following equation:

$$q = \frac{1}{2}\rho V^2$$

where ρ is an average air density for the windy months of the year and V is wind speed in metres per second. While air density depends on both air temperature and atmospheric pressure, the density of dry air at 0°C and standard atmospheric pressure of 1.2929 kg/m^3 was used as an average value for the wind pressure calculations. As explained by Boyd[(10)], this value is within 10% of the monthly average air densities for most of Canada in the windy part of the year.

As a result of the updating procedure, the 1-in-50 reference wind velocity pressures remain unchanged for most of the locations listed in Table C-2; both increases and decreases were noted for the remaining locations. Many of the decreases resulted from the fact that anemometers at most of the stations used in the previous analysis were installed on lighthouses, airport hangers and other structures. Wind speeds on the tops of buildings are often much higher compared to those registered by a standard 10 m tower. Eliminating anemometer data recorded on the tops of buildings from the analysis resulted in lower values at several locations.

Hourly wind speeds that have 1 chance in 10 and 50[(1)] of being exceeded in any one year were analyzed using the Gumbel extreme value distribution fitted using the method of moments with correction for sample size. Values of the 1-in-30-year wind speeds for locations in the Table were estimated from a mapping analysis of wind speeds. The 1-in-10- and 1-in-50-year speeds were then computed from the 1-in-30-year speeds using a map of the dispersion parameter that occurs in the Gumbel analysis.[(4)]

Table C-1 has been arranged to give pressures to the nearest one-hundredth of a kPa and their corresponding wind speeds. The value of "q" in kPa is assumed to be equal to 0.00064645 V^2, where V is given in m/s.

[1] Wind speeds that have a one-in-"n"-year chance of being exceeded in any year can be computed from the one-in-10 and one-in-50 return values in the Table using the following equation:

$$V_{1/n} = \frac{1}{1.4565}\left\{V_{1/50} + 0.4565\,V_{1/10} + \frac{V_{1/50} - V_{1/10}}{1.1339} \times \ln\frac{-0.0339}{\ln(1-1/n)}\right\}$$

Table C-1
Wind Speeds

q	V	q	V	q	V	q	V
kPa	m/s	kPa	m/s	kPa	m/s	kPa	m/s
0.15	15.2	0.53	28.6	0.91	37.5	1.29	44.7
0.16	15.7	0.54	28.9	0.92	37.7	1.30	44.8
0.17	16.2	0.55	29.2	0.93	37.9	1.31	45.0
0.18	16.7	0.56	29.4	0.94	38.1	1.32	45.2
0.19	17.1	0.57	29.7	0.95	38.3	1.33	45.4
0.20	17.6	0.58	30.0	0.96	38.5	1.34	45.
0.21	18.0	0.59	30.2	0.97	38.7	1.35	45.7
0.22	18.4	0.60	30.5	0.98	38.9	1.36	45.9
0.23	18.9	0.61	30.7	0.99	39.1	1.37	46.0
0.24	19.3	0.62	31.0	1.00	39.3	1.38	46.2
0.25	19.7	0.63	31.2	1.01	39.5	1.39	46.4
0.26	20.1	0.64	31.5	1.02	39.7	1.40	46.5
0.27	20.4	0.65	31.7	1.03	39.9	1.41	46.7
0.28	20.8	0.66	32.0	1.04	40.1	1.42	46.9
0.29	21.2	0.67	32.2	1.05	40.3	1.43	47.0
0.30	21.5	0.68	32.4	1.06	40.5	1.44	47.2
0.31	21.9	0.69	32.7	1.07	40.7	1.45	47.4
0.32	22.2	0.70	32.9	1.08	40.9	1.46	47.5
0.33	22.6	0.71	33.1	1.09	41.1	1.47	47.7
0.34	22.9	0.72	33.4	1.10	41.3	1.48	47.8
0.35	23.3	0.73	33.6	1.11	41.4	1.49	48.0
0.36	23.6	0.74	33.8	1.12	41.6	1.50	48.2
0.37	23.9	0.75	34.1	1.13	41.8	1.51	48.3
0.38	24.2	0.76	34.3	1.14	42.0	1.52	48.5
0.39	24.6	0.77	34.5	1.15	42.2	1.53	48.6
0.40	24.9	0.78	34.7	1.16	42.4	1.54	48.8
0.41	25.2	0.79	35.0	1.17	42.5	1.55	49.0
0.42	25.5	0.80	35.2	1.18	42.7	1.56	49.1
0.43	25.8	0.81	35.4	1.19	42.9	1.57	49.3
0.44	26.1	0.82	35.6	1.20	43.1	1.58	49.4
0.45	26.4	0.83	35.8	1.21	43.3	1.59	49.6
0.46	26.7	0.84	36.0	1.22	43.4	1.60	49.7
0.47	27.0	0.85	36.3	1.23	43.6	1.61	49.9
0.48	27.2	0.86	36.5	1.24	43.8	1.62	50.1
0.49	27.5	0.87	36.7	1.25	44.0	1.63	50.2
0.50	27.8	0.88	36.9	1.26	44.1	1.64	50.4
0.51	28.1	0.89	37.1	1.27	44.3	1.65	50.5
0.52	28.4	0.90	37.3	1.28	44.5	1.66	50.7

Table C-2
Climatic Design Data for Selected Locations in Vancouver

Location	Elev., m	Design Temperature				Degree-Days Below 18°C	15 Min. Rain, mm	One Day Rain, 1/50, mm	Ann. Rain, mm	Moist. Index	Ann. Tot. Ppn., mm	Driving Rain Wind Pressures, Pa, 1/5	Snow Load, kPa, 1/50		Hourly Wind Pressures, kPa	
		January		July 2.5%												
		2.5% °C	1% °C	Dry °C	Wet °C								Ss	Sr	1/10	1/50
Vancouver (General)	120	-6	-8	28	20	2925	10	107	1325	1.44	1400	160	1.9	0.3	0.35	0.45
Vancouver (2020s)	120	-4	-6	30	22	2471	n/a	117	1350	n/a	n/a	n/a	1.8	n/a	0.36	0.43
Vancouver (2050s)	120	-2	-4	32	24	2102	n/a	127	1371	n/a	n/a	n/a	1.7	n/a	0.36	0.43

Seismic Hazard

The parameters used to represent seismic hazard for specific geographical locations are the 5% damped horizontal spectral acceleration for 0.2, 0.5, 1.0, 2.0, 5.0 and 10.0 second periods, the horizontal Peak Ground Acceleration (PGA) and the horizontal Peak Ground Velocity (PGV), with all values given for a 2% probability of being exceeded in 50 years. The six spectral parameters are deemed sufficient to define spectra closely matching the shape of the Uniform Hazard Spectra (UHS). Hazard values are mean values based on a statistical analysis of the earthquakes that have been experienced in Canada and adjacent regions.[11] The seismic hazard values were updated for this edition of the By-law by updating the earthquake catalogue, revising the seismic source zones, adding fault sources for the Cascadia subduction zone and certain other active faults, revising the Ground Motion Prediction Equations (GMPEs),[12] and using a probabilistic model to combine all inputs.

For most locations, the new GMPEs are the most significant reason for changes in the hazard results from the 2014 By-law. One exception is for areas of western Canada for which adding the Cascadia subduction source contribution to the model probabilistically causes the most significant change. For locations in western Canada, the seismic hazard at long periods has increased significantly for areas affected by the Cascadia interface. For other areas, the explicit inclusion of fault sources, such as those in Haida Gwaii, has also affected the estimated hazard.

Further details regarding the representation of seismic hazard can be found in the Commentary on Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

Table C-3
Seismic Design Data for Selected Locations in Vancouver

Location	Seismic Data							
	$S_a(0.2)$	$S_a(0.5)$	$S_a(1.0)$	$S_a(2.0)$	$S_a(5.0)$	$S_a(10.0)$	PGA	PGV
Burnaby (General)(1) 0.768	0.673	0.386	0.236	0.076	0.027	0.333	0.500	
North Vancouver(1) 0.794	0.699	0.399	0.243	0.077	0.027	0.345	0.518	
Richmond(1) 0.885	0.787	0.443	0.266	0.083	0.029	0.383	0.578	
Vancouver (City Hall)	0.848	0.751	0.425	0.257	0.080	0.029	0.369	0.553
Vancouver (Granville & 41 Ave)	0.863	0.765	0.432	0.261	0.081	0.029	0.375	0.563

Notes to Table C-3:

(1) Data for regions immediately adjoining Vancouver provided here for context.

References

1. Environment Canada, Climate Trends and Variation Bulletin: Annual 2007, 2008.

2. Intergovernmental Panel on Climate Change (IPCC), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp., 2007.

3. American Society of Heating, Refrigerating, and Air-conditioning Engineers, Handbook of Fundamentals, Chapter 14 – Climatic Design Information, Atlanta, GA, 2009.

4. Lowery, M.D. and Nash, J.E., A comparison of methods of fitting the double exponential distribution. J. of Hydrology, 10 (3), pp. 259–275, 1970.

5. Newark, M.J., Welsh, L.E., Morris, R.J. and Dnes, W.V. Revised Ground Snow Loads for the 1990 NBC of Canada. Can. J. Civ. Eng., Vol. 16, No. 3, June 1989.

6. Newark, M.J. A New Look at Ground Snow Loads in Canada. Proceedings, 41st Eastern Snow Conference, Washington, D.C., Vol. 29, pp. 59-63, 1984.

7. Bruce, J.P. and Clark, R.H. Introduction to Hydrometeorology. Pergammon Press, London, 1966.

8. Skerlj, P.F. and Surry, D. A Critical Assessment of the DRWPs Used in CAN/CSA-A440-M90. Tenth International Conference on Wind Engineering, Wind Engineering into the 21st Century, Larsen, Larose & Livesay (eds), 1999 Balkema, Rotterdam, ISBN 90 5809 059 0.

9. Cornick, S., Chown, G.A., et al. Committee Paper on Defining Climate Regions as a Basis for Specifying Requirements for Precipitation Protection for Walls. Institute for Research in Construction, National Research Council, Ottawa, April 2001.

10. Boyd, D.W. Variations in Air Density over Canada. National Research Council of Canada, Division of Building Research, Technical Note No. 486, June 1967.

11. Adams, J., Halchuk, S., Allen, T.I., and Rogers, G.C. Fifth Generation seismic hazard model and values for the 2015 National Building Code of Canada. Geological Survey of Canada Open File, 2014.

12. Atkinson, G. M. and Adams J. Ground motion prediction equations for application to the 2015 Canadian national seismic hazard maps, Can. J. Civ. Eng. 40, 988–998, 2013.

Table C-4 [Deleted.]

Table C-5
Required Performance of Windows and Doors in Part 9 Buildings(1)
Forming part of Appendix C

Location	Climatic Data		Specified Loads		NAFS			
	1/5 DRWP	1/50 HWP	DRWP	Wind Load	Required Fenestration Performance			
	Pa	kPa	Pa	Pa	(psf)	DP	PG	Water Resist.
Vancouver	160	0.45	160	911	19.03	960	20	180

Notes to Table C-5:

(1) Table C-5 may not be used for skylights. (See Sentence 9.7.4.3.(1).)