A NEW LOOK AT GROUND SNOW LOADS IN CANADA

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ABSTRACT

The last recalculation of ground snow load values was performed by Environment Canada for the 1977 edition of the Supplement to the National Building Code. Since that time, an examination has been made of the meteorological variables (density of the annual snow pack for example) which are elements of the ground snow load, and their properties have been reassessed. The methodology by which the variable values are derived has also been somewhat changed. Computer techniques have been utilized to help calculate new values (and their errors) at more than 1800 meteorological observing stations using the latest available data set (mainly the 1951 to 1980 period).

HISTORICAL PERSPECTIVE

The mathematical expression for a snow load on a horizontal surface (such as the ground) is derived as follows:

$$F = mg$$

$$\text{The ground snow load GSL} = FA^{-1}$$

$$= g(V\rho)\ A^{-1}$$

$$= g(hA\rho)\ A^{-1}$$

$$= g(h\rho) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

(F = force; m = mass; g = acceleration due to gravity; A = area; V = volume; ρ = density; h = height)

The Period 1941 to 1960

Snow load calculations were first published in the 1941 Building Code of Canada by the National Research Council. They were derived from the equation L = S + R (Thomas, 1955) where L is the snow load on a flat roof, S is the sum of the average snowfalls in January, February and March over a number of years and R is correspondingly the average rainfall in inches. This method did not take into account the maximum loads which can result from extreme rain-soaked snowfalls and the calculated values were mostly underestimated when compared to the results of modern accepted methods.

In the early 1950's Thomas introduced changes in the method of calculating the ground snow load which overcame this problem. He used an equation of the following form (although it is not explicitly stated in his paper) which follows logically from equation 1,

$$GSL_{max} = 5[(S.D._{max} \times S.G._{snow}) + R_{24\ max}] \quad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

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where, GSL_{max} is the maximum snow load on a horizontal surface

$S.D._{max}$ is the maximum reported snow depth

$S.G._{snow}$ is the specific gravity of snow (arbitrarily set at 0.2 times that of water)

R_{24} max is the estimated maximum 24 hour rainfall

5 is the approximate conversion factor to change units from inches of water to pounds per square foot.

The results obtained were more useful than previous efforts and more consistent with modern values, but still suffered from being too low. A map of the GSL was published (National Research Council, 1953; Thomas, 1955) but was based on only 10 years of data from 1941 to 1950. Furthermore, Thomas explicitly states that the isolines were kept as smooth as possible.

This is surprising in view of the fact that snowfall is not distributed in a geographically homogeneous fashion, and is very dependant upon topography. Furthermore the map contains several inconsistencies as follows; (a) greater loads are shown to the lee of Lake Huron/Georgian Bay than to the lee of Lake Superior, while the reverse is more likely, based upon snowfall climatology; (b) the greatest loads anywhere in Canada are shown in Labrador and adjacent Québec which is clearly not the case given the much greater snowfalls in the two major mountain ranges of B.C. Although Thomas explains that the load values apply to valley-bottom stations, the map divorced from its accompanying text is misleading (a criticism which was also made by Turkstra, 1959).

As an extension of this work, computed maximum snow loads were later published (Thomas and Boyd, 1958) for 170 stations across Canada.

The Period 1961 to 1980

For the 1961 National Building Code, a set of new GSL values were computed (Boyd, 1961) for more than 200 meteorological stations. This time, Gumbel's extreme value method (Gumbel, 1954) was employed to find the depth of snow on the ground that would be equalled or exceeded once in 30 years. Again, the specific gravity of snow was assumed to be 0.2 times that of water everywhere in Canada although it was stated that the range was from 0.2 to 0.4. The maximum one-day rainfall used was that found during the 2 or 3 month period of the year when snow depths are greatest. From the calculated set of values, estimates were made for another 300 or so locations across Canada.

The equation used to calculate the ground snow load was apparently as follows (no explicit reference to it has been found in the literature) and was in Imperial units;

$$GSL_{1/30} = g(S_{1/30}\, \rho_s + R_{24}\, \rho_w) \quad \ldots\ldots\ldots\ldots 3$$

where $GSL_{1/30}$ is the once in 30-year return ground snow load

g is the acceleration due to gravity

$S_{1/30}$ is the once in 30-year return maximum snow depth

ρ_s is the density of snow

R_{24} is the maximum 24-hour rainfall in months which receive significant snow (generally December to March)

ρ_w is the density of water

A further improvement at this time was Boyd's attempt to deal with the problems introduced by different methods employed by the Meterological Service to observe snow depth (see section 3.2).

His 1961 map of the maximum snow load on the ground showed values that were up to 33% greater in some areas than those of Thomas. Also, the greatest loads in B.C. now equalled the greatest loads in eastern Canada, Boyd again noted that much greater snow loads were known to exist on the higher mountain slopes than at valley bottoms but made no attempt to deal with this problem either on the published map or on his much larger scale working maps.

Although in general the 1961 map was significantly improved over the 1953 version, the problem with snow loads to the lee of the Great Lakes was accentuated still further. Loads to the lee of Lake Huron were mapped as much as 40% greater than to the lee of Lake Superior, Furthermore, they were larger in value than those shown over the Long Range Mountain area of Newfoundland, and equal to those shown over the coastal mountains of B.C. Clearly, his map was misleading in some aspects of its presentation due to the problem posed by topographical variations in snowfall.

Boyd's 1961 GSL map was published unchanged in the 1965, 1970 and 1975 National Building Codes and the lists of GSL values for over 600 locations remained virtually the same during that period. It is not now known with certainty which of these values were calculated and which were estimated. In the 1977 Code, Boyd appears to have recalculated values for about 480 stations for periods ranging from 5 to 31 years. About one-quarter of them had records of at least 20 years, which Boyd stated was much more information than was used for previous estimates of snow loads. No map was published of the 1977 values, but working maps exist which continue to show the same shortcomings as the earlier published map. With very few changes, the 1977 values were republished in the 1980 code, again without a map.

CURRENT WORK

Current work on updating the GSL calculations has proceeded along the same basic path, i.e. using Gumbel's extreme value method to obtain the maximum snow depths and adding the maximum 24-hour rain according to equation 3. Data from 1596 meteorological stations measuring daily and/or month-end snow depths has been utilized. Additionally, snow loads have been calculated for 293 snow course stations in British Columbia for which snow water equivalent measurements are available. In this case the following equation is used,

$$GSL_{1/30} = g(\rho_w W_{e_{1/30}}) \quad \ldots\ldots\ldots\ldots\ldots 4$$

where $W_{e_{1/30}}$ is the once in 30-year return maximum snow water equivalent depth.

Of the total number of stations (1889), 1091 Atmospheric Environment Service stations and 151 B.C. Ministry of Environment snow courses have 15 or more years of data, and the remainder have no less than 10 years. The period of record is mainly the interval between 1951 and 1980, but records from as early as 1935 are available for some B.C. snow courses.

DIFFERENCES IN PROCEDURE FROM EARLIER WORK

Some differences from earlier procedures have been instituted in recent work. These are comprised of (a) a re-evaluation of the snow density term in equation 3; (b) a revised method of correcting maximum snow depths measured at month-end to make them more consistent with maximum snow depths determined from daily measurements; (c) a recalculation of the maximum 24-hour winter rain. Furthermore, a subjective technique of spatial analysis has been used to produce a national map of GSL values (see Figure 1). This technique is based upon the assumption that topographic elevation is a major control on the spatial distribution of snow depth and hence on GSL values. Some smoothing of the values is suggested as a consequence of this analysis, and in the table of results a flag has been placed beside values which are inconsistent with the map. Additionally, the standard error in the GSL values has been calculated as discussed in section 4.1

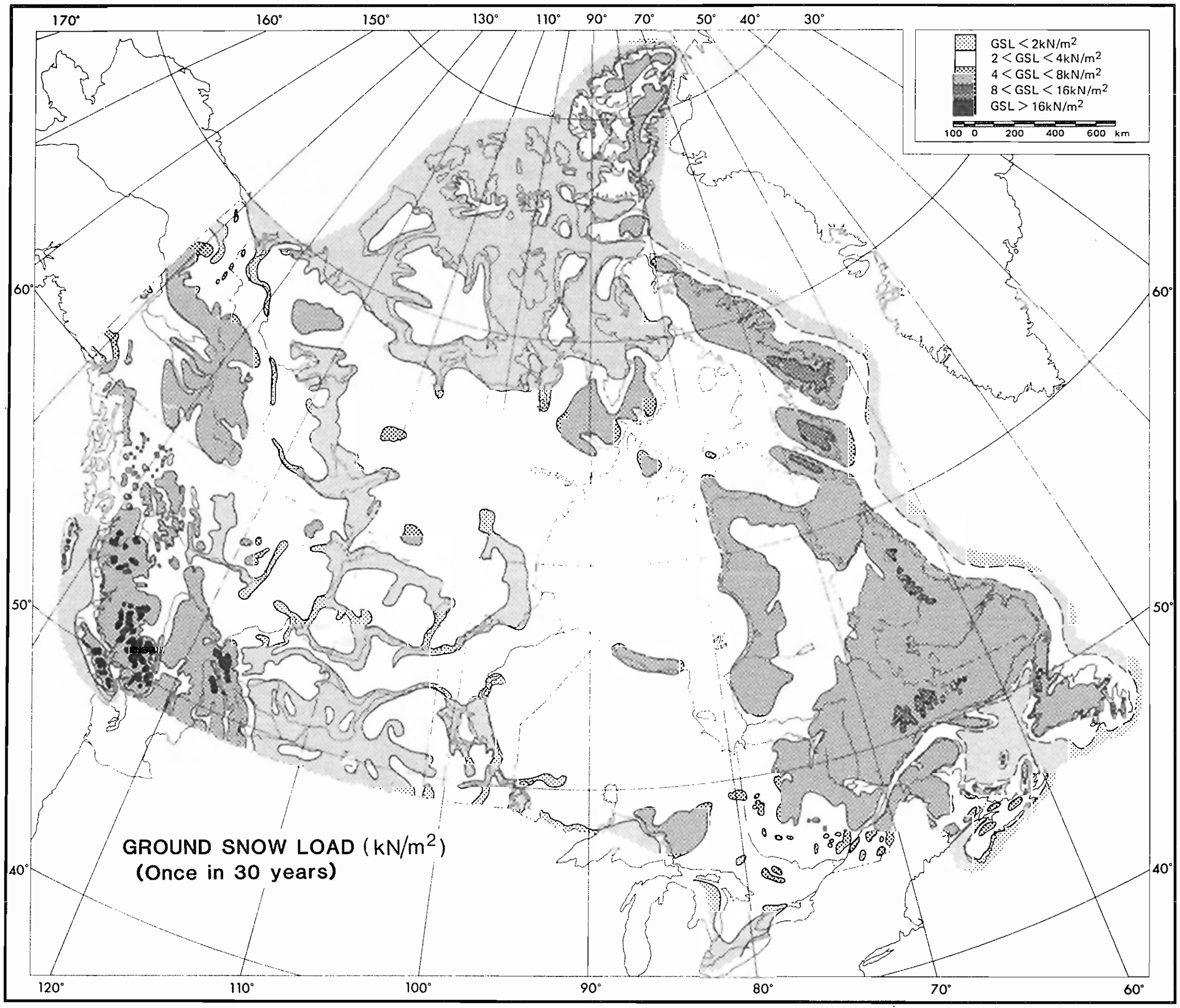

FIGURE 1

Snow Density

It is an understatement to say that determining a representative value of snow density for a particular location is a complicated problem (for example see Longley, 1960). Snow density has been the subject of many investigators using many techniques and according to the literature (Mckay and Gray, 1981; Nord and Taesler, 1973; Yen, 1969; Eagleson, 1970; Tobiasson and Redfield, 1977; Dingman et al, 1978; McKay and Findlay, 1971) can vary from as little as 10 kg/m³ in the case of wild snow to as much as 700 kg/m³ in the case of thawing firn snow.

The 1971 work of McKay and Findlay in classifying average snow density by forest region is particularly useful and has been adapted for use in the current work. Basically they reasoned that forest type in Canada is governed to a large degree by climatic conditions. They then identified 11 regions of forest types, namely boreal, subalpine, montane, coast, columbia, taiga, tundra, aspen grove, prairie, Great Lakes, St. Lawrence and acadian. Using data from 230 snow courses they derived the means and standard deviations of seasonal snow pack density in each region and also the variation of snow density with time. Their results indicate a range of mean density from 190 to 390 kg/m³ during the non-melt period of the year and from 240 to 430 kg/m³ during the spring-melt period. These values tend to agree with earlier published results (Williams and Gold, 1958) showing a range from 220 to 370 kg/m³ for a far more limited national sample of snow course stations.

In order to check the work of McKay and Findlay, average seasonal density values have been derived from summary data published (British Columbia, 1980) for 332 snow courses. A range was found from as low as 160 kg/m³ in northeastern B.C. (to the lee of the Rocky Mountains) to as high as 500 kg/m³ on the ice fields of the coastal mountains. Claus found maximum mean values as high as 530 kg/m³ on the coastal mountains. Figure 2 shows an analyzed map of the 332 B.C. snow density values and suggests that a modification should be made to the work of McKay and Findlay in the case of B.C. Using their 4 basic regions in that province, new average seasonal values have been calculated for each one and are included in Table 1. With regard to the rest of Canada, McKay and Findlay's regional values were checked using a limited sample of observations taken during one winter season. The means obtained in this fashion fell within the standard deviations published by McKay and Findlay, and their work has been acccepted without further question. Mean seasonal values derived from it are given in Table 1 for the remaining 7 regions.

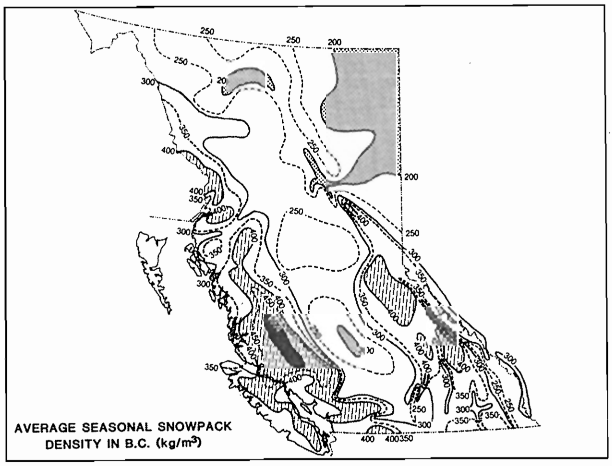

FIGURE 2

An examination of the means east of the Rocky Mountains reveals that there is little significant regional difference for the great area of country bordered by the Tundra to the north, the international boundary to the south and the Atlantic to the east. Throughout this area the 6 regional mean seasonal snow densities vary only from 190 kg/m³ (Boreal region) to 220 kg/m³ (Acadian and Great lakes regions). Consequently, they have been combined into Zone 1 with a weighted mean seasonal snow density of 205 kg/m³ (standard deviation 59 kg/m³).

The remaining region east of the Rocky Mountains (namely the Tundra region) is classified as Zone 2. Due to the relative homogeneity of topography and wind conditions of the region the average seasonal snow densities throughout this large area is 300 kg/m³ with a standard deviation of 80 kg/m³. The boundary between Zone 1 and Zone 2 is approximately the tree line. The regions west of the Rocky Mountains are grouped into Zone 3 (except for isolated pockets of Zone 1 Boreal Region) where no attempt has been made to combine the regional densities into one zonal value because of their disparity.

REGION	REGIONAL NUMBER	DENSITY kg/m^3	STANDARD DEVIATION kg/m^3	NUMBER OF SNOW COURSES
A = Acadian	1	220 *	50 *	15 *
AG = Aspen Grove	2	220 *	40 *	19 *
B = Boreal	3	190 *	60 *	74 *
C = Coast	4	430	25	36
CL = Columbia	5	360	35	70
GL = Great Lakes	6	220 *	60 *	41 *
M = Montane	7	260	25	80
P = Prairie	8	210 *	40 *	16 *
SA = Subalpine	9	360	30	48
T = Tundra	10	300 *	80 *	11 *
TA = Taiga	11	200 *	80 *	9 *

Table 1. Average seasonal snow density by region, calculated from a total of 419 snow course stations. Asterisks (*) indicate values derived by McKay and Findlay 1971.

Figure 3 shows the geographic distribution of the three zones and eleven regions. Due to the scale of this map, the boundaries are of course only approximate.

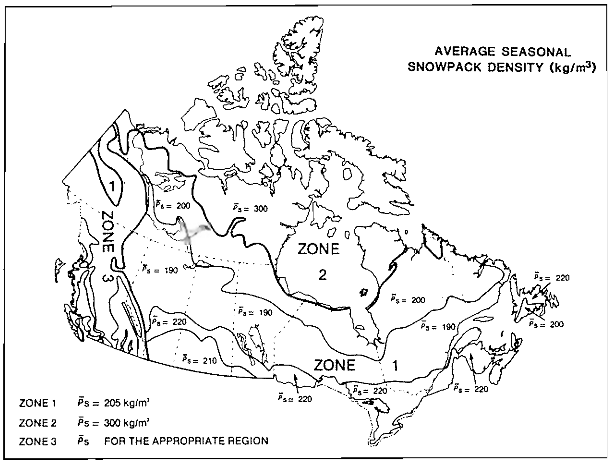

FIGURE 3

Values for Zones 1 and 2 and from Figure 2 have been used in the calculation of ground snow load and are believed to be more realistic than the single value of 200 kg/m^3 which was previously used for this purpose.

Corrections to the Snow Depth Data

A serious problem which arises when using AES snow depth data is the difference in the measurement period of the principal station network (which makes daily measurements) and the climatological network (which makes only a month-end measurement). In areas with variable winter climates such as the west and east coasts of Canada and and the Great Lakes area, it is obvious that thawing episodes can radically change the snow depth during the course of a month. A measurement made at the end of the month may for example indicate zero snow depth although on any number of days during that period there may well have been significant snow accumulations. Even in areas with the stable cold winter climate that characterizes much of continental Canada, ablation of the snow causes diferences between the two types of measurement. When it is necessary to determine the annual maximum snow depth at a place, then clearly, the measurements made only at the end of the month are not adequate. Yet month-end measurements outnumber daily measurements by four to one and it is desireable to make use of this wealth of data available from the climatological network.

A method of adjusting the month-end data in order to make it compatible with the daily data has already been proposed and utilized (Boyd, 1961) in obtaining annual maximum snow depths. Using data at each of 76 stations in eastern Canada which make both types of measurement, Boyd derived a ratio of the annual maximum snow depth (from daily data) to the annual maximum snow depth derived from month-end data. He discovered that month-end values should be increased from 20 to 30% and calculated a simple average ratio value of 1.236 for the entire area. Lacking further data, this value was then assumed to be appropriate throughout Canada.

Considerably more data is now at hand and so Boyd's adjustment method has been revised and new ratio values have been calculated as follows. The complete archive of all stations reporting snow depths has been examined and a set of 211 has been found which meets all the following criteria;

(a) both daily and month-end snow depths must be reported,
(b) at least 15 seasons of data must be available for each type of report,
(c) in the season defined as September to June, no data must be missing during the core months of November to April inclusive.

A melting index ($d_{1/30}$) is now defined by the equation;

$$d_{1/30} = \frac{S_{1/30}\text{ (daily data)}}{S_{1/30}\text{ (month-end data)}} \quad ....5$$

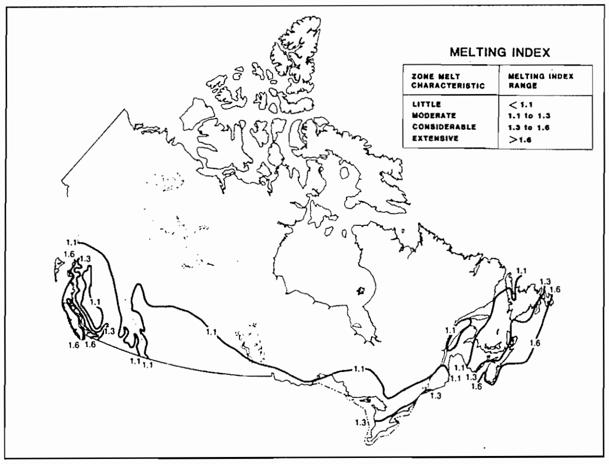

Figure 4

Evaluating $d_{1/30}$ for each of the 211 stations reveals that values range from 1.01 to 3.13. When they are plotted on a map (Figure 4), a pattern emerges which is consistent with the distribution of mean annual temperature. In such a comparison, the $d_{1/30} = 1.10$ distinctly forms the demarcation between regions of melting and those of little melt and is analagous to the isotherm of zero mean annual temperature. In the area of little melt, the mean value of $d_{1/30}$ (derived from 88 stations) is 1.07 with a standard deviation of 0.04. Throughout the area of melting a latitudinal gradient of $d_{1/30}$ values exists. In order to simplify the use of the map, this area has been arbitrarily divided into 3 zones where climatic melting conditions are considered to be similar. These zones are separated by the 1.30 and 1.60 isopleths. The statistics of all four zones are given in Table 2. It is of interest to note that the national weighted average value of $d_{1/30}$ derived from the sample is 1.174 with a standard deviation of 0.24 compared to Boyd's value of 1.236. Use of the zonal averages is, however, preferred over use of the national average. An appropriate average value of $d_{1/30}$ has been assigned from the large scale working version of Figure 4 to each station reporting only month-end snow-depths. Once in 30-year snow depths calculated from month-end data have been made comparable to values of $S_{1/30}$ calculated from daily data by equation 5 in the form;

$$S_{1/30}\text{ (daily data)} = d_{1/30} \times S_{1/30}\text{ (month-end data)}.........6$$

ZONE MELT CHARACTERISTIC	RANGE OF MELTING INDEX	AVERAGE VALUE OF MELTING INDEX ($d_{1/30}$)	STANDARD DEVIATION	NUMBER OF STATIONS
LITTLE	$d_{1/30} < 1.10$	1.07	0.04	88
MODERATE	$1.10 \leq d_{1/30} < 1.30$	1.17	0.10	83
CONSIDERABLE	$1.30 < d_{1/30} < 1.60$	1.41	0.12	26
EXTENSIVE	$d_{1/30} \geq 1.60$	1.91	0.45	14

Table 2. Average values of the melting index by zone.

Maximum 24-hour Winter Rain

Using published data for the 1951-1980 period (Environment Canada 1982), values of the maximum one-day winter (December to March, except in the Yukon and NWT November to March inclusive) rainfall were plotted on a map. These were subjectively analyzed and smoothed isohyets produced (Figure 5). The published value was used in the ground snow load calculation unless it was inconsistent with the map in which case it was replaced by a value derived from the map.

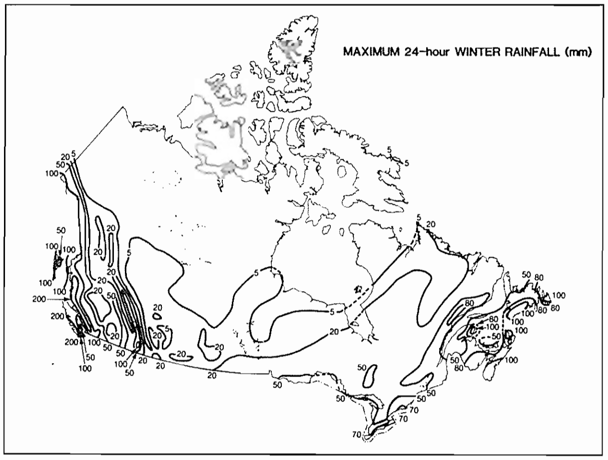

FIGURE 5

$GSL_{1/30}$ CALCULATION

Both equations 3 and 4 (in the following forms) were used to calculate $GSL_{1/30}$ from appropriate data sets;

$$GSL_{1/30} = 0.00981\ (0.01\ S_{1/30}\ \rho_s + R_{24})\ \text{kN/m}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots 7$$

$$GSL_{1/30} = 0.00981\ (0.01\ d_{1/30}\ S_{1/30}\ \rho_s + R_{24})\ \text{kN/m}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots 8$$

$$GSL_{1/30} = 0.00981\ W_{e_{1/30}}\ \text{kN/m}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots 9$$

Equation 9 utilizing water equivalent data from snow courses or measured by snow pillows is preferred because it avoids the problems of equations 7 and 8 associated with choosing an appropriate snow density and arbitrarily adding the maximum one-day winter rain. However, snow depth data is available from 5278 stations in the National Climate Archive, and except for B.C., water equivalent data is difficult and time consuming to access. In practice, data was used from only those snow depth stations that could meet the following restrictions;

(a) a minimum of 10 years of data must be available,

(b) the data must fit the Gumbel cumulative distribution function (equation 10) regression line with a coefficient of determination no less than 0.80.

(c) In the case of month-end measurements, the snow depth values must be greater than zero.

The once in 30-year value of maximum snow depth or maximum equivalent was obtained from a Type 1 double exponential extreme value distribution with the following cumulative distribution function;

$$F(x) = \exp\{ -\exp [-a(x-b)] \} \quad \ldots\ldots\ldots\ldots\ldots\ldots 10$$

Other distributions were considered, for example the lognormal, which is favoured by some (Ellingwood and Redfield, 1983), as well as Fisher-Tippet Type II and Type III, but the literature (Readshaw and Baird, 1981) suggests that there is no definitive test of fit to determine whether one distribution is better than another. Because opinions vary concerning which plotting position and method of fit (least squares, method of moments, method of maximum likelihood) produce the best results, it was decided not to change the previous Canadian methodology, namely using the Gumbel plotting position (Gumbel, 1954) and a least squares best fit for the regression line.

Errors

The expression used to calculate standard error (α) is as follows:

$$\alpha^2 = \left(\frac{\partial f}{\partial m_1}\right)^2 \alpha_1^2 + \left(\frac{\partial f}{\partial m_2}\right)^2 \alpha_2^2 + \ldots + \left(\frac{\partial f}{\partial m_n}\right)^2 \alpha_n^2$$

where $m_1, m_2 \ldots, m_n$ are the means of a number of measured quantities and $\alpha_1, \alpha_2 \ldots, \alpha_n$ are their standard errors. Applying this to equation 3 gives:

$$\alpha_{GSL}^2 = \left(\frac{\partial f}{\partial g}\right)^2 \alpha_g^2 + \left(\frac{\partial f}{\partial \rho_S}\right)^2 \alpha^2{}_{\rho_S} + \left(\frac{\partial f}{\partial S_{1/30}}\right)^2 \alpha_{S_{1/30}}^2 + \left(\frac{\partial f}{\partial \rho_W}\right)^2 \alpha^2{}_{\rho_W} + \left(\frac{\partial f}{\partial R_{24}}\right)^2 \alpha_{R_{24}}^2$$

$$= (\rho_S S_{1/30} + \rho_W R_{24})^2 \alpha_g^2 + (g S_{1/30})^2 \alpha_{\rho_S}^2 + (\rho_S g)^2 \alpha^2{}_{S_{1/30}}$$

$$+ (g R_{24})^2 \alpha^2{}_{\rho_W} + (g \rho_W)^2 \alpha_{R_{24}}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 11$$

If the order of magnitude of the values are substituted in equation 11 then,

$$\alpha_{GSL}^2 = 10^{\circ} + 10^6 + 10^6 + 10^{-4} + 10^2$$

Ignoring all but the second and third terms, equation 11 can be rewritten as:

$$\alpha_{GSL} \simeq g\,[(S_{1/30}\,\alpha_{\rho_s})^2 + (\rho_s\,\alpha_{S_{1/30}})]^{\frac{1}{2}} \;\dots\dots\dots\dots 12$$

Thus, in the case when daily snow depth data is used, it can be seen that the values of snow depth and snow density and their associated errors contribute most to the standard error of the ground snow load.

The general form of equation 8 is the same as for equation 3 but including the factor $d_{1/30}$ as follows;

$$GSL_{1/30} = g(d_{1/30}\,S_{1/30}\,\rho_s + R_{24}\rho_w) \;\dots\dots\dots\dots 13$$

In this case, the reasoning used to derive equation 12 gives;

$$\alpha_{GSL} \simeq g[d_{1/30}\,S_{1/30}\,\alpha_{\rho_s})^2 + (d_{1/30}\,\rho_s\,\alpha_{S_{1/30}})^2 + (S_{1/30}\rho_s\,\alpha_{d_{1/30}})^2]^{\frac{1}{2}} \dots 14$$

Thus when month-end snow depth data is used, the error in $d_{1/30}$ must also be taken into account. In the case when water equivalent data is used it can be reasoned from equation 4 that;

$$\alpha_{GSL} \simeq g\rho_w\,\alpha_{w_e} \;\dots\dots\dots\dots 15$$

A COMPARISON OF CHANGES IN NATIONAL BUILDING CODE GSL VALUES

An analysis has been made of the change in GSL values published in the National Building Code in 1977 and the values proposed in 1983, (a) to document the magnitude of the changes when recalculations are made using updated data sets, and (b), to examine the biases of the change. Figure 6 reveals that the root mean square (RMS) change from 1977 to 1983 in provinces with mountainous areas (B.C., Alberta, Yukon) was quite large, ranging from 23% to 55%. The bias in these changes was strongly positive, showing a definite trend to increased values from 1977 to 1983. This sharp increase could be due either to (a) an increase in data locations and a longer period of record, or (b) changes in the quantities used to calculate the GSL values, or (c) improvements in observing techniques, or (d) increased snowfalls due to climate change, or some combination of these things. However, it is suspected that reasons (a) and (b) are the main causes. Elsewhere across Canada, the RMS changes range from 12% to 25%, and the BIAS figures indicate that GSL values have tended to increase a little with three exceptions namely Ontario, Newfoundland and PEI, where there was a trend towards lower ground snow loads.

The equations used to calculate the RMS change and BIAS in values are as follows:

$$\text{RMS change} = [\frac{1}{N}\sum_{1}^{N}(\Delta GSL\%)^2]^{\frac{1}{2}} \;\dots\dots\dots\dots 16$$

$$\text{Change BIAS} = \frac{1}{N}\sum_{1}^{N}(\Delta GSL\%) \;\dots\dots\dots\dots 17$$

where; N = number of values

$$\Delta GSL\% = 100\;\frac{(GSL_{1983} - GSL_{1977})}{GSL_{1977}},$$

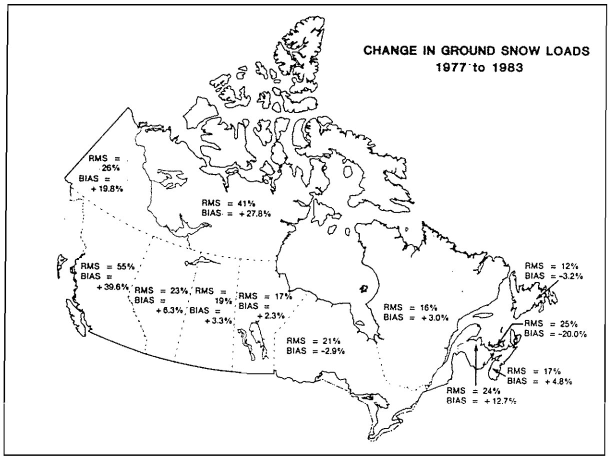

FIGURE 6

CONCLUSION

Compared to previous calculations, the 1983 ground snow load values are based upon a larger data set with a longer period of record. The biggest change in values between 1977 and 1983 occurred in B.C. (55%) and the Northwest Territories (41%) due to significant increases in the value of snow density assumed for these areas. Increases along the north shore of the St. Lawrence, in the snowbelt zone east of Lake Superior and along the eastern coast of Baffin Island are primarily due to the expanded data base. Errors typically range from 15% to 35% of the GSL values.

On a large scale, the geographic distribution of the 1983 $GSL_{1/30}$ is similar to previous maps (Boyd, 1961; Thomas, 1955). The largest values are found adjacent to the east and west coasts with a broad area of minimum values stretching northwards from the Prairies to the Arctic Archipelago. However on a smaller scale considerable differences are found in the latest map due to the analysis technique of taking topography into account. The largest calculated value anywhere in Canada is 48.5 kN/m² at Orchid Lake, B.C. at an elevation of 1190 metres in the south coastal mountains, and the smallest is 0.5 kN/m² at Pambrun, Saskatchewan. Table 3 summarizes the statistics of maximum GSL, minimum, mean etc; by province.

PROVINCE	N	MAX	MIN	x_m	x_d	$\overline{x}$	σ
B.C.	518	48.5	1.1	3.7	5.3	8.2	7.6
ALTA	180	20.7	0.9	2.0	2.1	2.3	1.7
SASK	174	3.6	0.5	1.7	1.9	1.9	0.6
MAN	119	3.8	1.0	2.3	2.3	2.3	0.6
ONT	306	5.6	0.7	2.8	2.6	2.5	0.8
QUE	352	7.7	2.0	4.0	3.8	3.9	1.0
NB, NS, PEI, NFLD	157	7.5	1.4	2.8	3.6	3.8	1.2
YUKON, NWT	83	8.6	1.3	2.8	2.7	3.0	1.4

Table 3. Ground snow load statistics by province. Values are kN/m². N is the number of stations used, max is the maximum value, min is the minimum value, X_m is the mode, X_d is the is the median, $\overline{x}$ is the mean and σ is the standard deviation of the mean.

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