H.B. Dickens
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SUPPLEMENT TO THE BUILDING CODE FOR THE NORTH

Issued by the
Associate Committee on the
NATIONAL BUILDING CODE OF CANADA
National Research Council
Ottawa, Canada

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PREFACE

This special Supplement has been compiled at the specific request of the Committee on the Building Code for the North to assist users of the Northern Code. The Supplement contains information on Climate, Soils & Muskeg, Permafrost & Foundations, Fire & Sound Ratings, and Truss Designs together with a list of reference to DBR/NRC papers on permafrost and building in the North. A sketch illustrating typical crawl space and ventilated foundation space construction is also included.

Copies of the Building Code for the North ($1.00) and this Supplement ($1.25) are available from:

The Secretary
Associate Committee on the National Building Code of Canada
National Research Council
Ottawa 7, Ontario.

SPECIAL NOTE

Users of the Building Code for the North should note that the provisions which appear in dark type in the Code are those prepared by the Committee to cover the special requirements for building in northern regions. All light-type requirements are taken directly from the 1965 edition of the Short Form of the National Building Code.

CLIMATIC INFORMATION FOR BUILDING DESIGN IN CANADA

SUPPLEMENT No. 1
NATIONAL BUILDING CODE OF CANADA

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CLIMATIC INFORMATION
for
BUILDING DESIGN IN CANADA

by

DONALD W. BOYD
(D.O.T. Meteorologist with DBR/NRC)

A joint contribution from the Meteorological Branch, Department of Transport, and the Division of Building Research, National Research Council.

The great diversity of climate in Canada has a considerable effect on the performance of buildings, and consequently the design of buildings should reflect this diversity. The purposes of this handbook are: firstly, by means of maps, to indicate the variability and general distribution of earthquake intensity, permafrost, and those climatic elements that are most frequently considered in building design; secondly, to explain briefly how the design weather values are computed; and, thirdly, to present recommended design data for a number of cities and towns and smaller populated places. It is not practical to list values for all municipalities but recommended design weather data for any location in Canada can be obtained by writing to the Secretary, Associate Committee on the National Building Code, National Research Council, Ottawa.

The choice of climatic elements that are included in this handbook and the form in which they are expressed has been dictated largely by the requirement for specific values in several sections of the National Building Code of Canada 1965. A few additional charts are included. The following notes explain briefly the significance of these particular elements in building design and indicate what observations were used and how they were analysed to yield the required design values. To select design values for other locations in Canada, the observed or computed values of each element for specific observation stations were plotted on maps to the scale of one inch to 100 miles. Isolines were drawn on these working charts to show the distributions of the design values. The charts in this handbook have been reduced from the working charts, but these small copies are not intended as a source of design values.

In the Table, design weather data are listed for 582 locations, which have been chosen for a variety of reasons. Incorporated cities and towns with populations of over 5000 have been included unless they are close to other larger cities. For sparcely populated areas many smaller towns and villages have been listed. The design weather data for weather stations themselves are the most reliable and hence these stations have often been listed in preference to locations with somewhat larger populations. A number of requests for recommended design weather data for other locations have been received and where most of the elements were estimated these were also added to the list. The tabulated values are those recommended by the Associate Committee on the National Building Code and are not necessarily the same as those used in local bylaws. In some cases the values obtained from the large-scale charts have not been rounded off, for reasons explained later. Some municipalities may wish to round off these values in their bylaws.

Neither the charts nor the list of design values should be expected to give a complete picture of the variations of these climatic elements. The list of observed or computed values and the large-scale manuscript charts will be used for estimating values for locations not included in the Table, if application is made to the Secretary as already mentioned. In the absence of weather observations at any particular location, a knowledge of the local topography may be important. For example, cold air has a tendency to collect in depressions, precipitation frequently increases with elevation, and winds are generally stronger near large bodies of water. These and other relationships affect the corresponding design values, and will be taken into consideration where possible in answering inquiries.

All the weather records that were used in preparing the charts were, of necessity, observed at inhabited locations, and hence the charts apply only to populated areas. This is particularly significant in mountainous areas where the lines on the charts apply only to the populated valleys and not to the mountain slopes and high passes, where, in some cases, very different conditions are known to exist.

WINTER DESIGN TEMPERATURES (CHARTS 1 AND 2)

A building and its heating system should be designed to maintain the inside temperature at some pre-determined level. To do 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 usually not 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.

Winter design temperature is based on an analysis of winter air temperatures only. Wind and solar radiation also affect the inside temperature of most buildings but there is no convenient way of combinating their effects with that of outside air temperature. The use of average wind and radiation conditions is usually satisfactory for design purposes.

The choice of a method to determine the winter design temperature depends to some extent on the form of the available temperature records. In Canada, hourly temperatures in degrees Fahrenheit for ten successive years were available on punched cards for over 100 stations, and from these cards it was possible to obtain frequency distributions. The winter design temperature is defined, therefore, as the lowest temperature at or below which only a certain small percentage of the hourly outside air temperatures in January occur. The Climatology Division, Meteorological Branch, Department of Transport, prepared tabulations showing the number of hours in January in the ten years from 1951 to 1960 inclusive in which the temperature fell in each of over 50 two-degree intervals. From this it was possible to select the two-degree interval below which only a small number of temperatures fell. To find the required temperature to the nearest degree an interpolation rule was devised based on the normal distribution. Using this rule it was possible to select the temperature below which 1 per cent or 2½ per cent of the January temperatures fell.

Tabulations and design temperatures for 118 stations were obtained. The temperatures were plotted on maps and used to estimate design temperatures for the other stations in the Table. Since the pattern of winter design temperature charts is similar to that of mean annual minimum temperature charts, the latter chart in the Atlas of Canada (1) influenced the pattern of these winter design temperature charts in the Far North where hourly temperature observations are scarce.

Most of the design temperatures on the 2½ per cent chart in the Prairie Provinces and British Columbia are 5 to 10 degrees higher than they are on the corresponding chart by Thomas in the 1953 edition of the National Building Code of Canada (2). Each chart is based on temperatures for only a 10-year period: the 1953 chart on the period from 1941 to 1950 and the current chart on the period from 1951 to 1960. The differences emphasize the statistical inadequacy of a 10-year period, but unfortunately temperature reports have been punched on cards for longer periods for only a very few stations. The earlier period includes the unusually cold January of 1950 when the average temperature in the four western provinces ranged from 12 to 32 degrees below normal. By omitting this exceptional month it is thought that the present values will more nearly describe a typical winter.

In most cases the temperatures observed at airports have had to be used and no adjustments have been made to allow for the city effect. The winter design temperatures are not reliable to within one degree, but the differences between the 1 and 2½ per cent values (which average about four degrees) are more reliable. The design temperatures, therefore, are listed to the nearest degree as an indication of these differences.

The 2½ per cent winter 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 per cent value may be used.

SUMMER 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 do 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 and humidity at the predetermined levels will usually not be serious if the increases in temperature and humidity are 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 summer design temperatures in this supplement are based on an analysis of July air temperatures and humidities only. Wind and solar radiation also affect the inside temperature of most buildings and may in some cases be of more importance than the outside air temperature. It seems, however, that no method of allowing for variations in radiation has yet become generally accepted. When requirements have been standardized it may be possible to provide more complete weather information for summer conditions but in the meantime only dry-bulb and wet-bulb design temperatures can be provided.

The frequency distributions of combinations of dry-bulb and wet-bulb temperatures for each month from June to September have been tabulated for 33 Canadian weather stations by Boughner (3). If the summer dry-bulb and wet-bulb design temperatures are defined as the temperatures that are exceeded 2½ per cent of the hours in July, then design values can be obtained directly for these 33 stations.

As mentioned above, the pattern of winter design temperature is similar to that for the mean annual minimum. In the same way, the pattern of summer design temperature is much like that of the mean annual maximum. Crow (4) used these similarities as a basis for computing design temperatures for places in the U.S.A. for which only daily maximum and minimum temperatures were observed. The July dry-bulb design temperatures for the 33 Canadian stations were subtracted from the mean annual maximum temperatures (for the same period of years) and the differences plotted on a map. The differences are all between 3 and 11 degrees. With this small range, the 33 stations seem to be enough to establish differences (within an accuracy of about one degree) for any location. Mean annual maxima based on the period 1921 to 1950 were available for about 170 locations. For these, the differences were read or estimated from the map and July dry-bulb design temperatures obtained. Values were estimated for over 400 additional locations.

The July wet-bulb design temperatures for the 33 stations were plotted directly on a map. The range from 62 to 75 (excluding Yukon and NWT) is a little more than for the dry-bulb differences, but is still small enough to yield reasonably accurate wet-bulb design temperatures. Values were read from the map for all locations with dry-bulb design values of 75° F or higher.

In many cases the temperatures observed at airports have had to be used and no adjustments have been made to allow for the city effect.

The summer design temperatures are not reliable to within one degree although they have been estimated and tabulated to the nearest degree.

HEATING DEGREE-DAYS (CHART 3)

It has long been known that the amount of fuel or energy required to keep the interior of a building at about 70°F. when the outside air temperature is below 65°F. is roughly proportional to the difference between 65°F. and the outside temperature. Wind speed and solar radiation, and the extent to which a building is exposed to these elements, also affect the heat required, but there is no convenient way of combining these effects. For average wind and radiation conditions, however, the proportionality with the temperature difference still holds and hence the heating degree-days are based on temperature alone.

Since the fuel required is also proportional to the duration of cold weather, a convenient method of combining these elements of temperature and time is to add the differences between 65°F. and the mean temperatures for every day in the year when the mean temperature is below 65°F. It is assumed that no heat is required when the mean outside air temperature for the day is 65°F. or higher.

Daily degree-days have been computed for many years at Victoria, Winnipeg, Toronto and Halifax. The values given in the Table for these four cities are the average annual totals for the 30-year period from 1931 to 1960.

Daily degree-days are not available for the full 30-year period for other stations. An approximate but reasonably accurate method of obtaining degree-days from monthly mean temperatures was devised by Thom (5). This method was used by Thomas and Boyd (6) in 1956 to compute normal monthly and annual degree-day totals based on the period 1921 to 1950, which were used as a basis for the map in the 1961 Supplement. In 1964 an electronic computer at the National Research Council Computation Centre was used to compute monthly and annual degree-days for over 600 stations based on the period 1931 to 1960 (7). The annual totals were plotted on a map (Chart 3) and used to estimate values for locations without weather stations. Computed values are shown in the Table to the nearest unit as computed but should not be relied on to within less than 100 to 150 degree-days. Values read from the manuscript chart are to the nearest 100 degree-days.

RAINFALL INTENSITY (CHART 4)

Roof drainage systems are designed to carry off the rainwater from the most intense rainfall that is likely to occur. A certain amount of time is required for the rainwater to flow across or 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 cope only 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 the average once in ten 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 ten years. The safety factors included in the tables in Part 7 of the National Building Code, 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.

Chart 4 is a revision of the corresponding charts by Thomas (2) and by Bruce (8) which show the 15-minute rainfall, in inches, that will probably be exceeded on the average once in ten years. As Bruce explained, there were available to him only nine locations in Canada with recording rain gauge observations covering a reasonable length of time. From these he computed the 15-minute, ten-year, rainfall. Bruce also computed the maximum 6-hour rainfall expected once in ten years for 85 locations and used the ratios of 15-minute to 6-hour rainfalls at six stations where both were available to estimate the 15-minute value for the other locations. Rainfall intensities for some locations in northern Canada estimated by the United States Weather Bureau and the latest rainfall intensity figures for cities in the United States near the Canadian border were also used. Since the publication of his paper Bruce has analysed the rainfall records from several additional stations and these have been used in redrawing the chart.

It would be very difficult to estimate the pattern of rainfall intensity in British Columbia where precipitation is extremely variable. Along the coast an attempt has been made, based on reports from Victoria and Vancouver and a few stations in the State of Washington. In the interior of British Columbia, the value of 0.6 inch based on a seven-year record from Penticton is the only available indication of the intensity for all the valleys in the southeastern part of the Province. In the Fraser Valley and further north, the value may be slightly smaller.

ONE-DAY RAINFALL (CHART 5)

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. Although the period during which rainwater may accumulate is unknown, it is common practice to use the maximum one-day rainfall for estimating the additional load.

For most weather stations in Canada the total rainfall for each day is published. The maximum "one-day" rainfall (as it is usually called) for several hundred stations has been determined and published by the Climatology Division (9). Since these values are all for predetermined 24-hour periods, beginning and ending at the same time each morning, it is probable that most of them have been exceeded in periods of 24 hours including parts of two consecutive days. The maximum "24-hour" rainfall (i.e. any 24-hour period) according to Hershfield and Wilson is, on the average, about 113 per cent of the maximum "one-day" rainfall. (10)

Most of the rainfall amounts that were used in preparing Chart 5 were based on reports covering between 20 and 30 years. These maximum values differ greatly within relatively small areas where little difference would be expected. The variable length of records may account for part of this variability which might be reduced by an analysis of annual maxima instead of merely selecting the maximum in the period of record. Whatever the reason, the variability has necessitated a considerable amount of smoothing in drawing the chart and hence the isolines do not in all cases agree with the observed maximum one-day rainfalls. The tabulated values are intended to be representative of the immediate area, and therefore include some local variations which cannot be shown on the small-scale chart.

ANNUAL TOTAL PRECIPITATION (CHART 6)

The total amount of precipitation that normally falls in one year is frequently used as a general indication of the wetness of a climate. As such it is thought to have a place in this handbook. Total precipitation is the sum in inches of the measured depth of rainwater and one tenth of the measured depth of snow (since the average density of fresh snow is about one tenth that of water).

The average annual total precipitations for the 30-year period from 1921 to 1950 were used in preparing Chart 6. The values were selected from a list of precipitation normals prepared by the Climatology Division (11). All stations with records for the full 30 years were plotted on the map or compared with nearby stations that had already been plotted to ensure consistency. Many adjusted values were used in areas where unadjusted 30-year values were not available. The corresponding chart in the Atlas of Canada (1) was used for reference.

SNOW LOADS (CHART 7)

The roof of a building should be able to support the greatest weight of snow that is likely to accumulate on it. Some observations of snow loads on roofs have been made in recent years, but they are not sufficiently numerous to form the basis for a snow load chart. Similarly, observations of the weight or water equivalent of the snow on the ground are not sufficient for such a chart. Although the roof load and water equivalent observations are necessary (as mentioned below) the chart must be based on the more numerous observations of the depth of snow on the ground.

In estimating the basic design snow load from snow depth observations, these steps were followed:

1. The depth of snow on the ground which will be equalled or exceeded once in 30 years, on the average, was computed.
2. A density was assumed and used to convert snow depths to loads.
3. An adjustment was added to allow for the increase in the load caused by rainwater absorbed by the snow.
4. Because the accumulation of snow on roofs is often different from that on the ground, certain adjustments should be made to the ground snow load to provide a design snow load on a roof.

These steps are explained in more detail in the following paragraphs.

The annual maximum depths of snow on the ground for periods ranging from 10 to 18 years were available for over 200 stations. These data were assembled and analysed using Gumbel's extreme value method as explained by Boyd (12). The resulting chart showed the distribution in Canada of the snow depth which will probably be equalled or exceeded on the average once in 30 years.

The specific gravity of old snow generally ranges from 0.2 to 0.4 times that of water. It is usually assumed in Canada that 0.1 is the average specific gravity of new snow. The 30-year maximum snow depth will almost certainly occur immediately after an unusually heavy snowfall and hence a large proportion of the snow cover will have a low density. It therefore seemed reasonable to assume a mean specific gravity under these unusual circumstances of about 0.2 for the whole snow cover. In practice it is convenient to assume that one inch of snow cover corresponds to a load of exactly one pound per square foot. This corresponds to a specific gravity of 0.192, the value which was used in preparing the Chart.

Because the heaviest loads in Canada frequently occur when early spring rain adds to an already heavy snow load, it was considered advisable to increase the snow load by the load of rainwater that it might retain. It is convenient to use the maximum one-day rainfall in the period of the year when snow depths are greatest. Boyd has explained how a 2- or 3-month period was selected (12).

The results from several winters of a survey of snow loads on roofs indicated that average roof loads were generally much less than loads on the ground. The conditions under which the design snow load on the roof may be taken as 80 or 60 per cent of the ground snow load are given in Section 4.1 of the National Building Code 1965. The Code 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. Recommended adjustments are given in Supplement No. 3 to the National Building Code, Canada, 1965.

Chart 7 shows the general distribution of snow loads on the ground, that is, the load due to snow which will be exceeded on the average once in 30 years, plus the load due to the maximum one-day rainfall in the late winter or early spring. Values of the snow loads on the ground were read from the large-scale original of Chart 7 and are listed in the Table. The snow loads are tabulated in whole pounds per square foot but are not reliable to this accuracy.

Charts on such a small scale as those in this Supplement cannot show local differences in the weather elements, even where these are known to exist. All the weather observations used in preparing Chart 7 were, of necessity, taken at inhabited locations, and hence the charts apply only to permenently populated areas. This is particularly significant in mountainous areas where the lines on the chart apply only to the populated valleys and not to the mountain slopes, where, in some cases, much greater snow depths are known to accumulate and must be taken into account in the design of roofs.

WIND LOADS (CHART 8)

All structures should be built to withstand the pressures and suctions caused by the strongest wind that is likely to blow at the site in many years. The following steps were followed in estimating these pressures and suctions from the records of hourly wind speeds:

1. The annual maximum hourly wind speeds were analysed to obtain the hourly wind speed that will be equalled or exceeded, on the average, once in 30 years.
2. The result of a comparison of hourly wind speeds with the corresponding maximum gust speeds was used to convert maximum hourly speeds to maximum gust speeds.
3. An average air density was assumed in order to compute the "velocity pressure".
4. For heights over 40 feet the velocity pressure was increased.
5. The design pressures are finally obtained by multiplying the velocity pressure by a factor which depends on the shape of the building.

These shape factors are described in Supplement No. 3 of the National Building Code. The other four steps are discussed in the following paragraphs.

The number of miles of wind that pass an anemometer head in each hour, or the hourly average wind speed, is the only wind speed record that is kept at many wind-measuring stations in Canada. These hourly mileages must therefore be used for any statistical analysis that is to cover the country. The annual maximum hourly mileages for over 100 stations for periods from 10 to 22 years were analysed using Gumbel's extreme value method, to estimate the hourly mileages that would be equalled or exceeded, on the average, once in 30 years.

The pressure on the wall of a building does not respond instantaneously to rapid changes in the wind speed and hence the most rapid wind fluctuations may have little effect on the larger buildings. Chimneys and towers, being smaller, are affected more quickly. The duration of the wind gust used in design should therefore depend on the size and shape of the structure. This is not feasible at present, and in practice the average response time of a Dines pressure tube anemometer (which is about 2 or 3 seconds) is used as a reasonable period for the design gust speed. Dines pressure tube anemometers (from which gust speeds could be obtained) and cup anemometers (from which hourly mileages are read) were both operated at 11 stations for 3 or more years in the period from 1950 to 1957. A comparison of over 1500 hourly mileages of 30 miles or over with the corresponding maximum gust speeds yielded the equation:

$$G = 5.8 + 1.29V$$

where G is the gust speed in miles per hour and V is the hourly mileage. This equation was used to convert all the "30-year hourly mileages" to "30-year gusts". These are the values that were used to prepare Chart 8: wind gust speeds that will be equalled or exceeded, on

the average, once in 30 years. Values read from the original chart are shown in the Table under the heading "Gust".

Pressures and suctions caused by the wind depend not only on the speed of the wind but also on the air temperature and the atmospheric pressure. If *G* is the design wind or the wind gust speed in miles per hour, then the velocity pressure, *P*, in pounds per square foot is given by the equation:

$$P = CG^2$$

where *C* depends on air temperatures and atmospheric pressure. The value 0.0027 is within 10 per cent of the monthly average value of *C* for most of Canada in the windy part of the year. This value (0.0027) has been used to compute all the velocity pressures in the Table from the corresponding gust speeds.

For buildings over 40 feet high, the velocity pressure must be increased according to a table in Section 4.1 of the National Building Code 1965 which is based on the assumption that the gust speed increases in proportion to the one-tenth power of the height.

PERMAFROST (CHART 9)

Suggest new wording for fold out map

The line on Chart 9 indicates the *approximate* southern limit of permafrost in Canada. The distribution of permafrost varies from continuous in the north to discontinuous in the south. In the continuous zone, permafrost occurs everywhere under the ground surface and is generally hundreds of feet thick. Southward, the continuous zone gives way gradually to the discontinuous zone where permafrost exists in combination with some areas of unfrozen material. The discontinuous zone is one of broad transition between continuous permafrost and ground having no permafrost. In this zone, permafrost may vary from a widespread distribution with isolated patches of unfrozen ground to predominantly thawed material containing islands of ground that remain frozen. In the southern area of this discontinuous zone, permafrost occurs as scattered patches and is only a few feet thick.

It is emphasized that the line on this map must be considered as the approximate location of a braod transition zone many miles wide in which permafrost thins out in scattered islands. The location of individual islands cannot be shown on the map. Prior to construction it is particularly important to conduct careful site investigations at any proposed building location in the vicinity of the line. Permafrost also exists at high altitudes in southern Labrador-Ungava, and in the mountains of Western Canada a great distance south of the line shown on the map.

EARTHQUAKE INTENSITY (CHART 10)

Earthquake intensity is the estimated intensity of earthquake forces that may occur. An indication of the possible damage to which buildings might be subjected is given by zones. The location and extent of these zones were determined on the basis of data received from the Dominion Observatories Branch, Department of Mines and Technical Surveys. These data are based on a system of earthquake zoning established by the United States Coast and Geodetic Survey.

The zones shown in Chart 10 indicate intensities as follows:

Zone 0	No damage
Zone 1	Minor damage
Zone 2	Moderate damage
Zone 3	Major damage

Where severe earthquakes have occurred in the recent past, the location is indicated with the magnitude according to the Gutenburg-Richter scale.

The earthquake factor to be used in the National Building Code 1965 is the same as the zone number except in Zone 3 where the factor is 4. The earthquake factors are listed in the Table.

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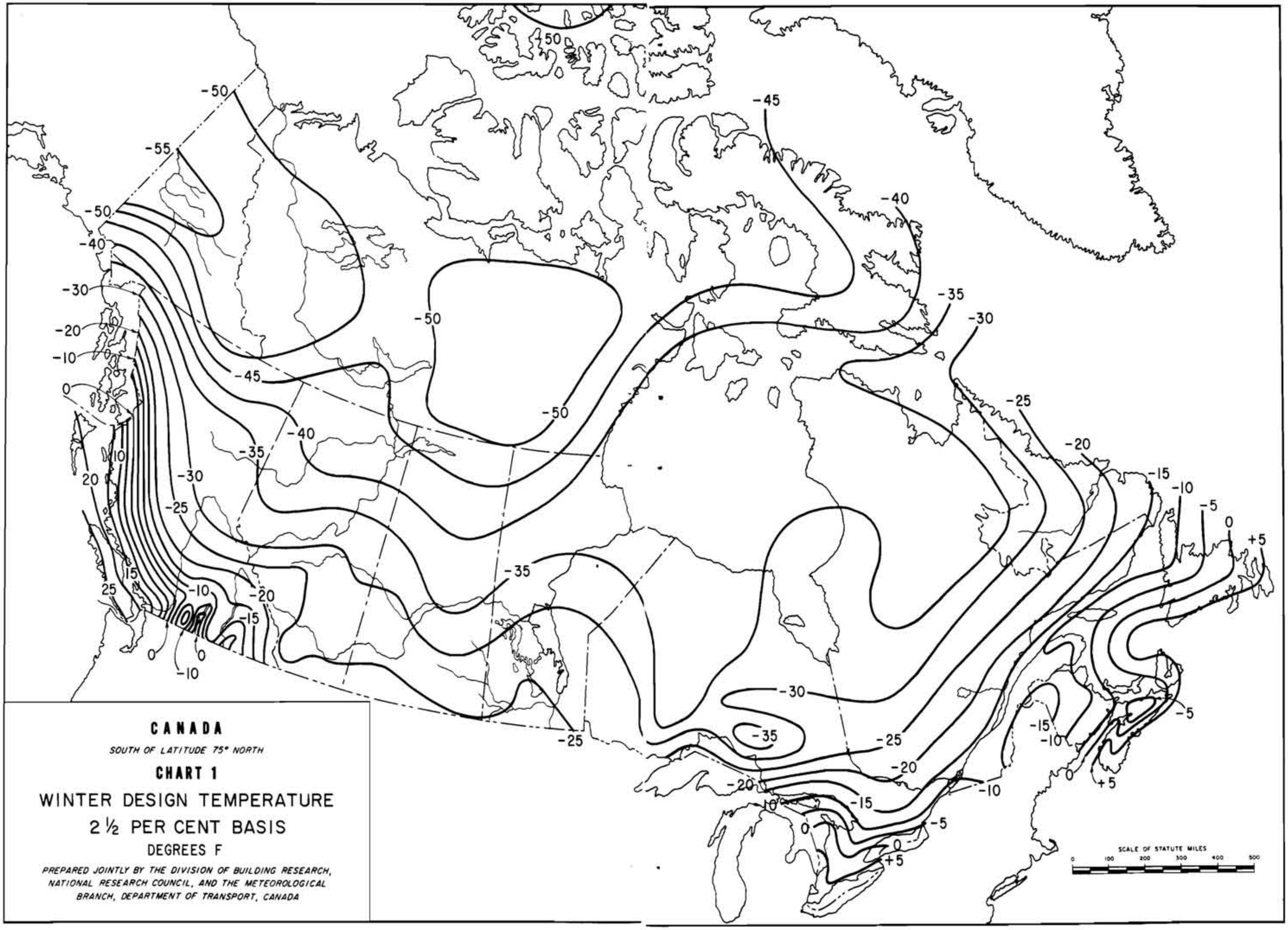
CHARTS 1 to 10


CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 1
WINTER DESIGN TEMPERATURE
2 ½ PER CENT BASIS
DEGREES F
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA
SCALE OF STATUTE MILES
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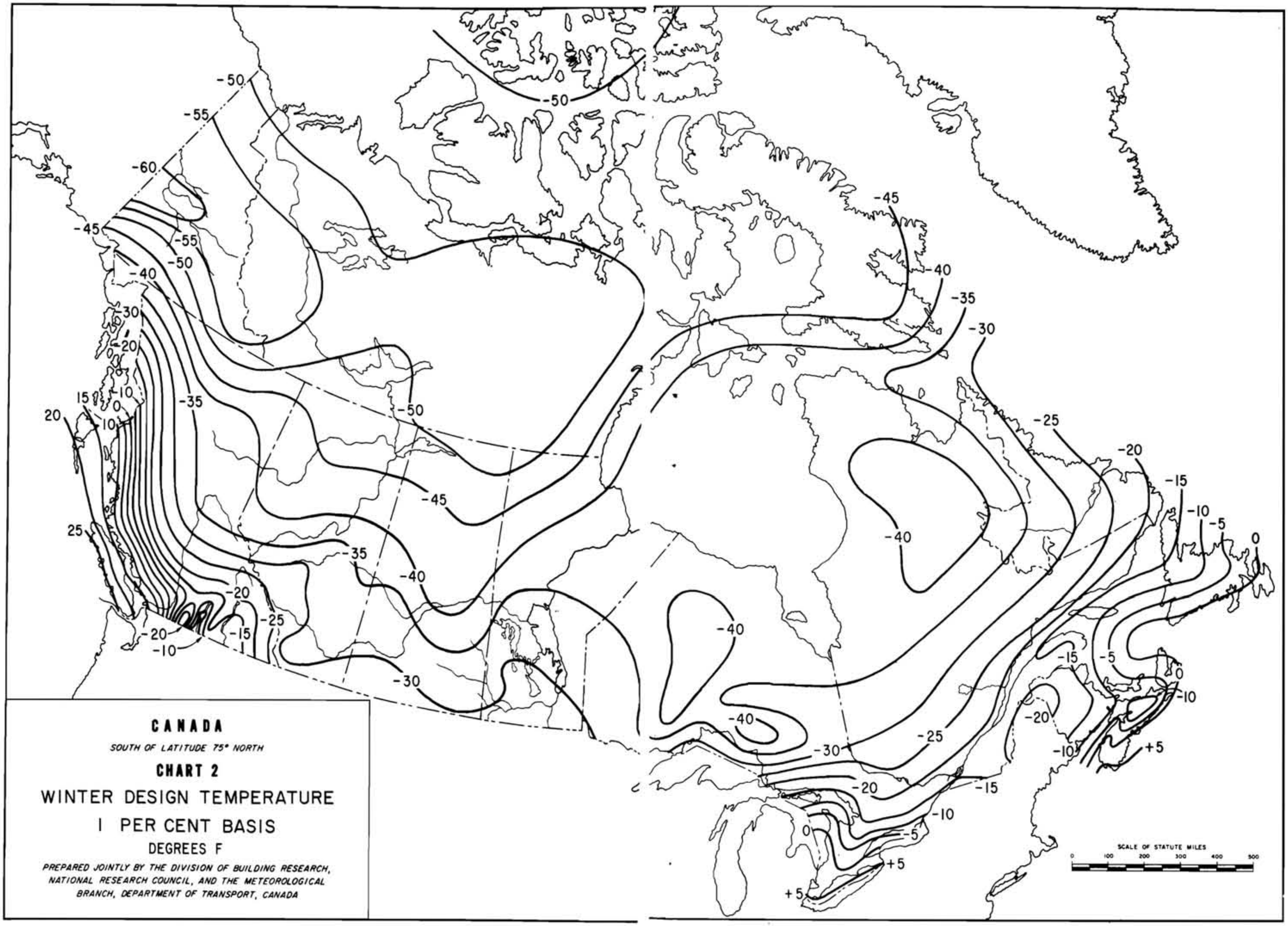
CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 2
WINTER DESIGN TEMPERATURE
1 PER CENT BASIS
DEGREES F
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA
SCALE OF STATUTE MILES
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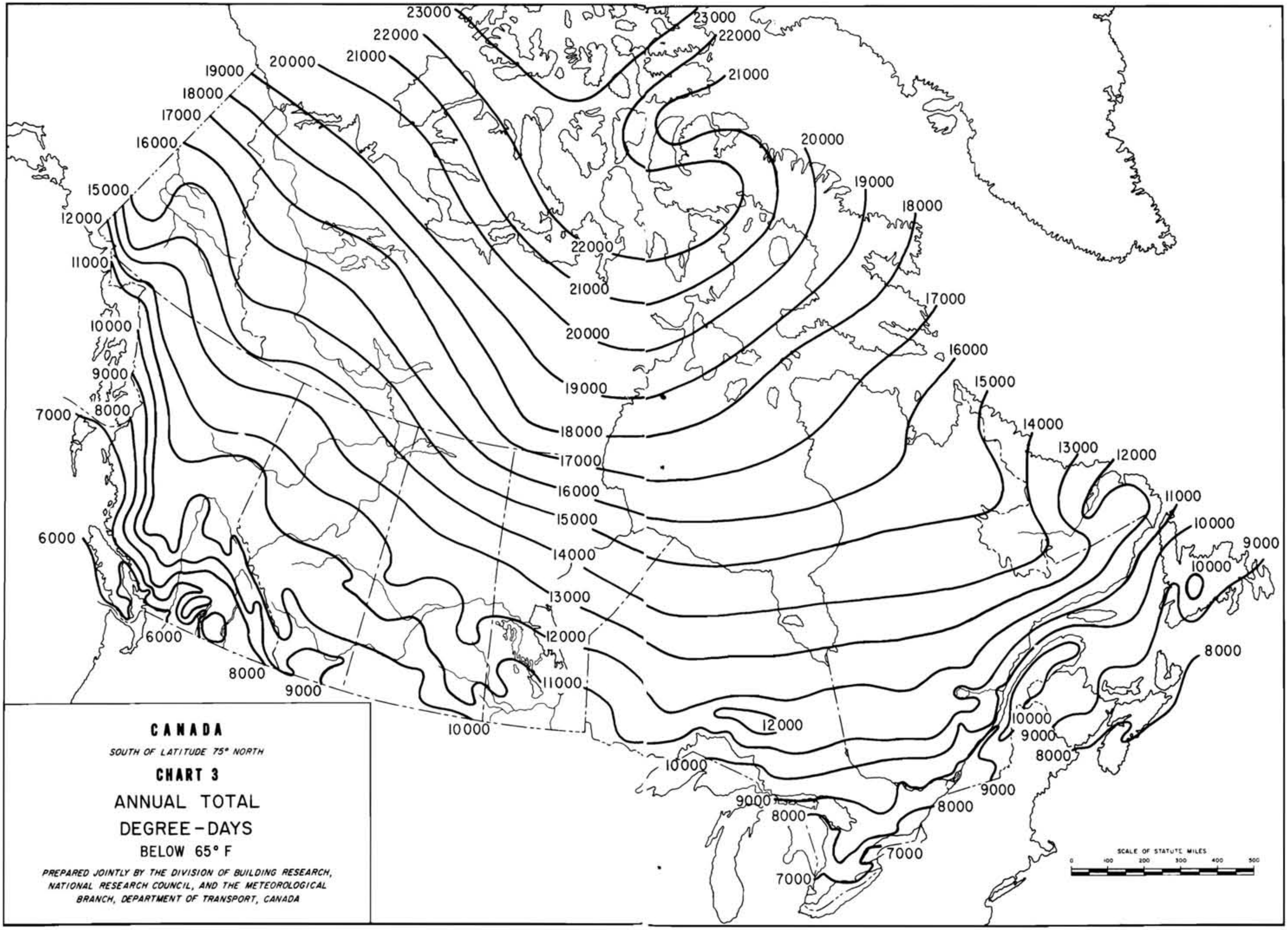
CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 3
ANNUAL TOTAL
DEGREE-DAYS
BELOW 65° F
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA
SCALE OF STATUTE MILES
0 100 200 300 400 500
23000
22000
21000
20000
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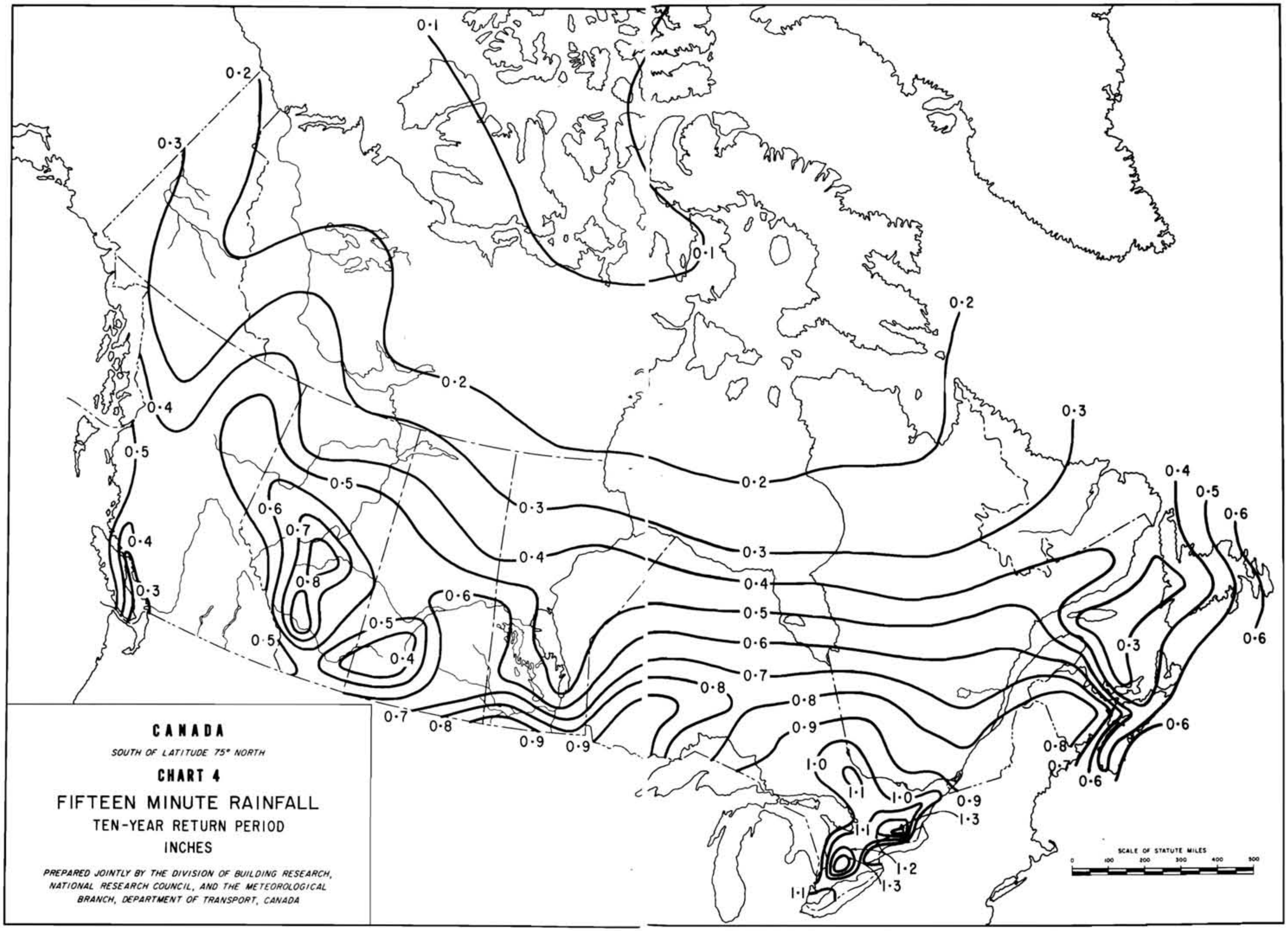
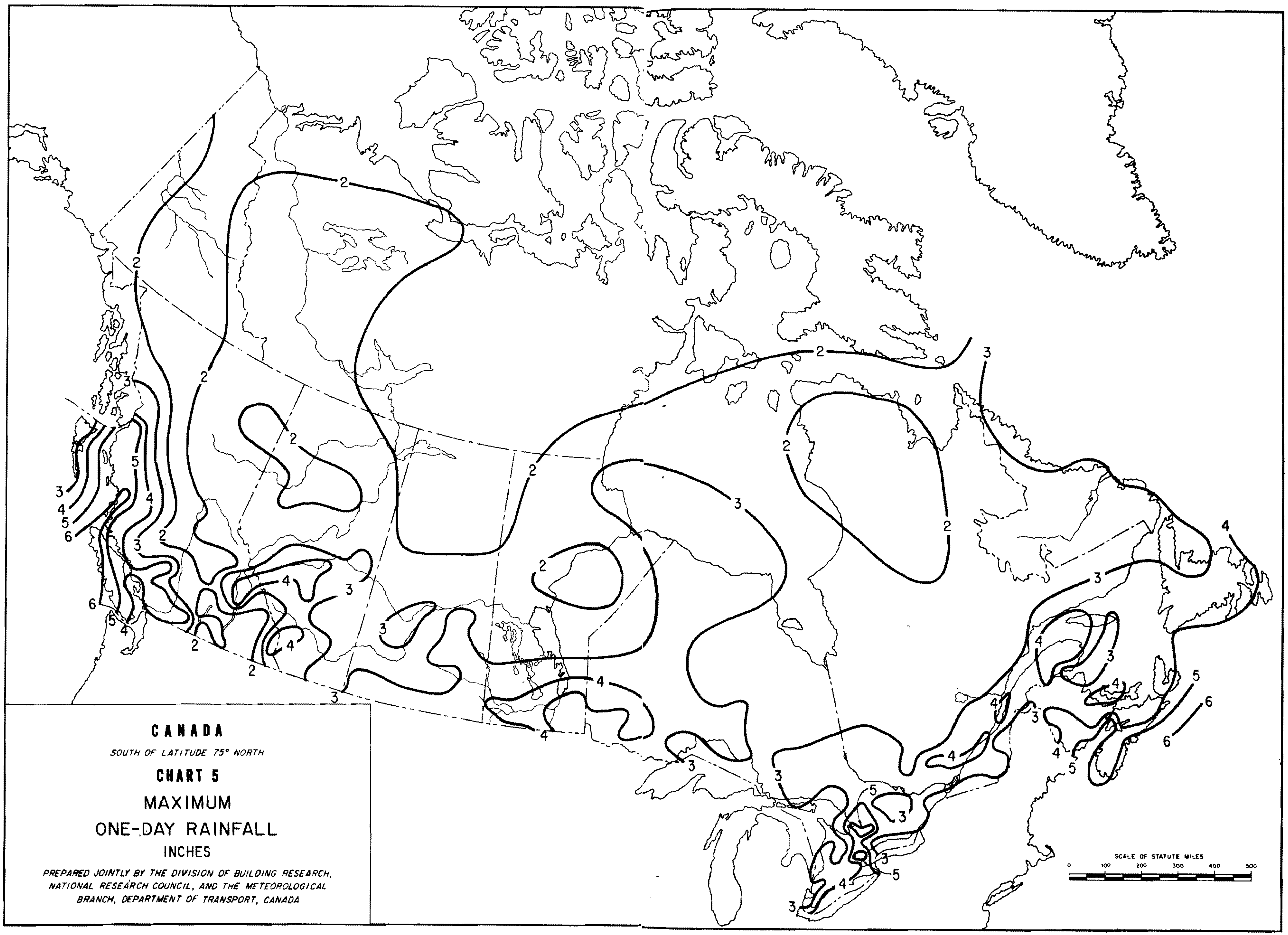
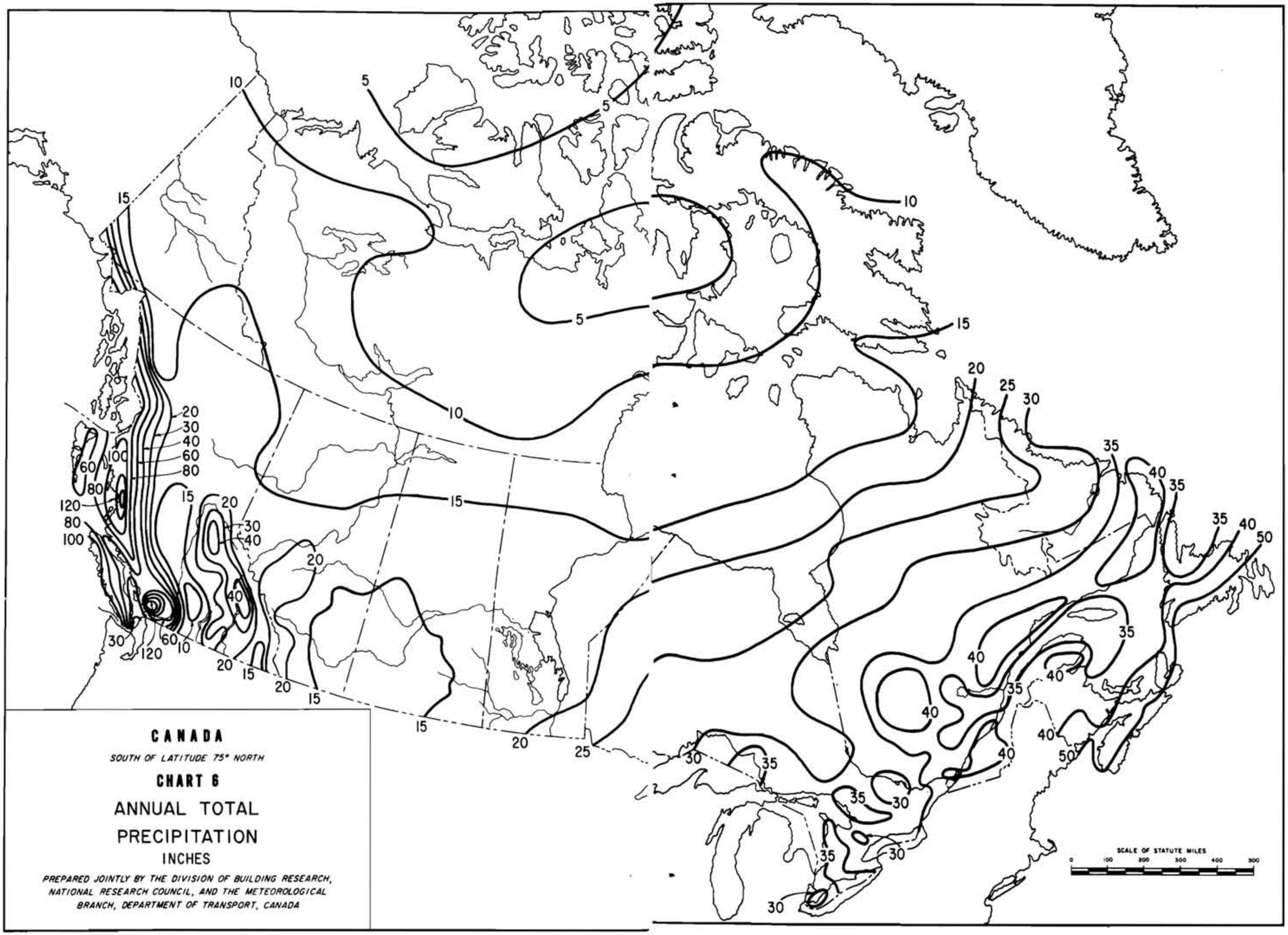
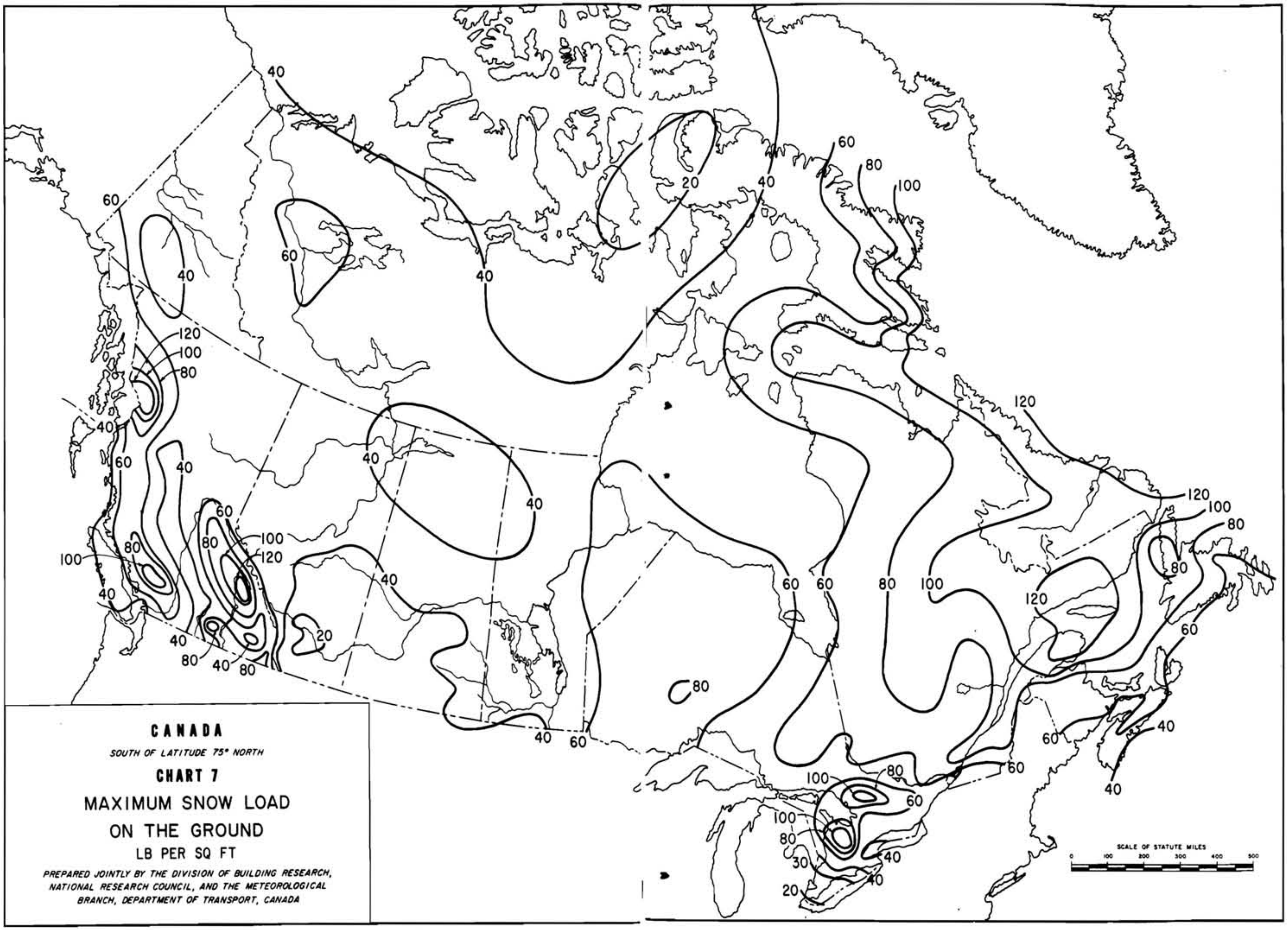
10000
9000
8000
7000
6000


CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 4
FIFTEEN MINUTE RAINFALL
TEN-YEAR RETURN PERIOD
INCHES
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA
SCALE OF STATUTE MILES
0 100 200 300 400 500

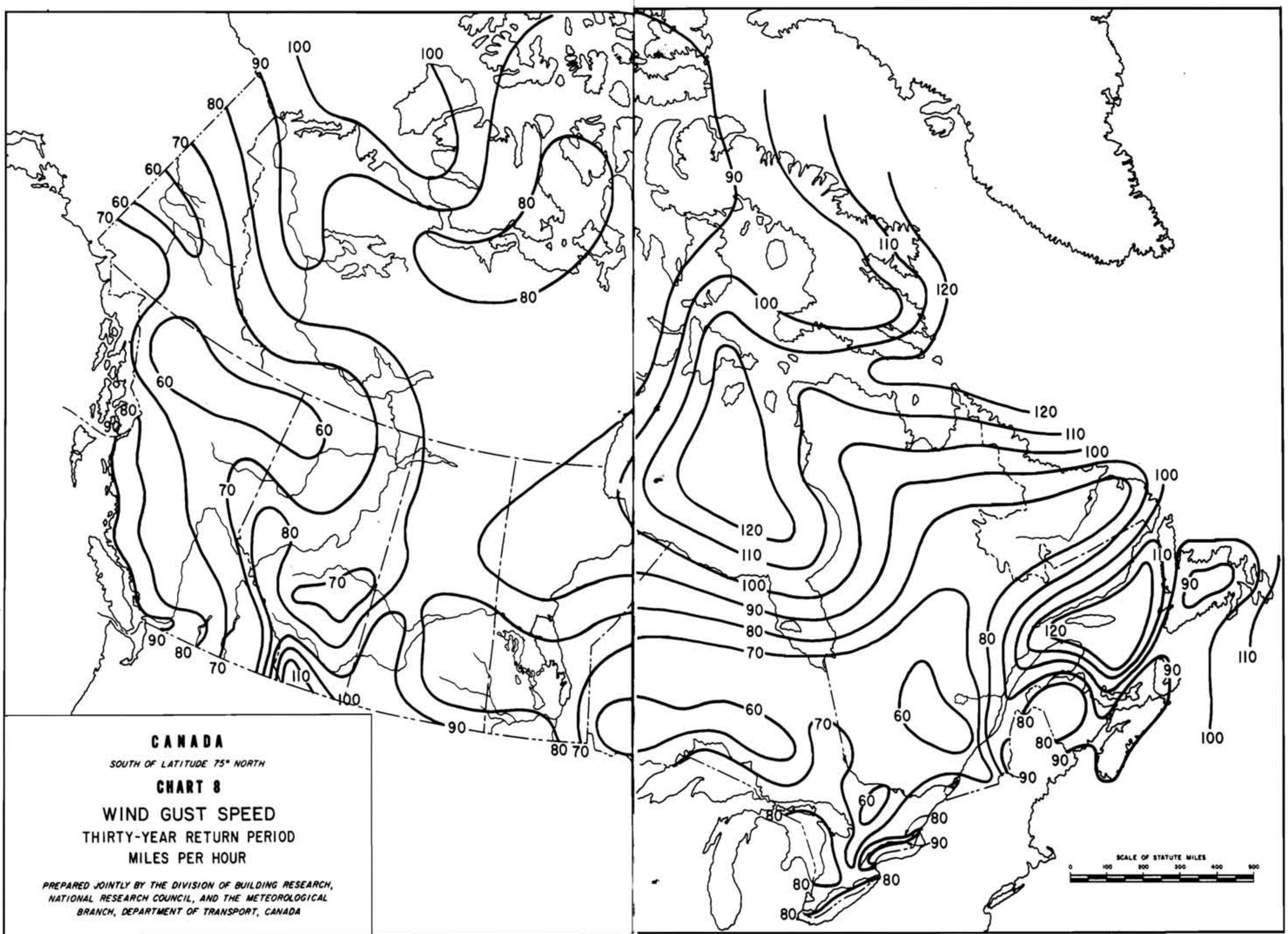

CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 5
MAXIMUM
ONE-DAY RAINFALL
INCHES
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA
SCALE OF STATUTE MILES
0 100 200 300 400 500


CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 6
ANNUAL TOTAL PRECIPITATION
INCHES
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA
SCALE OF STATUTE MILES
0 100 200 300 400 500

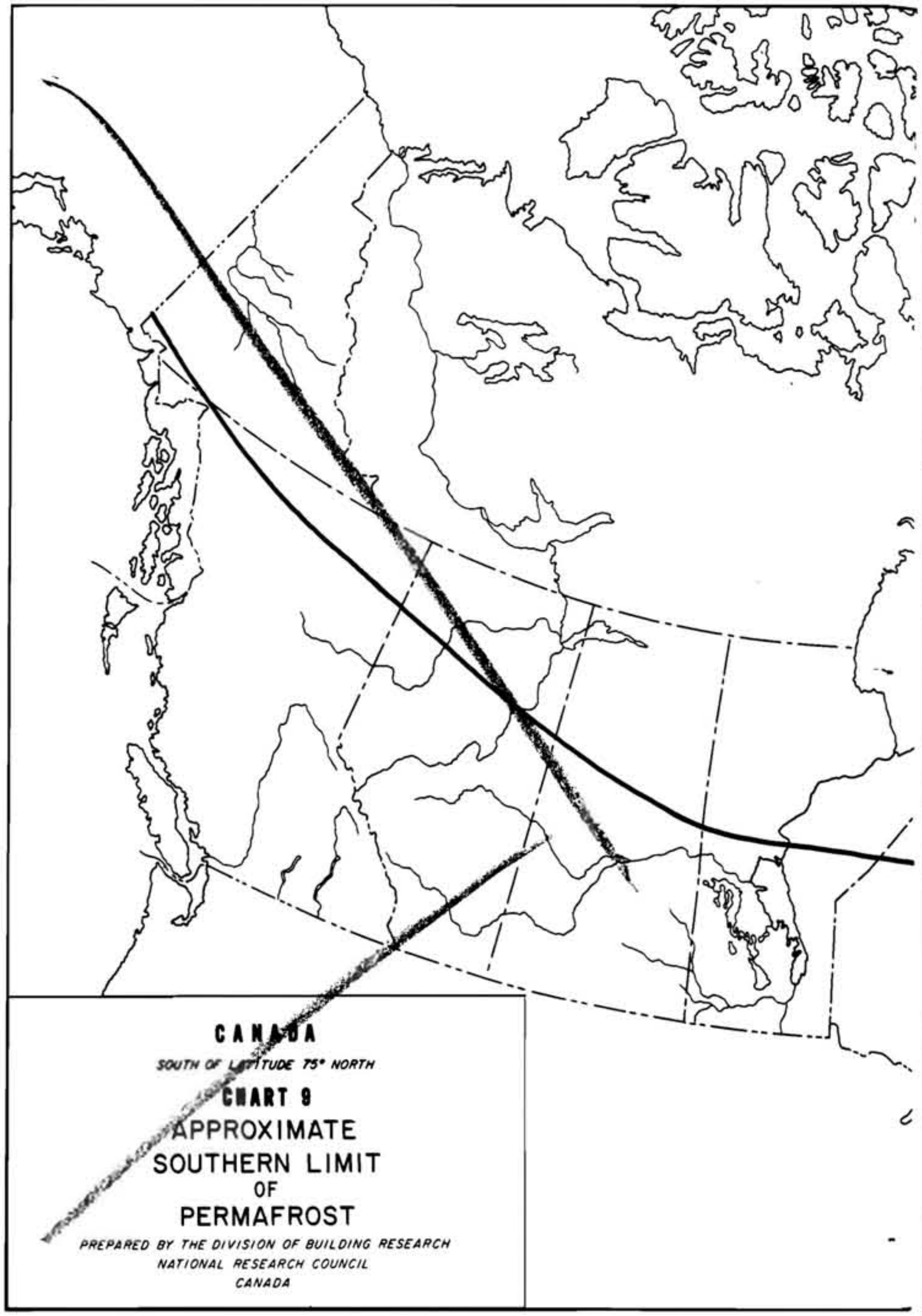
Section 1


CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 7
MAXIMUM SNOW LOAD
ON THE GROUND
LB PER SQ FT
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA
SCALE OF STATUTE MILES
0 100 200 300 400 500

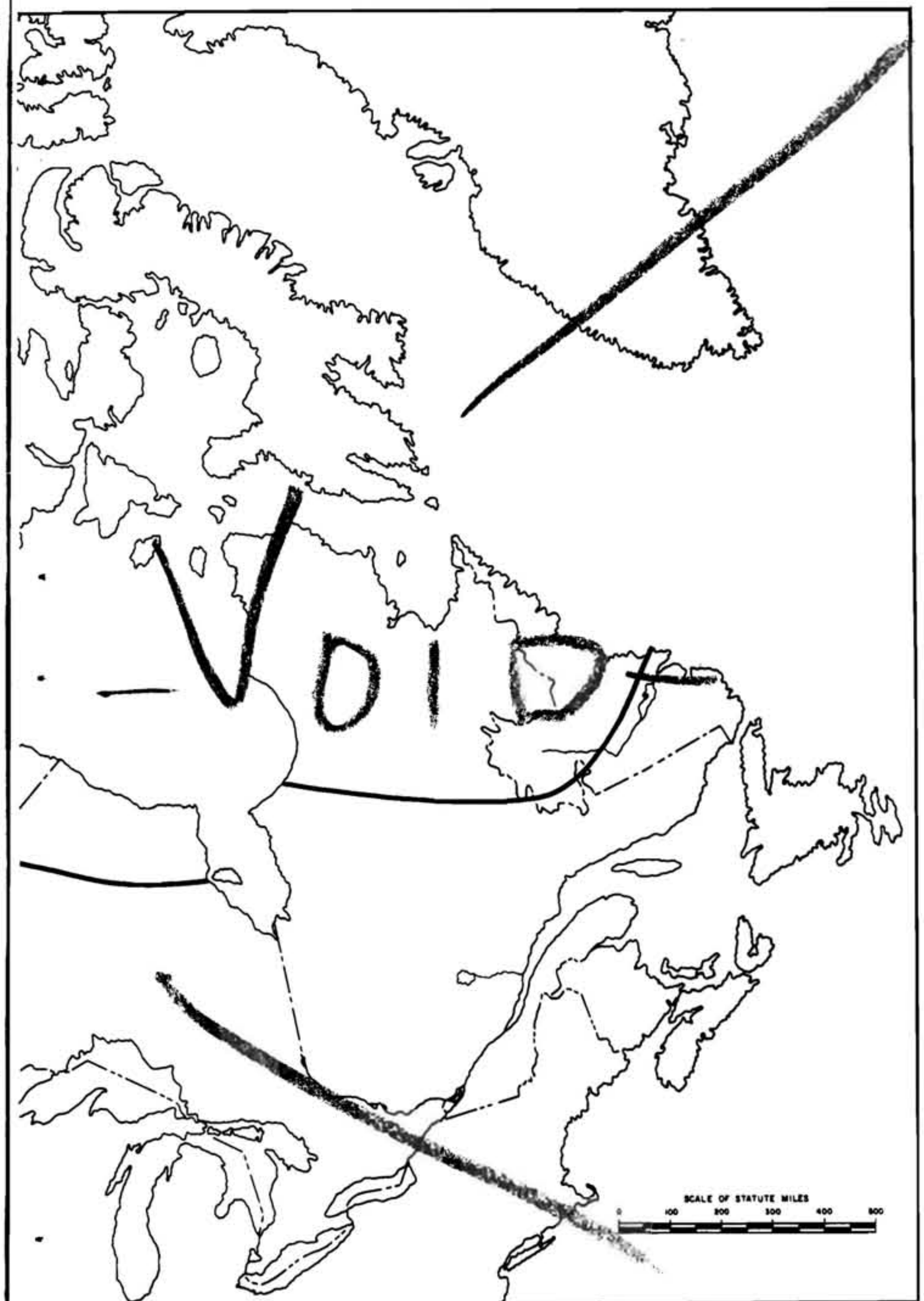
Section 1


CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 8
WIND GUST SPEED
THIRTY-YEAR RETURN PERIOD
MILES PER HOUR
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA
SCALE OF STATUTE MILES
0 100 200 300 400 500

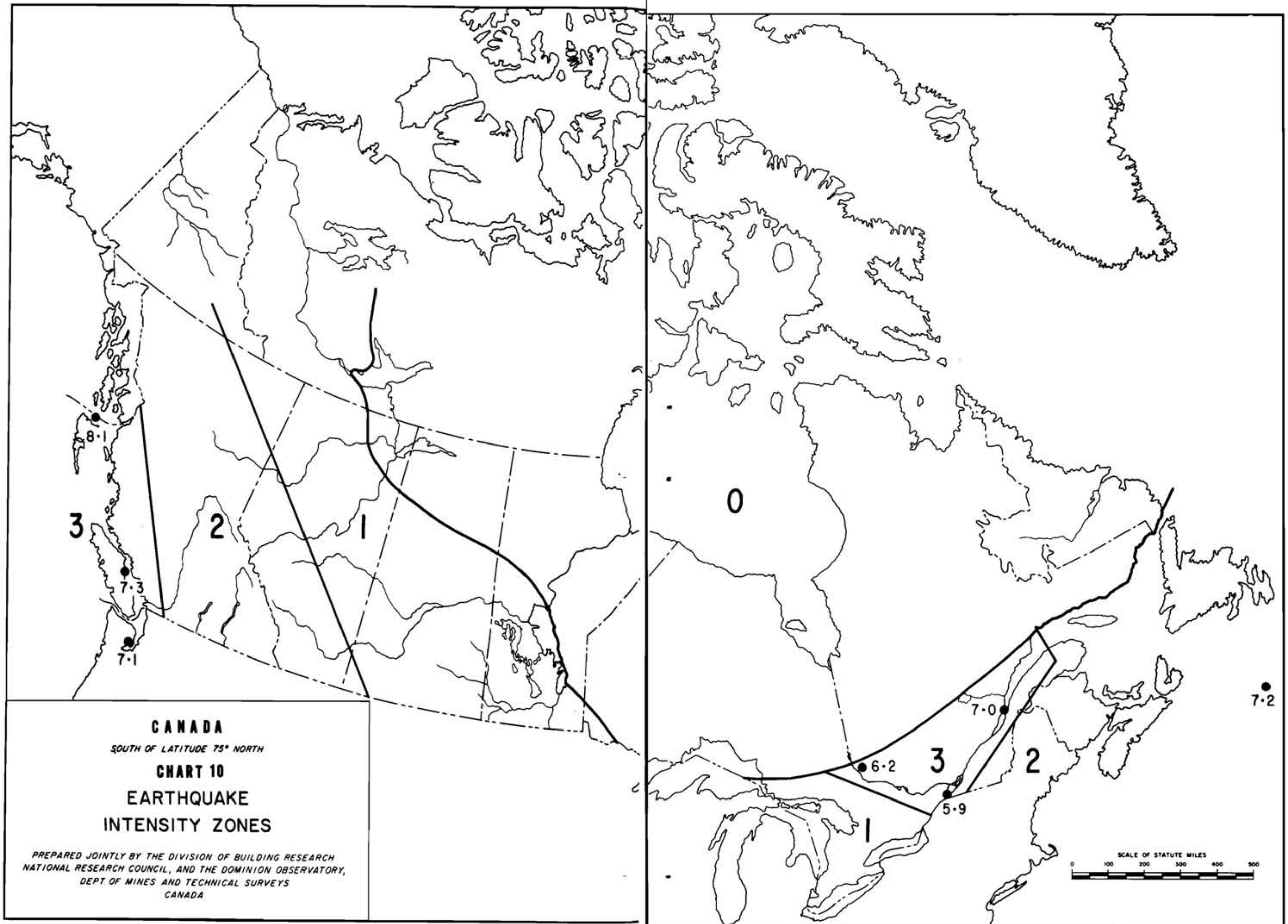
See Map at Back.



Section 1



Section 1


CANADA
SOUTH OF LATITUDE 75° NORTH
CHART 10
EARTHQUAKE
INTENSITY ZONES
PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL, AND THE DOMINION OBSERVATORY,
DEPT OF MINES AND TECHNICAL SURVEYS
CANADA
3
2
1
0
3
2
1
8·1
7·3
7·1
7·0
6·2
5·9
7·2
SCALE OF STATUTE MILES
0
100
200
300
400
500

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earthquake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
British Columbia												
Abbotsford	13	11	84	68	5735	0.4	4.0	60	50	90	22	4
Agassiz	7	4	87	69	5464	0.4	4.5	60	60	104	29	2
Alberni	22	20	87	65	5865	0.4	4.5	67	52	92	23	4
Ashcroft	−14	−19	95	69	7452	0.5	2.0	9	27	73	14	2
Beatton River	−36	−40	78	64	12831	0.5	2.0	17	60	65	11	2
Campbell River	18	15	79	64	5900	0.3	4.5	55	58	92	23	4
Carmi	−11	−16	91	69	9565	0.6	2.0	21	80	71	14	2
Chilliwack	10	7	86	68	5496	0.4	4.5	59	55	96	25	4
Comox	18	15	80	64	5980	0.3	4.0	53	57	92	23	4
Courtenay	18	15	81	64	6000	0.3	4.0	53	57	92	23	4
Cranbrook	−17	−22	89	66	8743	0.5	2.5	15	44	67	12	2
Crescent Valley	−5	−11	88	67	7946	0.6	2.0	29	67	67	12	2
Crofton	21	19	81	64	5800	0.3	4.0	38	35	92	23	4
Dawson Creek	−35	−40	81	64	10800	0.6	2.5	15	49	75	15	2
Dog Creek	−20	−24	87	68	9383	0.4	2.0	15	37	75	15	2
Duncan	21	19	85	64	5900	0.3	4.0	32	35	92	23	4
Fort Nelson	−41	−44	84	64	12777	0.5	2.5	16	44	60	10	1
Fort St. John	−34	−39	80	64	10874	0.6	2.5	15	53	74	15	2
Glacier	−17	−22	81	64	10504	0.6	3.5	52	161	67	12	2
Golden	−19	−23	86	64	9093	0.5	2.5	18	75	70	13	2
Haney	15	12	85	67	6055	0.3	4.5	65	45	94	24	4
Kamloops	−10	−16	94	69	6799	0.5	2.0	10	35	75	15	2
Kelowna	0	−5	91	69	6776	0.6	2.0	12	41	80	17	2
Kimberley	−16	−21	88	66	8965	0.5	2.0	15	38	67	12	2
Kitimat (Plant Site)	2	−1	76	62	7562	0.5	5.5	88	70	82	18	4
Kitimat (Town Site)	+2	−1	76	62	7600	0.5	6.0	88	90	82	18	4
Langley	17	14	84	67	5500	0.3	4.5	60	44	92	23	4
Lytton	−3	−8	95	69	5934	0.5	2.5	17	60	77	16	2
Mission City	14	11	85	68	5500	0.4	5.0	70	50	94	24	4
Nanaimo	20	17	78	64	5554	0.3	3.0	37	46	92	23	4
Nelson	−5	−11	88	67	7200	0.6	2.5	29	65	67	12	2
New Westminster	19	15	84	66	5412	0.3	4.5	55	40	90	22	4
North Van. City	19	15	78	66	5700	0.4	5.0	70	40	90	22	4
Penticton	3	−1	91	69	6522	0.6	2.0	12	27	88	21	2
Port Alberni	22	20	87	65	5865	0.4	4.5	67	52	92	23	4
Port Hardy	21	19	70	61	6730	0.5	5.5	60	53	92	23	4
Port McNeill	21	19	73	62	6400	0.5	5.0	50	52	92	23	4
Powell River	15	12	79	64	5362	0.3	4.0	35	65	90	22	4
Prince George	−31	−37	82	65	9755	0.4	2.0	22	59	63	11	2
Prince Rupert	15	11	71	60	7029	0.5	5.5	94	33	86	20	4
Princeton	−16	−23	90	69	8368	0.5	4.5	13	49	82	18	2
Quesnel	−29	−34	87	66	9072	0.4	2.5	19	58	67	12	2
Revelstoke	−16	−21	91	68	7756	0.6	4.0	39	88	67	12	2
Richmond	19	15	81	66	5400	0.3	4.5	57	34	90	22	4
Salmon Arm	−10	−15	92	69	7530	0.6	2.0	20	50	73	14	2
Sandspit	20	18	63	—	6705	0.5	4.0	70	28	96	25	4
Smithers	−22	−26	79	63	9693	0.4	2.5	18	39	75	15	2
Smith River	−51	−54	80	63	13917	0.3	2.0	18	48	62	10	1
Squamish	12	8	84	67	5800	0.4	4.5	100	63	86	20	4
Stewart	−10	−13	76	61	8648	0.4	3.5	72	160	77	16	2
Terrace	−5	−10	80	62	8300	0.5	4.5	47	75	80	17	4
Tofino	27	26	66	—	6000	0.5	6.0	95	40	96	25	4
Trail	−5	−11	91	68	6711	0.6	2.5	24	62	70	13	2
Vancouver	19	15	78	66	5515	0.3	4.5	57	34	90	22	4
Vernon	−5	−10	91	69	7420	0.6	2.0	16	41	77	16	2
Victoria	23	20	76	62	5579	0.2	3.5	26	25	92	23	4
Williams Lake	−23	−28	87	67	9300	0.4	2.0	18	44	73	14	2
Youbou	22	20	87	65	6200	0.4	4.5	65	50	90	22	4
Alberta												
Banff	−22	−26	81	64	10551	0.7	2.5	18	56	82	18	2
Beaverlodge	−35	−41	82	64	10682	0.6	3.0	17	47	71	14	2
Brooks	−26	−31	90	67	9700	0.6	3.5	13	20	84	19	2
Calgary	−25	−29	85	64	9703	0.9	3.5	17	19	83	19	2
Campsie	−30	−35	82	66	11019	0.8	4.0	18	42	77	16	1
Camrose	−28	−33	85	67	10500	0.7	3.5	15	27	67	12	1
Cardston	−24	−29	85	65	8863	0.5	4.0	18	30	115	36	2
Claresholm	−26	−31	85	65	9400	0.6	3.5	17	15	107	31	2
Cold Lake	−33	−38	83	68	11800	0.6	3.0	17	41	75	15	1
Coleman	−25	−30	83	65	9400	0.5	4.0	20	45	100	27	2
Coronation	−24	−28	87	67	10624	0.6	2.5	14	49	70	13	1

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earth-quake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
Cowley	−26	−31	84	65	9446	0.5	3.5	19	37	114	35	2
Drumheller	−25	−29	86	66	10200	0.7	2.5	14	21	77	16	2
Edmonton	−26	−29	83	67	10268	0.9	4.0	18	27	78	16	1
Edson	−30	−35	83	64	10837	0.6	3.0	20	46	80	17	2
Embarras Portage	−43	−47	82	66	13700	0.4	2.5	15	32	75	15	0
Fairview	−38	−43	80	65	11307	0.6	2.0	18	44	70	13	2
Fort Vermilion	−42	−46	84	65	13113	0.3	2.5	13	50	64	11	1
Grande Prairie	−37	−43	81	64	11129	0.6	3.0	18	46	81	18	2
High River	−25	−29	84	64	9752	0.8	5.0	20	38	94	24	2
Jasper	−28	−32	84	64	10112	0.4	3.0	14	52	80	17	2
Keg River	−40	−44	83	65	12500	0.4	2.5	15	52	60	10	1
Lac la Biche	−32	−38	83	67	11256	0.6	3.0	17	40	75	15	1
Lacombe	−28	−33	86	66	10527	0.7	3.5	18	30	69	13	2
Lethbridge	−24	−31	88	66	8644	0.5	3.5	17	22	105	30	2
McMurray	−39	−42	84	67	12462	0.6	3.5	16	42	75	15	1
Medicine Hat	−26	−30	93	69	8852	0.4	3.0	14	27	85	20	2
Peace River	−37	−43	80	65	11700	0.6	2.0	13	47	67	12	1
Penhold	−28	−33	85	65	10602	0.7	4.0	16	30	75	15	2
Pincher Creek	−26	−31	85	65	9198	0.5	3.5	21	37	112	34	2
Ranfurly	−30	−35	86	67	10964	0.7	3.5	17	31	67	12	1
Red Deer	−28	−33	86	65	10302	0.7	4.5	16	30	75	15	2
Rocky Mountain House	−25	−28	83	64	10167	0.8	4.0	23	41	70	13	2
Slave Lake	−34	−40	81	66	11385	0.7	3.0	18	42	72	14	1
Stettler	−27	−32	87	66	10243	0.7	3.0	16	25	70	13	2
Suffield	−26	−31	92	69	9820	0.5	2.5	13	22	88	21	2
Taber	−25	−31	89	67	8703	0.5	3.0	15	22	100	27	2
Valleyview	−36	−42	81	65	11200	0.7	2.0	18	44	80	17	2
Vegreville	−29	−33	85	67	11000	0.7	3.5	17	31	70	13	1
Vermilion	−31	−36	86	68	11253	0.6	3.0	17	28	66	12	1
Wagner	−34	−40	81	66	11316	0.7	2.5	17	43	72	14	1
Wainwright	−28	−32	86	67	11000	0.6	2.5	15	26	70	13	1
Wetaskiwin	−27	−31	85	66	10383	0.8	3.0	17	28	70	13	1
Whitecourt	−32	−38	82	65	11229	0.7	2.5	21	48	77	16	2
Wimborne	−26	−30	85	65	10300	0.7	3.5	17	27	75	15	2
Saskatchewan												
Assiniboia	−25	−29	89	71	9800	0.6	3.0	14	24	88	21	1
Biggar	−29	−33	88	69	10805	0.5	4.0	14	36	94	24	1
Broadview	−29	−33	85	72	11147	0.6	3.5	17	41	70	13	1
Dafoe	−32	−38	84	70	11640	0.6	3.0	16	33	72	14	1
Dundurn	−30	−34	87	70	10714	0.4	3.0	14	35	84	19	1
Estevan	−25	−30	89	73	9950	0.8	3.0	17	43	87	20	1
Hudson Bay	−33	−37	84	71	11842	0.7	2.5	16	50	72	14	1
Humboldt	−32	−37	83	70	11500	0.6	2.5	15	35	74	15	1
Island Falls	−38	−41	80	69	13000	0.4	2.5	19	36	91	22	1
Kamsack	−29	−33	85	72	11517	0.7	3.0	16	50	75	15	1
Kindersley	−27	−32	90	69	10450	0.4	3.0	13	35	92	23	1
Lloydminster	−30	−35	85	68	11500	0.6	2.5	15	31	75	15	1
Maple Creek	−25	−29	89	70	9500	0.4	3.0	14	32	92	23	2
Meadow Lake	−33	−38	83	69	12000	0.6	2.5	15	42	82	18	1
Melfort	−34	−40	83	70	11700	0.6	3.0	16	38	70	13	1
Melville	−28	−33	85	71	11300	0.7	3.5	16	47	75	15	1
Moose Jaw	−27	−32	89	71	9894	0.5	2.5	15	28	80	17	1
Nipawin	−36	−41	82	70	12000	0.6	3.0	16	43	72	14	1
North Battleford	−29	−33	86	69	11082	0.6	3.0	13	39	95	24	1
Prince Albert	−35	−41	84	70	11630	0.6	3.0	16	44	72	14	1
Qu'Appelle	−29	−34	85	71	11100	0.6	2.5	17	41	77	16	1
Regina	−29	−34	88	71	10806	0.6	3.0	15	35	77	16	1
Saskatoon	−30	−34	86	69	10856	0.4	3.0	14	35	81	18	1
Strasbourg	−29	−34	86	71	10800	0.6	3.5	15	41	77	16	1
Swift Current	−25	−29	89	70	9849	0.3	2.5	15	24	91	22	1
Uranium City	−47	−50	79	66	15000	0.3	2.0	13	37	82	18	0
Weyburn	−27	−32	89	72	10500	0.7	3.0	16	35	82	18	1
Yorkton	−28	−33	85	72	11362	0.7	3.5	17	50	75	15	1
Manitoba												
Beausejour	−26	−29	83	73	10700	0.6	3.5	20	46	75	15	1
Boissevain	−24	−28	89	74	10269	0.9	4.0	19	40	88	21	1
Brandon	−26	−29	87	73	10828	0.8	4.0	19	46	82	18	1

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earthquake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
Churchill	−38	−40	75	66	16728	0.3	3.5	14	66	93	23	0
Dauphin	−26	−29	86	72	10798	0.6	3.5	18	52	75	15	1
Flin Flon	−36	−40	81	69	12414	0.5	3.0	17	45	88	21	1
Gimli	−28	−30	83	73	11057	0.5	4.5	19	45	75	15	1
Island Lake	−32	−35	78	69	13200	0.5	2.5	20	62	80	17	0
Lac du Bonnet	−28	−30	82	73	10900	0.6	3.0	20	48	72	14	1
Lynn Lake	−40	−43	81	68	14300	0.3	2.0	16	38	92	23	0
Morden	−22	−25	89	74	10068	0.9	4.0	21	38	84	19	1
Neepawa	−25	−29	86	73	10899	0.7	4.0	20	53	78	16	1
Pine Falls	−28	−30	81	73	11000	0.5	4.0	19	46	73	14	1
Portage la Prairie	−22	−25	87	74	10800	0.7	5.0	20	40	80	17	1
Rivers	−27	−30	85	73	10884	0.8	4.0	19	47	80	17	1
St. Boniface	−25	−28	87	74	10700	0.6	3.5	20	45	79	17	1
St. Vital	−25	−28	87	74	10700	0.6	3.5	20	45	79	17	1
Sandilands	−25	−28	85	74	10800	0.7	3.5	22	47	75	15	1
Selkirk	−26	−29	84	74	10800	0.6	3.5	20	45	77	16	1
Split Lake	−35	−38	80	68	14400	0.4	2.0	16	56	94	24	0
Steinbach	−25	−28	87	74	10700	0.7	3.5	21	45	75	15	1
Swan River	−30	−33	84	72	11500	0.6	3.0	17	52	73	14	1
The Pas	−32	−35	81	71	12281	0.6	3.0	17	59	80	17	1
Thompson	−35	−38	80	69	13900	0.4	2.0	17	50	92	23	0
Transcona	−25	−28	87	74	10700	0.6	3.5	20	45	79	17	1
Virden	−27	−30	86	73	10800	0.8	4.0	18	46	80	17	1
Whiteshell	−28	−30	82	73	10900	0.6	3.0	20	48	72	14	1
Winnipeg	−25	−28	87	74	10679	0.6	3.5	20	45	79	17	1
Ontario												
Ailsa Craig	4	1	88	74	7300	1.2	3.5	38	40	86	20	1
Ajax	−2	−5	87	75	7500	1.1	3.0	32	43	88	21	1
Alexandria	−11	−16	86	74	8400	0.9	3.0	37	58	75	15	4
Alliston	−7	−11	85	74	8300	1.1	4.5	30	65	67	12	1
Almonte	−14	−18	86	74	8700	1.0	3.0	33	60	75	15	4
Ansonville	−27	−32	86	71	11400	0.9	2.5	30	69	75	15	0
Armstrong	−38	−44	83	71	12458	0.9	4.0	27	82	61	10	0
Arnprior	−16	−20	87	74	8800	0.9	3.0	31	60	72	14	4
Atikokan	−29	−34	85	72	11066	1.0	3.5	25	65	60	10	0
Aurora	−4	−8	86	74	7900	1.1	4.0	29	48	77	16	1
Bancroft	−15	−19	84	73	9100	1.1	2.5	30	73	67	12	1
Barrie	−9	−13	85	73	8200	1.1	5.0	32	60	67	12	1
Barriefield	−7	−10	82	75	7800	0.9	4.5	34	50	80	17	1
Beaverton	−10	−14	86	73	8400	1.1	5.5	34	50	70	13	1
Belleville	−7	−11	86	75	7709	1.3	3.0	32	50	77	16	1
Belmont	4	0	88	75	7300	1.2	3.5	37	38	82	18	1
Bowmanville	−3	−6	86	75	7600	1.1	3.0	32	44	90	22	1
Bracebridge	−13	−17	84	72	8800	1.0	4.5	40	69	60	10	1
Bradford	−7	−11	86	74	8100	1.1	4.5	30	52	70	13	1
Brampton	0	−4	87	75	7721	1.1	6.0	31	50	77	16	1
Brantford	3	−1	88	75	7202	1.1	4.0	31	48	75	15	1
Brighton	−5	−8	86	75	7800	1.3	3.0	32	48	86	20	1
Brockville	−9	−13	85	75	7900	1.0	3.5	38	54	77	16	4
Brooklin	−3	−7	87	75	7800	1.1	3.0	31	44	84	19	1
Burks Falls	−14	−18	84	71	9300	1.1	4.0	36	106	64	11	1
Burlington	3	0	88	75	6800	1.0	4.0	31	40	80	17	1
Caledonia	4	1	88	75	7200	1.1	4.0	31	46	75	15	1
Campbellford	−9	−13	87	74	8100	1.3	3.5	31	55	75	15	1
Camp Borden	−8	−12	85	73	8200	1.1	4.5	28	65	67	12	1
Cannington	−9	−13	86	74	8400	1.1	5.0	32	50	70	13	1
Carleton Place	−13	−17	86	74	8600	1.0	3.0	33	58	75	15	4
Cavan	−7	−11	87	74	8200	1.2	3.0	31	52	77	16	1
Centralia	4	1	88	74	7243	1.2	3.5	38	41	84	19	1
Chapleau	−31	−36	82	71	10900	0.9	3.5	30	64	60	10	0
Chatham	6	3	90	75	6503	1.1	4.0	30	27	77	16	1
Chelmsford	−15	−20	86	70	9700	1.0	3.0	30	55	77	16	1
Chesley	0	−4	86	72	7800	1.1	3.0	35	100	80	17	1
Clinton	4	0	86	73	7600	1.1	3.5	35	50	84	19	1
Coboconk	−12	−16	85	73	8700	1.1	5.0	38	60	67	12	1
Cobourg	−4	−7	86	75	7700	1.2	3.0	32	45	90	22	1
Cochrane	−28	−32	85	71	11412	0.9	2.5	31	68	70	13	0
Colborne	−5	−8	86	75	7700	1.2	3.0	32	45	88	21	1
Collingwood	−6	−10	84	72	8400	1.1	4.0	32	85	72	14	1
Cooksville	2	−2	87	75	7000	1.0	5.5	31	40	82	18	1

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earthquake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
Cornwall	−9	−14	86	75	8200	1.0	2.5	38	55	75	15	4
Corunna	6	2	90	74	7000	0.9	3.5	32	30	80	17	1
Deep River	−20	−24	88	73	9500	0.9	3.5	29	56	60	10	4
Deseronto	−7	−11	84	75	7500	1.1	3.5	33	50	77	16	1
Dorchester Station	3	−1	88	75	7400	1.3	3.5	36	42	80	17	1
Dorion	−27	−32	82	70	10800	0.7	3.0	29	68	67	12	0
Dresden	5	2	90	75	6800	1.1	3.0	31	29	77	16	1
Dryden	−29	−32	78	72	11147	0.9	4.0	25	62	60	10	0
Dunbarton	−1	−4	87	75	7400	1.1	4.0	32	42	88	21	1
Dunnville	7	4	87	75	7000	1.0	4.0	35	48	77	16	1
Durham	−2	−6	85	73	8474	1.1	3.0	35	110	77	16	1
Dutton	5	2	89	75	6900	1.1	3.5	35	32	80	17	1
Earlton	−26	−32	87	71	10792	1.0	3.5	29	53	78	16	0
Eastview	−13	−17	87	74	8600	0.9	3.5	35	60	75	15	4
Edison	−28	−32	82	72	11000	0.9	3.5	25	62	60	10	0
Elmvale	−9	−13	84	72	8400	1.1	5.0	33	75	70	13	1
Embro	3	−1	86	75	7600	1.3	3.5	35	52	80	17	1
Englehart	−26	−32	87	71	10900	1.0	4.0	29	56	75	15	0
Espanola	−13	−17	84	70	9300	1.0	3.5	32	55	75	15	1
Exeter	4	1	88	74	7500	1.2	3.5	38	45	84	19	1
Fergus	−2	−6	85	74	8452	1.2	3.5	33	106	70	13	1
Fonthill	6	3	87	75	6800	1.0	4.0	33	50	77	16	1
Forest	6	2	89	74	7031	1.0	3.5	34	35	84	19	1
Fort Erie	7	5	87	75	6600	1.0	4.0	34	55	80	17	1
Fort Frances	−27	−31	85	73	10700	1.0	3.5	28	62	60	10	1
Fort William	−23	−27	83	70	10405	0.7	3.0	28	73	67	12	0
Galt	1	−3	86	75	7600	1.2	4.0	33	55	70	13	1
Gananoque	−7	−11	83	75	7800	0.9	3.5	36	52	80	17	1
Georgetown	0	−4	86	75	7817	1.1	5.0	32	55	72	14	1
Geraldton	−31	−36	83	71	12000	0.8	3.0	27	63	60	10	0
Glencoe	5	2	90	75	7000	1.1	3.5	35	34	77	16	1
Goderich	4	1	85	73	7712	1.1	3.5	31	50	86	20	1
Gore Bay	−9	−13	86	70	9009	1.0	2.5	32	45	74	15	1
Graham	−35	−40	84	71	11838	0.9	4.0	27	70	60	10	0
Gravenhurst	−13	−17	84	72	8700	1.1	4.5	40	62	60	10	1
Grimsby	5	2	88	75	6592	1.0	4.5	31	38	80	17	1
Guelph	0	−4	85	75	7749	1.2	4.5	33	60	68	12	1
Guthrie	−10	−14	85	73	8300	1.1	5.0	33	56	67	12	1
Hagersville	5	2	88	75	7200	1.1	4.0	33	44	77	16	1
Haileybury	−25	−30	87	71	10700	1.0	3.5	29	56	77	16	0
Haliburton	−15	−19	84	73	9038	1.1	3.5	34	75	60	10	1
Hamilton	3	0	88	75	6821	1.0	4.0	31	40	80	17	1
Hanover	0	−4	87	73	8000	1.1	3.0	36	106	80	17	1
Hastings	−9	−13	87	74	8200	1.3	3.5	31	55	75	15	1
Hawkesbury	−13	−18	86	74	8800	0.9	3.5	39	62	75	15	4
Hearst	−28	−32	84	71	11900	0.8	2.5	28	56	63	11	0
Honey Harbour	−10	−13	84	72	8400	1.0	5.0	35	80	72	14	1
Hornepayne	−35	−40	84	71	12066	0.8	3.0	25	54	60	10	0
Huntsville	−14	−18	84	72	8726	1.0	4.0	36	104	60	10	1
Ingersoll	3	−1	87	75	7400	1.3	3.5	35	46	80	17	1
Jarvis	5	2	88	75	7100	1.1	4.0	34	41	77	16	1
Jellicoe	−32	−37	83	71	11800	0.8	3.0	28	65	60	10	0
Kapuskasing	−28	−31	84	71	11560	0.8	2.5	28	56	66	12	0
Kemptville	−12	−16	86	75	8338	1.1	3.0	34	57	75	15	4
Kenora	−28	−31	83	73	10796	0.9	3.5	25	62	60	10	0
Killaloe	−18	−22	87	73	9074	1.0	3.0	28	55	67	12	4
Kincardine	3	0	84	72	7800	1.0	3.0	35	75	86	20	1
Kingston	−7	−10	82	75	7724	0.9	4.5	34	50	80	17	1
Kinmount	−13	−17	85	73	8800	1.1	4.0	38	65	64	11	1
Kirkland Lake	−27	−32	87	71	11269	1.0	3.5	29	62	75	15	0
Kitchener	1	−3	85	75	7566	1.3	4.0	33	60	72	14	1
Lakefield	−10	−14	86	74	8500	1.2	3.5	30	60	72	14	1
Lansdowne House	−38	−44	82	70	13021	0.7	2.5	24	69	67	12	0
Leamington	7	4	90	75	6547	1.1	3.5	30	22	80	17	1
Lindsay	−9	−13	87	74	8400	1.2	4.0	32	55	72	14	1
Lions Head	−1	−5	82	71	8000	1.0	3.0	35	75	80	17	1
Listowel	0	−4	85	74	8500	1.3	3.0	38	94	80	17	1
London	3	−1	88	75	7349	1.3	3.5	38	42	84	19	1
Lucan	4	0	88	75	7395	1.3	3.5	38	42	86	20	1
Maitland	−9	−13	85	75	7900	1.0	3.0	38	54	77	16	4
Markdale	−3	−7	84	73	8600	1.1	3.0	33	100	75	15	1

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earthquake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
Martin	−32	−37	84	72	11600	0.9	4.5	26	67	60	10	0
Matheson	−27	−32	86	71	11400	0.9	3.0	29	68	75	15	0
Mattawa	−19	−23	87	72	9800	1.0	3.5	31	55	67	12	4
Midland	−9	−13	84	72	8400	1.0	5.0	34	80	72	14	1
Milton	1	−3	87	75	7500	1.1	5.0	31	50	77	16	1
Milverton	0	−4	85	74	8300	1.3	3.0	38	80	77	16	1
Minden	−14	−18	84	73	8900	1.1	4.0	38	65	60	10	1
Mitchell	2	−2	86	74	8076	1.3	3.0	38	60	82	18	1
Moosonee	−32	−36	84	70	12723	0.7	2.5	31	56	60	10	0
Morrisburg	−9	−14	86	75	8105	1.0	3.0	38	55	75	15	4
Mount Forest	−2	−6	84	74	8800	1.2	3.0	33	110	75	15	1
Muskoka Arpt.	−13	−17	84	72	8758	1.1	4.5	40	62	60	10	1
Nakina	−30	−34	83	71	11969	0.8	3.0	28	65	60	10	0
Napanee	−7	−11	84	75	7600	1.1	3.5	33	50	77	16	1
Newcastle	−3	−6	86	75	7600	1.1	3.0	32	44	90	22	1
New Liskeard	−25	−30	87	71	10700	1.0	3.5	29	56	77	16	0
Niagara Falls	5	2	87	75	6881	1.0	3.5	32	48	77	16	1
North Bay	−17	−21	84	70	9677	1.1	4.0	33	54	69	13	1
Norwood	−10	−14	87	74	8300	1.2	3.5	32	60	75	15	1
Oakville	2	−1	87	75	6700	1.0	4.5	31	40	82	18	1
Orangeville	−4	−8	85	74	8526	1.2	3.0	33	80	70	13	1
Orillia	−11	−15	85	73	8463	1.1	5.0	34	52	64	11	1
Oshawa	−2	−5	87	75	7600	1.1	3.0	32	42	88	21	1
Ottawa	−13	−17	87	74	8693	0.9	3.5	35	60	75	15	4
Owen Sound	−1	−5	84	72	7762	1.0	3.0	33	87	80	17	1
Pagwa	−29	−33	83	71	11599	0.8	3.0	30	63	60	10	0
Paris	3	−1	87	75	7400	1.2	3.5	37	50	75	15	1
Park Hill	5	2	89	74	7300	1.2	3.5	37	40	86	20	1
Parry Sound	−10	−13	83	71	8480	1.0	3.5	38	85	72	14	1
Pembroke	−18	−22	88	73	9100	0.9	3.5	29	55	64	11	4
Penetanguishene	−9	−13	84	72	8400	1.0	5.0	34	80	72	14	1
Perth	−12	−16	86	74	8300	1.1	3.0	34	58	75	15	4
Petawawa	−19	−23	88	73	9200	0.9	3.5	29	56	60	10	4
Peterborough	−9	−13	87	74	8300	1.2	3.5	31	60	75	15	1
Petrolia	5	2	90	75	6900	1.0	3.0	32	31	80	17	1
Picton	−5	−9	85	75	7500	1.1	3.0	33	48	82	18	1
Plattsville	2	−2	85	75	7600	1.3	3.5	33	58	75	15	1
Point Alexander	−20	−24	88	73	9500	0.9	3.5	29	56	60	10	4
Porcupine	−28	−33	87	71	11400	0.9	3.0	28	68	72	14	0
Port Arthur	−23	−27	83	70	10405	0.7	3.0	28	73	67	12	0
Port Burwell	6	3	88	75	7000	1.0	4.0	36	32	80	17	1
Port Colborne	7	4	87	75	6700	1.0	4.0	34	55	80	17	1
Port Credit	2	−2	87	75	6800	1.0	5.5	31	40	82	18	1
Port Dover	6	3	88	75	7046	1.0	4.0	34	38	80	17	1
Port Elgin	2	−1	83	71	7800	1.0	3.0	36	87	86	20	1
Port Hope	−4	−7	86	75	7700	1.2	3.0	32	45	90	22	1
Port Perry	−6	−10	87	74	8100	1.2	3.5	31	45	77	16	1
Port Stanley	6	3	89	75	7000	1.0	4.0	36	32	80	17	1
Prescott	−9	−13	85	75	8000	1.0	3.0	38	54	77	16	4
Princeton	3	−1	85	75	7400	1.2	3.5	33	50	75	15	1
Raith	−30	−35	83	71	11100	0.8	3.0	27	70	61	10	0
Red Lake	−29	−32	82	72	11400	0.7	4.0	21	62	64	11	0
Renfrew	−17	−21	87	74	8787	0.9	3.0	30	62	70	13	4
Ridgeway	7	5	87	75	6600	1.0	4.0	34	55	80	17	1
Rockland	−14	−18	87	74	8800	0.9	3.5	36	62	75	15	4
St. Catharines	5	2	88	75	6537	1.0	3.5	31	38	80	17	1
St. Marys	3	−1	87	75	7600	1.3	3.5	38	50	82	18	1
St. Thomas	5	1	89	75	7073	1.0	3.5	36	35	80	17	1
Sarnia	6	2	90	74	7061	0.9	3.5	32	30	80	17	1
Sault Ste. Marie	−15	−20	85	70	9500	1.0	2.5	32	50	75	15	1
Schreiber	−30	−34	81	70	11131	0.8	3.0	31	48	67	12	0
Seaforth	3	−1	87	74	7800	1.2	3.5	36	53	84	19	1
Simcoe	5	2	88	75	7100	1.1	4.0	35	38	77	16	1
Sioux Lookout	−29	−32	83	72	11313	0.9	4.5	27	63	60	10	0
Smiths Falls	−12	−16	86	75	8300	1.1	3.0	34	57	75	15	4
Smithville	5	2	87	75	7200	1.0	4.5	32	41	77	16	1
Smooth Rock Falls	−28	−32	85	71	11500	0.8	2.5	30	62	67	12	0
Southampton	2	−2	83	71	7811	1.0	3.0	37	87	84	19	1
South Porcupine	−28	−33	87	71	11400	0.9	3.0	28	68	72	14	0
Stirling	−9	−13	86	74	7976	1.3	3.0	31	51	74	15	1
Stratford	2	−2	85	75	7900	1.3	4.5	38	61	80	17	1

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earth-quake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
Strathroy	4	1	90	75	7200	1.2	3.0	37	38	82	18	1
Sturgeon Falls	−16	−20	85	70	9500	1.1	3.5	33	55	70	13	1
Sudbury	−15	−20	86	70	9600	1.0	3.0	29	55	78	16	1
Sundridge	−15	−19	84	71	9400	1.1	4.0	36	94	67	12	1
Tavistock	2	− 2	85	75	7700	1.3	3.5	35	60	80	17	1
Thamesford	3	− 1	87	75	7400	1.3	3.5	36	46	80	17	1
Thedford	5	2	89	74	7100	1.1	3.5	34	37	86	20	1
Tillsonburg	5	1	88	75	7200	1.1	4.0	35	38	77	16	1
Timagami	−22	−26	87	71	10200	1.1	3.5	29	60	72	14	4
Timmins	−28	−33	87	71	11400	0.9	3.0	28	68	70	13	0
Toronto	1	− 3	87	75	6827	1.0	5.0	31	40	84	19	1
Trenton	− 5	− 9	86	75	7510	1.3	3.0	32	50	80	17	1
Trout Lake	−36	−40	77	68	14040	0.5	3.5	25	78	77	16	0
Uxbridge	− 7	−11	86	74	8170	1.2	4.0	31	44	75	15	1
Walkerton	1	− 3	88	73	7647	1.1	3.5	36	100	82	18	1
Wallaceburg	6	3	90	75	6668	1.1	3.0	31	27	77	16	1
Waterloo	1	− 3	85	75	7566	1.3	4.0	33	60	72	14	1
Watford	5	2	90	75	7000	1.1	3.0	34	35	80	17	1
Wawa	−32	−37	81	70	10331	0.9	3.0	36	50	66	12	0
Welland	6	3	87	75	6691	1.0	4.0	34	52	77	16	1
West Lorne	5	2	89	75	6900	1.1	4.0	35	30	80	17	1
Whitby	− 2	− 5	87	75	7500	1.1	3.0	32	43	88	21	1
White River	−39	−44	84	71	11674	0.8	3.5	30	46	60	10	0
Wiarton	1	− 3	83	71	8063	1.0	3.0	37	80	80	17	1
Windsor	7	4	90	75	6579	1.1	3.0	33	22	74	15	1
Wingham	2	− 2	87	73	7800	1.1	3.5	36	81	82	18	1
Woodstock	3	− 1	85	75	7542	1.3	3.5	34	50	77	16	1
Wyoming	5	2	90	74	7000	1.0	3.0	32	33	80	17	1
Quebec												
Acton Vale	−12	−17	85	74	8600	0.8	3.5	41	60	67	12	4
Alma	−21	−25	85	71	10700	0.7	3.0	38	72	67	12	4
Amos	−28	−32	84	71	11537	0.9	3.0	33	69	67	12	0
Ancienne Lorette	−13	−19	82	73	9372	0.8	4.0	41	81	84	19	4
Arvida	−20	−24	85	71	10528	0.7	3.0	39	75	70	13	4
Asbestos	−14	−19	84	73	8800	0.9	3.5	42	70	70	13	2
Aylmer	−13	−17	87	74	8700	0.9	3.5	35	60	75	15	4
Baie Comeau	−16	−20	76	67	10400	0.6	3.0	35	102	100	27	4
Beaconsfield	−10	−16	86	74	8200	0.8	3.0	38	54	75	15	4
Bedford	−10	−15	85	74	8200	0.9	3.0	38	55	75	15	2
Beloeil	−11	−16	85	74	8400	0.8	3.0	39	58	72	14	4
Brossard	−11	−16	85	74	8300	0.8	3.0	37	58	75	15	4
Buckingham	−14	−18	87	74	9000	0.9	4.0	36	62	75	15	4
Campbells Bay	−18	−22	88	74	8900	0.9	3.5	30	58	67	12	4
Camp Valcartier	−13	−19	82	73	9400	0.8	4.0	41	81	84	19	4
Chicoutimi	−20	−24	83	71	10104	0.7	3.0	35	75	70	13	4
Coaticook	−12	−17	83	73	9194	0.9	3.0	39	55	72	14	2
Contrecoeur	−12	−17	85	74	8800	0.8	3.5	38	70	70	13	4
Cowansville	−11	−16	84	73	8400	0.9	3.0	39	55	75	15	2
Dolbeau	−23	−28	84	71	10900	0.7	2.5	32	75	64	11	0
Dorval	−10	−16	86	74	8203	0.8	3.0	38	54	75	15	4
Drummondville	−13	−18	85	74	8700	0.8	4.0	43	72	67	12	4
Fabreville	−11	−17	85	74	8400	0.8	3.5	42	60	75	15	4
Farnham	−11	−16	85	74	8418	0.9	3.0	38	55	75	15	2
Fort Chimo	−36	−39	74	—	15445	0.2	2.0	16	75	98	26	0
Fort Coulonge	−18	−22	88	74	8900	0.9	4.0	30	58	67	12	4
Gagnon	−28	−32	76	67	13700	0.4	2.5	33	112	80	17	0
Gatineau	−13	−17	87	74	8700	0.9	3.5	35	62	75	15	4
Gatineau-Pointe	−13	−17	87	74	8700	0.9	3.5	35	62	75	15	4
Gracefield	−19	−23	86	73	9300	0.9	3.5	32	60	67	12	4
Granby	−12	−17	84	74	8400	0.9	3.0	39	56	70	13	2
Great Whale River	−34	−37	76	65	14843	0.3	2.5	26	60	105	30	0
Harrington Harbour	−13	−18	64	—	11194	0.4	3.0	50	108	116	36	0
Havre St. Pierre	−16	−21	74	64	11200	0.4	3.5	38	125	115	36	0
Hemmingford	− 9	−14	85	74	8400	0.9	3.0	39	55	75	15	4
Hull	−13	−17	87	74	8700	0.9	3.5	35	62	75	15	4
Iberville	−10	−15	85	74	8500	0.9	3.0	38	55	75	15	4
Joliette	−13	−18	85	74	8954	0.8	4.0	33	81	68	12	4
Jonquiere	−20	−24	85	71	10500	0.7	3.0	35	75	70	13	4

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earth-quake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
Kenogami	−20	−24	85	71	10515	0.7	3.0	35	75	70	13	4
Knob Lake	−37	−40	76	66	14880	0.3	2.5	28	90	77	16	0
Knowlton	−11	−16	84	73	8500	0.9	3.0	39	55	72	14	2
Lachine	−10	−16	86	74	8200	0.8	3.0	38	54	75	15	4
Lachute	−13	−18	85	74	8900	0.9	3.5	40	65	75	15	4
La Malbaie	−14	−19	81	71	9800	0.8	4.5	32	85	86	20	4
La Salle	−10	−16	86	74	8200	0.8	3.0	38	54	75	15	4
La Tuque	−19	−24	86	73	9818	0.7	3.0	34	75	60	10	4
Lennoxville	−13	−18	84	73	8893	0.9	4.0	40	55	67	12	2
Léry	−10	−15	85	74	8300	0.9	3.0	38	55	75	15	4
Les Saules	−13	−19	82	73	9200	0.8	4.0	41	81	84	19	4
Levis	−13	−19	82	73	9000	0.8	4.5	45	84	84	19	4
Loretteville	−13	−19	82	73	9400	0.8	4.0	41	81	84	19	4
Louiseville	−13	−18	85	74	9200	0.8	4.5	39	82	64	11	4
Magog	−12	−17	84	73	8680	0.9	3.0	39	55	70	13	2
Malartic	−27	−31	85	71	11200	0.9	3.0	34	65	67	12	0
Maniwaki	−20	−24	85	73	9422	0.9	3.0	31	59	66	12	4
Masson	−14	−18	87	74	8900	0.9	4.0	36	62	75	15	4
Matane	−11	−15	75	68	9900	0.6	3.5	35	106	100	27	4
Megantic	−16	−20	81	73	9688	0.9	3.0	39	78	92	23	2
Mont Joli	−12	−16	74	69	9924	0.7	3.5	35	103	101	28	4
Mont Laurier	−20	−24	84	73	9793	0.9	3.5	33	65	66	12	4
Montmagny	−13	−19	82	73	9000	0.8	3.5	38	85	86	20	4
Montreal	−10	−16	86	74	8203	0.8	3.5	42	54	75	15	4
Montreal Nord	−10	−16	86	74	8200	0.8	3.5	42	54	75	15	4
Mount Royal	−10	−16	86	74	8200	0.8	3.5	42	54	75	15	4
Nitchequon	−37	−40	75	67	14398	0.3	2.0	31	103	72	14	0
Noranda	−27	−32	85	71	11400	0.9	3.5	32	65	70	13	0
Outremont	−10	−16	86	74	8200	0.8	3.5	42	54	75	15	4
Pierrefonds	−10	−16	86	74	8200	0.8	3.0	38	54	75	15	4
Pincourt	−10	−15	85	74	8300	0.9	3.0	38	55	75	15	4
Plessisville	−14	−19	84	74	9400	0.8	4.0	43	80	70	13	4
Pointe Claire	−10	−16	86	74	8200	0.8	3.0	38	54	75	15	4
Port Alfred	−19	−23	83	71	10500	0.7	3.0	37	75	70	13	4
Port Harrison	−36	−39	63	—	16549	0.2	2.0	15	43	108	31	0
Quebec	−13	−19	82	73	8937	0.8	4.5	45	84	84	19	4
Richmond	−13	−18	84	73	8700	0.9	3.5	41	63	67	12	2
Rimouski	−12	−16	74	69	9900	0.7	3.5	35	92	94	24	4
Rivière-du-Loup	−13	−18	80	71	9900	0.7	4.0	35	85	88	21	4
Roberval	−22	−26	84	71	10521	0.7	2.5	29	72	64	11	4
Rock Island	−11	−16	83	73	9000	0.9	3.0	39	55	75	15	2
Rouyn	−27	−32	85	71	11400	0.9	3.5	32	63	70	13	0
Ste. Agathe des Monts	−16	−20	81	73	9871	0.9	3.5	38	79	70	13	4
Ste. Anne de Bellevue	−10	−15	85	74	8300	0.9	3.0	38	55	75	15	4
St. Canut	−13	−18	85	74	9000	0.9	3.0	42	70	72	14	4
St. Félicien	−23	−28	84	71	11000	0.7	2.5	30	75	64	11	4
Ste. Foy	−13	−19	82	73	9000	0.8	4.5	45	84	84	19	4
St. Hubert	−11	−16	85	74	8337	0.8	3.0	37	58	75	15	4
St. Hyacinthe	−12	−17	85	74	8524	0.8	3.0	40	60	70	13	4
St. Jérôme	−13	−18	84	74	9283	0.9	3.0	42	70	72	14	4
St. Johns	−10	−15	85	74	8500	0.9	3.0	38	55	75	15	4
St. Lambert	−10	−16	86	74	8200	0.8	3.5	42	54	75	15	4
St. Laurent	−10	−16	86	74	8200	0.8	3.5	42	54	75	15	4
St. Nicolas	−13	−19	82	73	8900	0.8	4.0	44	84	82	18	4
Schefferville	−37	−40	76	66	14880	0.3	2.5	28	90	77	16	0
Senneterre	−28	−32	85	71	11400	0.9	3.0	40	70	67	12	0
Seven Islands	−22	−27	78	64	11327	0.5	3.5	42	116	110	33	0
Shawinigan	−15	−20	85	74	9380	0.8	3.5	36	81	60	10	4
Shawville	−17	−21	88	74	8900	0.9	3.5	30	58	70	13	4
Sherbrooke	−13	−18	84	73	8490	0.9	4.0	39	55	64	11	2
Sillery	−13	−19	82	73	9000	0.8	4.5	45	84	84	19	4
Sorel	−12	−17	85	74	8868	0.8	4.0	36	80	67	12	4
Sutton	−11	−16	84	73	8600	0.9	3.0	39	55	75	15	2
Temiscaming	−21	−25	87	71	9581	1.1	3.5	32	60	67	12	4
Thetford Mines	−14	−19	83	73	9815	0.8	4.0	41	81	82	18	2
Three Rivers	−13	−18	85	74	9306	0.8	4.5	40	84	64	11	4
Thurso	−14	−18	87	74	8900	0.9	4.0	36	62	75	15	4
Val d'Or	−27	−31	85	71	11169	0.9	3.0	35	64	67	12	0
Valleyfield	−9	−14	85	74	8300	0.9	3.0	38	54	75	15	4
Varennes	−11	−16	85	74	8500	0.8	3.5	40	60	72	14	4

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earthquake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
Verchères	−11	−17	85	74	8700	0.8	3.5	38	65	70	13	4
Verdun	−10	−16	86	74	8200	0.8	3.5	42	54	75	15	4
Victoriaville	−14	−19	84	74	9250	0.8	3.5	43	80	70	13	4
Ville d'Anjou	−10	−16	86	74	8200	0.8	3.5	42	54	75	15	4
Ville Marie	−24	−28	87	71	10557	1.0	3.5	28	62	75	15	0
Waterloo	−12	−17	84	73	8400	0.9	3.0	39	55	70	13	2
Westmount	−10	−16	86	74	8200	0.8	3.5	42	54	75	15	4
Windsor Mills	−13	−18	84	73	8500	0.9	5.0	40	60	67	12	2
New Brunswick												
Alma	− 5	−10	80	69	8400	0.7	4.5	39	60	86	20	2
Bathurst	−10	−15	86	71	9462	0.7	3.0	35	80	80	17	2
Campbellton	−14	−18	84	71	9358	0.7	4.5	40	112	84	19	2
Chatham	−10	−15	87	71	9065	0.7	3.0	37	62	75	15	2
Edmundston	−16	−20	81	72	9796	0.8	3.0	36	69	77	16	2
Fredericton	−10	−16	86	70	8671	0.9	4.5	41	60	75	15	2
Gagetown	− 9	−15	84	70	8235	0.8	4.0	41	60	84	19	2
Grand Falls	−16	−21	82	72	9635	0.8	3.0	38	66	75	15	2
Moncton	− 7	−12	85	71	8711	0.7	3.5	39	75	92	23	2
Oromocto	− 9	−15	85	70	8700	0.9	4.5	41	60	82	18	2
Sackville	− 5	−10	83	70	8420	0.7	4.0	38	63	88	21	2
Saint John	− 7	−12	79	68	8453	0.7	5.0	48	53	84	19	2
St. Stephen	− 8	−13	82	69	8400	0.8	5.0	45	50	90	22	2
Shippigan	− 7	−12	84	69	9500	0.5	2.5	35	92	96	25	2
Woodstock	−14	−19	87	71	8756	0.9	3.5	37	63	72	14	2
Nova Scotia												
Amherst	− 5	−10	82	70	8400	0.6	4.0	40	60	88	21	2
Bridgewater	5	1	82	69	7700	0.6	5.0	52	45	88	21	2
Dartmouth	4	0	80	68	7718	0.6	5.5	54	45	88	21	2
Debert	− 7	−12	82	70	8399	0.5	4.0	42	53	86	20	2
Digby	5	1	77	69	7076	0.5	5.0	44	48	86	20	2
Greenwood	1	− 2	83	70	7591	0.5	5.0	41	58	84	19	2
Halifax	4	0	80	68	7361	0.6	5.5	54	45	88	21	2
Kentville	0	− 4	83	70	7792	0.5	5.0	41	56	84	19	2
Liverpool	7	3	82	68	7362	0.6	5.5	57	37	90	22	2
Lockeport	7	3	78	68	7300	0.6	5.0	57	40	90	22	2
Louisburg	6	1	80	69	8100	0.5	4.0	53	45	94	24	2
Lunenburg	6	2	81	68	7700	0.6	5.0	55	45	90	22	2
New Glasgow	− 5	−10	83	70	8400	0.4	4.0	45	58	86	20	2
North Sydney	5	0	82	70	8100	0.4	3.5	50	50	90	22	2
Springhill	− 4	− 9	82	70	8400	0.6	4.0	45	55	86	20	2
Stewiacke	− 5	−10	82	70	8300	0.5	4.0	42	63	86	20	2
Sydney	5	0	82	70	8049	0.4	3.5	51	49	90	22	2
Tatamagouche	− 5	−10	83	70	8400	0.4	3.5	44	58	86	20	2
Truro	− 7	−12	82	70	8226	0.5	4.0	41	53	84	19	2
Wolfville	− 1	− 5	82	70	7900	0.5	5.0	41	56	84	19	2
Yarmouth	9	5	73	68	7340	0.5	4.5	49	55	87	20	2
Prince Edward Island												
Charlottetown	− 3	− 6	83	70	8486	0.3	4.0	43	66	86	20	2
Souris	− 1	− 5	81	70	8400	0.3	3.5	43	68	86	20	2
Summerside	− 3	− 8	82	70	8440	0.4	4.5	39	62	90	22	2
Tignish	− 3	− 8	82	69	8900	0.4	4.0	37	75	102	28	2
Newfoundland												
Argentia	5	1	75	67	8440	0.6	4.0	57	47	100	27	2
Bonavista	2	− 2	76	67	9200	0.6	4.0	48	72	96	25	2
Buchans	− 5	−12	81	68	10138	0.3	3.5	36	91	90	22	2
Cape Harrison	−20	−24	80	62	12603	0.3	3.0	29	128	90	22	0
Cape Race	6	2	69	—	9190	0.6	4.5	54	48	117	37	2
Corner Brook	− 5	−10	81	68	8978	0.3	3.5	45	90	100	27	2
Gander	− 1	− 5	82	68	9254	0.5	4.0	40	62	90	22	2
Goose Bay	−25	−27	81	67	11887	0.3	2.5	29	103	72	14	0
Grand Bank	7	3	71	—	8378	0.5	4.0	54	55	100	27	2
Grand Falls	− 5	−10	81	68	9352	0.4	3.0	37	72	90	22	2
Labrador City	−32	−36	75	60	14200	0.4	2.5	31	110	75	15	0

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

	Design Temperature				Degree Days Below 65°F	15 Min Rain	One Day Rain	Ann. Tot. Pcpn.	Gnd. Snow Load	Wind		Earthquake Factor
	Winter		July 2½%									
	2½%	1%	Dry	Wet						Gust	Press	
	°F	°F	°F	°F		in.	in.	in.	psf	mph	psf	
Port aux Basques	7	2	68	—	8800	0.4	4.0	56	75	96	25	2
St. Anthony	−11	−17	63	—	10896	0.4	3.0	32	111	105	30	2
St. John's	6	2	77	68	8991	0.6	4.0	57	72	103	29	2
Stephenville	− 1	− 6	76	68	8717	0.3	3.5	40	86	102	28	2
Wabana	5	1	77	68	8900	0.6	4.0	55	60	100	27	2
Wabush Lake	−32	−36	75	66	14200	0.4	2.5	31	110	75	15	0
Yukon												
Aishihik	−46	−49	72	61	14747	0.3	2.0	10	26	73	14	2
Dawson	−56	−59	79	61	15067	0.3	2.0	13	58	60	10	2
Snag	−60	−63	74	61	15768	0.3	2.0	14	50	60	10	2
Teslin	−41	−45	76	61	12898	0.2	1.5	13	34	63	11	2
Watson Lake	−51	−54	78	63	13740	0.3	2.0	17	54	61	10	2
Whitehorse	−42	−45	75	60	12475	0.2	1.5	11	27	72	14	2
North West Territories												
Aklavik	−48	−50	76	61	18017	0.2	1.5	10	46	88	21	1
Alert	−48	−50	54	—	23488	0.1	1.5	6	43	100	27	0
Arctic Bay	−46	−48	55	—	20933	0.1	1.0	6	19	86	20	0
Baker Lake	−50	−52	71	—	19790	0.1	1.5	7	32	86	20	0
Cambridge Bay	−48	−50	60	—	21628	0.1	1.0	6	32	72	14	0
Chesterfield	−40	−43	68	—	19568	0.2	1.5	11	50	88	21	0
Clyde	−43	−46	57	—	19881	0.2	2.0	10	54	107	31	0
Coppermine	−47	−49	67	—	19484	0.2	2.5	11	45	79	17	0
Coral Harbour	−38	−40	63	—	19452	0.2	2.0	9	61	130	46	0
Eskimo Point	−40	−43	70	—	18200	0.2	2.5	12	56	93	23	0
Eureka	−49	−51	55	—	24220	0.1	1.5	3	25	94	24	0
Fort Good Hope	−51	−53	81	62	17028	0.2	2.5	12	60	99	26	1
Fort Providence	−46	−49	75	63	14651	0.3	3.0	10	48	70	13	1
Fort Resolution	−44	−47	79	64	14796	0.3	1.5	11	45	74	15	0
Fort Simpson	−50	−53	82	63	14658	0.3	2.5	12	56	75	15	1
Fort Smith	−46	−49	83	65	14176	0.3	1.5	13	37	75	15	0
Frobisher	−42	−45	59	—	17876	0.2	2.0	14	50	100	27	0
Hay River	−41	−45	81	64	14518	0.3	2.0	12	50	70	13	0
Holman Island	−46	−48	64	—	19926	0.1	1.0	5	25	106	30	0
Inuvik	−48	−50	77	61	18200	0.2	2.0	10	46	90	22	1
Isachsen	−51	−53	51	—	24269	0.1	1.5	4	30	92	23	0
Mould Bay	−49	−51	49	—	23594	0.1	2.0	3	22	94	24	0
Norman Wells	−52	−55	81	62	16111	0.2	2.5	13	63	92	23	1
Nottingham Island	−37	−39	56	—	17705	0.2	2.0	12	85	92	23	0
Port Radium	−48	−50	71	—	16726	0.2	2.0	9	54	[illegible]	19	0
Rae	−48	−50	75	63	15800	0.2	2.0	9	48	[illegible]	17	0
Rankin Inlet	−40	−43	68	—	19300	0.2	2.0	11	52	[illegible]	22	0
Resolute	−47	−49	51	—	22673	0.1	1.5	5	27	86	20	0
Resolution Island	−32	−35	45	—	16021	[illegible]	1.5	16	117	125	42	0
Yellowknife	−47	−49	76	63	15634	0.2	2.0	8	42	80	17	0

Section 2

PERMAFROST AND FOUNDATIONS

by

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About one half of the total land area of Canada is underlain by perennially frozen ground, more commonly known as permafrost. (See Permafrost Map of Canada, inside back cover.) The term "permafrost" refers to the thermal condition of earth materials under which their temperature remains below 32°F continuously for a number of years. Permafrost is defined on the basis of temperature alone, and any material, whether sand, gravel, silt, peat, refuse piles or bedrock, that has been below freezing continuously for more than one year is called permafrost.

The permafrost region is normally divided into two principal zones, the continuous in the north and the discontinuous in the south. In the continuous zone permafrost occurs everywhere under the ground surface and is generally hundreds of feet thick. Southward, the continuous zone gives way gradually to the discontinuous zone where permafrost exists in combination with areas of unfrozen material. The discontinuous zone is one of broad transition between continuous permafrost and ground having no permafrost. In the more northerly reaches of the discontinuous zone, the distribution of permafrost may be very widespread with isolated patches of unfrozen ground, while near the southern extremity permafrost may be quite sporadic with extensive unfrozen areas. In the southern fringe area of the discontinuous zone, permafrost occurs as scattered patches or islands and is only a few feet thick.

Permafrost Characteristics

Between the ground surface and the permafrost table, that is, the upper surface of permafrost, there is a layer of soil or rock called the active layer which freezes in winter and thaws in summer. Its thickness may vary regionally from several feet in the southern fringe area to only a few inches in the north of the continuous zone and is dependent on the same climatic and terrain factors as affect the permafrost. Local variations in terrain factors, e.g., relief (slope and aspect), vegetation, drainage, snow cover and soil type, may cause the active layer to vary in thickness from less than one or two feet to several feet within any one area. The maximum depth of the active layer may not coincide with the permafrost table, i.e., there may be an unfrozen layer between the seasonal frost zone and the upper surface of permafrost. This condition is normally only encountered in the discontinuous zone.

Permafrost exists as a result of a thermal condition that is reflected in ground temperatures which never exceed 32°F. Fluctuations in air temperature during the year produce corresponding fluctuations in ground temperature, although their magnitude is reduced with increasing depth by the effect of the surface cover (moss and snow) as well as the thermal characteristics of the soil. In addition, a time lag is introduced with increase in depth. The depth at which fluctuations become imperceptible (usually between 20 and 50 ft.) is called "the level of zero annual amplitude" (Figure 1 — See FIG in CBD 64). Below this, ground temperatures change only in response to long-term climate changes extending over centuries.

The mean ground temperature in permafrost can vary appreciably under the influence of a number of factors, but in general it decreases with increase in latitude. In the southern fringe area the mean ground temperature of permafrost is slightly below 32°F (between 30 and 32°F); further north, but still in the discontinuous zone where permafrost is thicker and more widespread, it may range between 23° and 30°F; in the continuous zone it is usually less than 23°F.

There is a broad relationship between mean annual ground temperature and mean annual air temperature. Observations have indicated that the mean annual ground temperature is about 3 to 10°F higher than the mean annual ground temperature, depending on local conditions; the overall average is about 6°F.

Perennially frozen ground may contain a great deal of ice. Ice segregation can occur in a number of ways ranging from coatings or films on individual soil particles and minute hairline lenses scarcely visible to the naked eye to large inclusions up to several feet thick. All forms of ice segregation can occur in the same material including granular soils. Extremely high ice contents are prevalent in fine-grained materials but may be difficult to discern; in some cases, silty soils for example, the volume of ice may be as much as six times that of the soil.

Permafrost normally exhibits rock-like qualities compared to unfrozen soils; but its strength is dependent on its composition, texture, ice content and temperature. Its relatively high strength can be attributed in part to the cementing action of the ice, which binds the soil particles into a solid mass. The mechanical properties of frozen ground, in which ice fills some or all of the interstitial space between soil grains, therefore tend to approach those of ice. The strength of frozen ground increases with decrease in temperature and, in general, with increase in moisture (ice) content. For some soils, e.g., clays, the increase in strength is relatively small at temperatures just below freezing, due mainly to the amount of unfrozen water in the material. Frozen sands that are well cemented by ice usually have considerably greater strength than fine-grained materials, particularly at temperatures near thawing.

Engineering Considerations

Most of northern Canada was glaciated, and as a result fine-grained soils such as silts, clays and fine sands, or combinations of these, are found in many areas. Organic materials also occur extensively, usually overlying the mineral soil. These soils are generally frost susceptible and, when perennially frozen, contain large quantities of ice.

In northern areas surface water is conspicuous in the summer despite the generally low precipitation. Because permafrost is relatively impermeable, drainage is generally poor and movement of water can only occur above it. For this reason materials in the active layer are often saturated.

Accumulation of water on the ground surface can be a serious problem because of its thawing effect. Drainage is therefore vital. If natural drainage is impeded or proper drainage structures are not provided, construction operations can be seriously complicated by intensified frost action during the winter and accelerated thawing during the summer.

A major factor to be considered by the northern builder is frost action in the active layer, which freezes and thaws seasonally. Very large heaving forces can be produced. The active layer often consists of frost susceptible soils and, in addition, is saturated with moisture. A supply of water, which is a prerequisite for frost heaving, is thus available during freezing of the ground. Differential heaving resulting from frost action can cause serious damage to structures founded in the active layer or on the ground surface and to foundations placed in permafrost — unless they are protected against frost heave.

Permafrost is particularly sensitive to thermal changes. Any natural or man-made change, however slight, in the environmental conditions under which permafrost exists will greatly affect the delicate natural thermal equilibrium. For example, the clearing of an area or the erection of a building may result in thawing of the frozen ground or a raising of the permafrost table. Care must be taken, therefore, in all construction operations that detrimental conditions are not produced by changes in or disturbance of the original environment existing at the site. The depth of the active layer may change in time, depending on the use of the area.

The strength properties of frozen soils are greatly influenced by temperature and the duration of load application or deformation-with-time characteristics. Frozen soils at low temperature, (e.g., $< 30°F$) provide excellent bearing for structures under short-term loading. Their strength may be greatly reduced, however, with increase in temperature and quite variable in the high temperature range (i.e. 30-32°F). Similarly, the time-deformation (creep) characteristics are important with respect to the mechanical properties of frozen soils and significant differences can be expected between loadings of short and long term duration. A considerable reduction in strength can be experienced under a long-term load — the ultimate strength may be 4 to 10 times less than the instantaneous strength, depending upon the type of soil, its temperature and moisture content.

The moisture content (consisting of both ice and unfrozen water) of frozen soils is also an important consideration. Frozen sands and gravelly sands have little or no unfrozen water (and are usually well bonded by ice) and a negligible compressibility and thus have a high bearing capacity in the frozen state. They may possess a loose structure, however, such that on thawing considerable settlement can result from consolidation of the material under load. Clayey materials at temperatures near 32°F, because of their usually large unfrozen water content, are characterized by high compressibility and creep occurring with time under sustained load. The most serious difficulties arise with those materials, usually fine-grained, that have large ice contents. When thawed these materials turn to a slurry with little or no strength.

From the preceding outline it is evident that adequate site investigations are essential prior to engineering design and construction in permafrost areas. Information must be obtained not only on the distribution of permafrost but also on subsurface conditions, including data on the type and distribution of ice, the physical and mechanical properties of the soils and the thermal regime of the ground.

Foundation Design

Structures in permafrost areas are either placed on top of the active layer or annual frost zone, i.e., ground surface (surface foundations) or are supported, i.e., embedded, in the underlying permafrost (buried foundations) using posts or piles to transmit structure loads through the annual frost zone. Heat flow from the building is a fundamental consideration in foundation design complicating the design of all but the simplest buildings. Any change from natural conditions which results in a warming of the ground beneath a building can result in progressive lowering of the permafrost table (i.e., degradation of the permafrost) over a period of years. If the underlying soils are ice-laden, such progressive thawing will result in extreme settlements, usually differential and thus very damaging to the structure. A basement in permafrost may be a source of dangerous heat loss and thus must be critically assessed.

The results of site investigations and previous experience in the area will indicate the approach to be taken in the design of foundations and the construction techniques to be used. Selection of suitable foundation designs must be based on a knowledge of subsurface conditions and normally one of the two following basic approaches, which consider whether or not the site is underlain by ground ice, is used.

Permafrost conditions can be neglected when buildings are located on sound rock free of ice-filled fissures or clean, non-frost susceptible, well-drained sand and gravel deposits that —

(a) do not contain ice which would result in settlement upon thawing;
(b) would not settle excessively upon thawing because of their loose structure;
(c) are not underlain by unsuitable materials which would be affected by thawing during the life of the structure.

Conventional foundation designs and construction methods can be used under the conditions noted above where the materials are stable upon thawing.

On the other hand, foundations must be designed to maintain a stable thermal condition and prevent thawing in areas where perennially frozen materials contain segregated ice, the thawing of which would result in low bearing capacity and detrimental settlements (i.e., are unstable upon thawing.) Preservation of the permafrost can be achieved by ventilation or insulation (or a combination of these) construction techniques. Ventilation designs incorporate an air space or ventilation system (e.g., ducts) between the building floor and the ground surface through which air can circulate during the freezing season. Insulation does not prevent heat flow but does slow down the rate of heat conduction. Floor systems are usually insulated but in addition a layer of granular material is placed over the ground surface below the building and the floor is separated from the top of the gravel pad by an air space. The gravel pad, in addition to providing some insulating value, will smooth out or reduce differential movements resulting from seasonal movements in the active layer.

Surface foundations normally consist of mud sills, post and pads or footings placed on a gravel pad. Small buildings which can tolerate some movement may be placed on a shallow gravel pad 1-2 ft. thick. For larger, heavier and more costly buildings, however, a substantially thicker gravel fill (as much as 10 ft. thick) must be used and an air space provided between the floor and the top of the pad. The gravel fill should be sufficiently thick so that the permafrost table moves up into the pad and the annual frost zone (active layer) will, therefore, occur in the fill where freeze-thaw effects are negligible.

When buried foundations, e.g., piles or posts or piers with footings embedded in the permafrost, are used an air space or ventilation system between the building floor and the ground surface should be provided. Design experience is rather limited with respect to allowable values for bearing pressures and adfreeze bond of frozen soils in particular, and site conditions and foundation designs must, therefore, be carefully evaluated. Perennially frozen soils usually have relatively high bearing capacity, particularly at low temperatures and are essentially elastic under short-time or rapid loading and low stresses. Under long-time loading and high temperatures and stresses, however, the materials may creep. A footing should preferably be placed at least 2 feet below the permafrost table and laid on a gravel pad about one foot thick. Steps should be taken to prevent or control frost heave forces on posts, piers or piles in the active layer.

Pile foundations are widely used and when properly installed are capable of providing a very stable foundation under very difficult conditions. Wood and steel piles of various sections and even precast reinforced concrete piles have been used successfully in permafrost. They may be placed in steamed holes or slurry-backfilled drilled holes, driven in undersize or pilot holes or in high-temperature, fine-grained, frozen soils, steel sections may even be driven without prior preparation of the pile locations. Piles support the building loads and resist uplift due to frost heave in the active layer through adfreeze bond between the surface of the pile and the frozen soil. End bearing is usually neglected. Surface adfreeze bond increases with decrease in temperature but varies with ice content and degree of saturation of the soil.

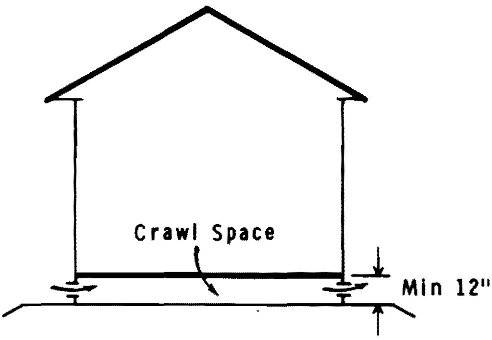
Piles should not be loaded until they are solidly refrozen following installation. Every possible precaution must be taken to minimize introduction of heat into the ground during installation for piles will not resist frost heave unless solidly frozen in the permafrost. Steam thawing introduces large quantities of heat into the ground and therefore must be carefully carried out and controlled to prevent over-steaming which will considerably increase the refreezing period and may even prevent freezeback from occurring. The refreezing period can vary considerably from a few weeks to several months, depending upon the time of year, the amount of heat introduced into the ground, the location of the site and the ground temperature. Piles should normally be installed during the Spring when ground temperatures are coldest. Steam thawing should not be used in marginal permafrost areas where high temperature (near 32°F) frozen soils occur. Because heat is introduced into the ground with the installation of each pile, close spacing may seriously raise the ground temperature under an entire site. A minimum pile spacing of 5 feet for low temperature frozen soils and 10 feet for high temperature frozen soils is suggested. To resist frost heave, piles should be embedded in permafrost to a depth of at least twice the thickness of the active layer during the life of the structure and to a minimum of 10 feet.

Foundations for buildings having special thermal or structural loading conditions and, in general, all buried foundations, which are most sensitive to changes in subsurface conditions, must be designed on the basis of a special investigation. Other approaches to foundation design than those described previously, may also be considered. For example, when foundation soils contain excessive ice and it is not possible to preserve the frozen condition, it may be convenient to thaw and consolidate or remove the poor soil and backfill with more acceptable material prior to construction. Similarly, when thawing of the ground is inevitable during the life of the structure and considerable consolidation of the foundation material is expected then "flexible" foundations which can be adjusted to eliminate structural deformations as differential settlement occurs, might be considered. These are special cases, however, and again must be based on a special investigation.

Care should be taken to avoid close spacing of structures erected by different methods, particularly when the construction of one building may affect the thermal regime of the foundation soils of another. If at all possible, sites underlain by materials containing large masses of ice or where thawing is anticipated should be avoided. Building sites, irrespective of the construction method, should be thoroughly prepared and graded to ensure drainage of surface water away from the structure and the site as a whole. Although construction in northern areas is complicated by the presence of perennially frozen ground, problems concerned with foundation design and construction can be reduced to a minimum if care is taken in the selection of suitable sites.

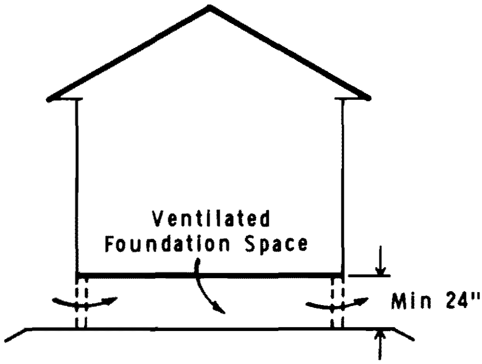
Definitions

ILLUSTRATIONS OF CRAWL SPACE AND
VENTILATED FOUNDATION SPACE ARRANGEMENTS



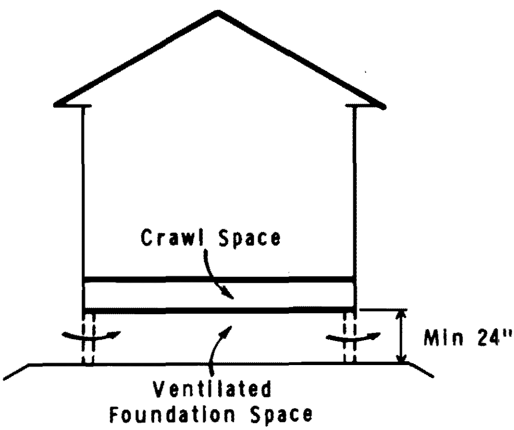
CRAWL SPACE

Openings for Natural Ventilation
to Have Tight Fitting Covers to
Control Air Leakage in Winter



VENTILATED
FOUNDATION SPACE

To Provide Relatively Unobstructed
Air Movement Beneath Building
at All Times



CRAWL SPACE COMBINED WITH
VENTILATED FOUNDATION SPACE

GUIDE

to a

FIELD DESCRIPTION

of

PERMAFROST

for

Engineering Purposes

INTRODUCTION

Almost one half of Canada's total land surface is underlain by permafrost and its existence has many implications to both scientific and engineering interests. Engineering experience has indicated that site investigations are essential in permafrost areas but no standard method for reporting permafrost conditions has been used or is available. This booklet has been prepared with the hope that the descriptive system outlined will fulfil this need.

The method for describing the ice phase in perennially frozen materials, which forms a major part of this "Guide", was originally developed by the Arctic Construction and Frost Effects Laboratory (now Cold Regions Research and Engireering Laboratories) of the U.S. Corps of Engineers, with assistance from the Division of Building Research, National Research Council, Canada. It is intended that the booklets on Soils (Technical Memorandum 37) and Muskeg (Technical Memorandum 44) previously published by the Associate Committee on Soil and Snow Mechanics be used as companions to this Guide.

Comments and criticism regarding the usefulness of this suggested descriptive system for permafrost are encouraged and will be welcomed.

Section 4

TABLE OF CONTENTS

1. WHAT IS MEANT BY "PERMAFROST"

Permafrost is defined as the thermal condition under which earth materials exist at a temperature below 32°F continuously for a number of years. Thus, all earth materials including bedrock, gravel, sand, silt, peat or mixtures of these materials may exist in the perennially below 32°F condition. Permafrost is defined exclusively on the basis of temperature, irrespective of texture, degree of induration, water content or lithologic character.

The term "perennially frozen", although cumbersome, is generally used to describe specific perennially frozen materials, e.g. perennially frozen silt, perennially frozen organic material. The presence of ice is not a necessary requisite of permafrost, but when ice is present it is of particular significance to engineers.

The term permafrost can also be used to describe the areal extent of the below 32°F condition. It has been found convenient to divide the permafrost region into two major zones—the continuous and the discontinuous. In the *continuous* zone permafrost is found everywhere under the ground surface to considerable depth; in the *discontinuous* zone permafrost is not as thick and exists in combination with areas of unfrozen material.

2. BASIS OF THE DESCRIPTIVE SYSTEM

Although permafrost is defined on a temperature basis, temperature is not a convenient or easily measured property for field description purposes. A more convenient approach to the field description of permafrost is to describe terrain features that may influence the existence of permafrost. Observations of terrain and the effects of construction on permafrost in northern Canada have suggested the following specific features of terrain that are of interest to engineers:

(1) Surface characteristics
- Vegetation cover
- Snow cover
- Relief and drainage

(2) Subsurface characteristics
  Depth of thaw
  Subsurface materials
    Soil phase
    Ice phase

Observations on these topics represent a minimum of field information that must be collected to describe permafrost adequately for an engineering appraisal of a site.

3. SURFACE CHARACTERISTICS

3.1 Vegetation Cover

The vegetative mantle of trees, shrubs, moss, lichen and other plants that covers much of the North acts as an insulator that protects and maintains permafrost. Vegetative cover is of additional interest in that it may indicate soil, ground water, wind and/or snow conditions. The major combinations of vegetation at a site should be delineated and described using the system outlined in the "Guide to a Field Description of Muskeg" (Technical Memorandum 44) published by the Associate Committee on Soil and Snow Mechanics.

3.2 Snow Cover

Although snow is basically a part of the climate, snow cover is generally considered as a terrain factor. The presence of snow reduces the depth of seasonal frost penetration during the winter and conversely inhibits thawing of frozen material in the spring. The type of snow, the depth of snow cover and their variability over a site throughout the winter season should therefore be observed.

3.3 Relief and Drainage

Terrain relief influences permafrost occurrence and since it is also a significant factor in drainage it is an important engineering consideration. Regional relief features should be described in addition to those observed at specific locations under investigation. Regional descriptions should include some indication of altitudes; whether the landscape is mountainous, hilly, undulating or flat; possible origin of the landform; and the regional drainage pattern. At specific sites small scale or micro features of relief and drainage should be noted. These small scale features are difficult to classify for descriptive purposes but would include details of patterned ground (sorted or unsorted circles, nets, polygons, steps and stripes), micro-drainage, slope and exposure to solar radiation.

A photographic record of the various surface characteristics (e.g. showing typical vegetation and snow cover, and relief and drainage features) is most valuable. A complete description of site conditions can be usefully summarized on a sketch map or air photograph of the area under investigation.

4. SUBSURFACE CHARACTERISTICS

4.1 Depth of Thaw

The seasonal depth of thaw and its variability within an area and from year to year has long been recognized as an important engineering consideration in permafrost areas. The depth of thaw refers to that portion below the ground surface at a specific location that is thawed at some time during the course of a summer. It increases progressively during the thawing season and therefore it is important to note the date on which a particular observation was made. When the seasonal thaw has reached its maximum depth (usually in the late fall) it then corresponds to the *"active layer"*. The *"active layer"* refers to the zone in which seasonal thawing *and* freezing occurs.

The depth and rate of thaw are affected by and closely related to terrain features. Any variations in an area are usually the result of differences in surface conditions such as vegetation, relief, drainage and snow cover and may also be related to changes in subsurface materials.

Initially, depth of thaw observations should be made in areas having different surface covers and then extended to locations within these areas that have noticeable changes in relief, drainage or subsurface materials. Appreciable differences in the depth of thaw for an area as small as 5 feet square are possible. It is important therefore to make many random observations at a site and to record not only the average but also the maximum and minimum depths of thaw for the area.

The depth of thaw can be conveniently measured using a probe that retains a sample of the thawed subsurface materials for examination. Records of the depth of thaw should also include notes on the date of observation, vegetation cover, relief, drainage, and a description of the subsurface materials in the various areas probed. Some assessment of the moisture content, density and ice segregation in the frozen soil underlying the thawed zone are of particular interest.

4.2 Subsurface Materials

The materials encountered in the frozen state vary, and can include bedrock, gravel, sand, silt, clay and organic material (peat). These frozen materials or combinations of them frequently contain considerable quantities of ice. Important engineering implications are involved when this condition occurs. It is important, therefore, to examine not only the soil but also the ice encountered in the soil. For engineering purposes, it is convenient to describe the soil and ice phases independently. At times a description of frozen bedrock may be required. It will be noted in the following paragraphs that the ice description system is based on the form of ice in frozen materials and is therefore applicable for either soils or bedrock.

4.2.1 Soil phase

The description of the soil phase applies to materials found in both the thawed and frozen states. Coarse- and fine-grained soils should be described according to the "Guide to a Field Description of Soils" (Technical Memorandum 37) published by the Associate Committee on Soil and Snow Mechanics. Partly organic soils, which are largely mineral types, are described as the predominant soil modified by the word "organic", e.g. organic silt. Soils that are mostly organic (peat), however, should be described according to the system outlined in "Guide to a Field Description of Muskeg" (Technical Memorandum 44).

4.2.2 Ice phase

The descriptive system for the ice phase is based on the *form* of ice found in frozen materials. It is not intended that this system be used to assess frozen materials according to properties or performance.

For descriptive purposes frozen materials are divided into three major groups in which the ice is:

not visible by eye,

visible by eye with individual ice layers *less* than 1 inch in thickness,

visible by eye with individual ice layers *greater* than 1 inch in thickness.

The major ice phase descriptive groups and their subdivisions are summarized in Table I. Letter symbols that suggest key descriptive terms of the ice forms for each subdivision have been included to help in the preparation of graphic logs or records. Written observations, however, are the fundamental feature of the descriptive system and the letter designations must be regarded only as a "shorthand" form. Guides for further descriptive details and illustrations of the basic types are included. It is not expected or intended that all of the detail shown in Table I should always be noted. In much engineering work only the most fundamental details need be recorded. Some definitions to clarify terms used in the ice phase descriptive system are given in Table II.

(*A*) *Ice not visible*

When ice is not discernible by eye its effectiveness as a cementing agent in bonding the mineral or organic portion is used as a further subdivision:

(a) ice that bonds or cements the subsurface materials into a *weak or friable mass*,

(b) ice that bonds the subsurface material into a *hard, solid mass*.

The presence of ice not generally discernible by eye may be revealed within the voids of the material by crystal reflections or by a sheen on fractured or trimmed surfaces. The impression to the unaided eye is that none of the frozen water occupies space in excess of the original voids in the soil. The opposite is true of soils where the ice segregation is visible by eye.

In some cases, particularly in materials well bonded by ice, a large portion of the material may actually be ice, even though it is not discernible by eye. When visual methods are inadequate, a simple field test to aid evaluation of the volume of excess ice can be made by placing a chunk of the material in a small jar, allowing it to thaw, and observing the quantity of water as a percentage of the total volume. If free water is noted it is termed "excess".

(*B*) *Visible ice segregation less than 1 inch thick*

When ice is discernible by eye and is less than 1 inch thick further subdivision is based on the form and orientation of the ice concentrations:

(a) individual ice crystals or inclusions,

(b) ice coatings on particles,

(c) random or irregularly oriented ice formations,

(d) stratified or distinctly oriented ice formations.

(*C*) *Visible ice segregation greater than 1 inch thick*

For descriptive purposes, ice formations greater than 1 inch thick may be considered as ICE. Two types of ice strata are recognized at present:

(a) ice with soil inclusions,

(b) ice without soil inclusions.

In some cases the occurrence of stratified or distinctly oriented ice formations in frozen soil increases to such an extent that the frozen material approaches "ice with silt lenses". Although the absence or inclusion of soil in ice is a first subdivision, the over-all form of the ice mass should also be included. Common forms of such "massive ice" are:

random or irregularly oriented layers, vertical, wedge-shaped sheets, and variable chunks or blocks sometimes hundreds of square feet in area.

5. FIELD INVESTIGATIONS AND RECORDS

The scope of field investigations of permafrost and the amount and type of information required will depend largely upon the use for which it is intended. A discontinuity in the occurrence of permafrost (areas free of permafrost or large variations in the depth to permafrost) has many implications to construction. Accordingly, a sufficient number of observations must be made at a site so that the areal occurrence of permafrost is adequately delineated. This is particularly important in the discontinuous zone where permafrost occurs in scattered patches or "islands" in combination with areas of thawed ground.

All information collected should be recorded on data sheets. Typical sheets of recorded information have been included. Most of the specific details required are noted; other pertinent information may be added.

TABLE I

ICE DESCRIPTIONS

A. ICE NOT VISIBLE[a]

Group Symbol	Subgroup Description		Subgroup Symbol		Field Identification
N	Poorly bonded or friable		Nf		Identify by visual examination. To determine presence of excess ice, use procedure under note[b] and hand magnifying lens as necessary. For soils not fully saturated, estimate degree of ice saturation: medium, low. Note presence of crystals or of ice coatings around larger particles.
	Well-bonded	No excess ice	Nb	Nbn	
		Excess ice		Nbe	

[a] *Frozen soils in the N group may, on close examination, indicate presence of ice within the voids of the material by crystalline reflections or by a sheen on fractured or trimmed surfaces. The impression received by the unaided eye, however, is that none of the frozen water occupies space in excess of the original voids in the soil. The opposite is true of frozen soils in the V group* (see p. 14).

[b] *When visual methods may be inadequate, a simple field test to aid evaluation of volume of excess ice can be made by placing some frozen soil in a small jar, allowing it to melt, and observing the quantity of supernatant water as a percentage of total volume.*

FIG A. ICE NOT VISIBLE

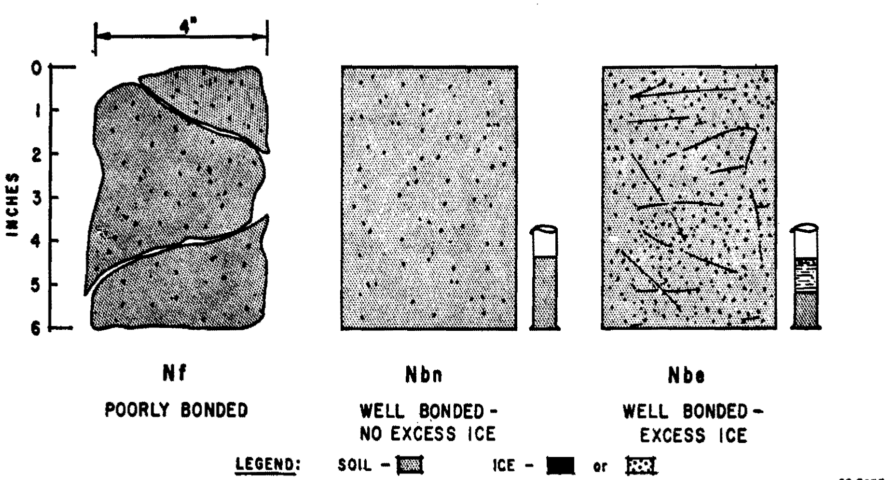


TABLE I (cont'd)

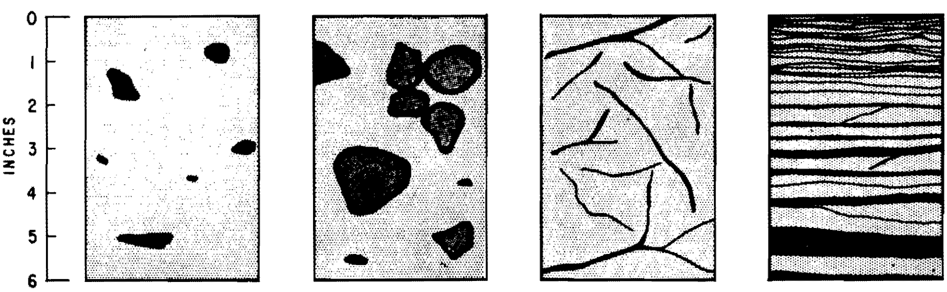
ICE DESCRIPTIONS

B. VISIBLE ICE—LESS THAN 1 INCH THICK[a]

Group Symbol	Subgroup		Field Identification
	Description	Symbol	
V	Individual ice crystal or inclusions	Vx	For ice phase, record the following when applicable: Location — Size Orientation — Shape Thickness — Pattern of arrangement Length Spacing Hardness, Structure, Colour } per Group C (see p. 16) Estimate volume of visible segregated ice present as percentage of total sample volume.
	Ice coatings on particles	Vc	
	Random or irregularly oriented ice formations	Vr	
	Stratified or distinctly oriented ice formations	Vs	

[a] *Frozen soils in the N group may, on close examination, indicate presence of ice within the voids of the material by crystalline reflections or by a sheen on fractured or trimmed surfaces. The impression received by the unaided eye, however, is that none of the frozen water occupies space in excess of the original voids in the soil. The opposite is true of frozen soils in the V group.*

FIG B. VISIBLE ICE LESS THAN ONE INCH THICK



Vx — INDIVIDUAL ICE INCLUSIONS

Vc — ICE COATINGS ON PARTICLES

Vr — RANDOM OR IRREGULARLY ORIENTED ICE FORMATIONS

Vs — STRATIFIED OR DISTINCTLY ORIENTED ICE FORMATIONS

LEGEND: SOIL — ▒ ICE — ■

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TABLE I (cont'd)

ICE DESCRIPTIONS

C. VISIBLE ICE—GREATER THAN 1 INCH THICK

Group Symbol	Subgroup		Field Identification
	Description	Symbol	
ICE	Ice with soil inclusions	ICE + soil type	Designate material as ICE[a] and use descriptive terms as follows, usually one item from each group, when applicable: Hardness: HARD, SOFT (of mass, not individual crystals) Structure[b]: CLEAR, CLOUDY, POROUS, CANDLED, GRANULAR, STRATIFIED Colour (Examples): COLOURLESS, GRAY, BLUE Admixtures (Examples): CONTAINS FEW THIN SILT INCLUSIONS
	Ice without soil inclusions	ICE	

[a] Where special forms of ice such as hoarfrost can be distinguished, more explicit description should be given.
[b] Observer should be careful to avoid being misled by surface scratches or frost coating on the ice.

FIG C. VISIBLE ICE GREATER THAN ONE INCH THICK

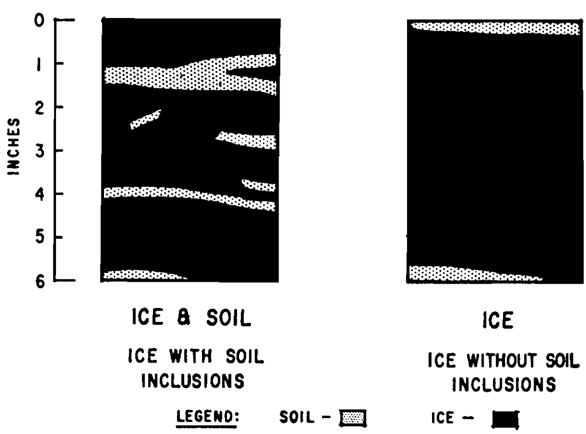


TABLE II

TERMINOLOGY

Ice Coatings on Particles are discernible layers of ice found on or below the larger soil particles in a frozen soil mass. They are sometimes associated with hoarfrost crystals, which have grown into voids produced by the freezing action.

Ice Crystal is a very small individual ice particle visible in the face of a soil mass. Crystals may be present alone or in combination with other ice formations.

Clear Ice is transparent and contains only a moderate number of air bubbles.

Cloudy Ice is relatively opaque due to entrained air bubbles or other reasons, but which is essentially sound and non-pervious.

Porous Ice contains numerous voids, usually interconnected and usually resulting from melting at air bubbles or along crystal interfaces from presence of salt or other materials in the water, or from the freezing of saturated snow. Though porous, the mass retains its structural unity.

Candled Ice is ice that has rotted or otherwise formed into long columnar crystals, very loosely bonded together.

Granular Ice is composed of coarse, more or less equidimensional, ice crystals weakly bonded together.

Ice Lenses are lenticular ice formations in soil occurring essentially parallel to each other, generally normal to the direction of heat loss and commonly in repeated layers.

Ice Segregation is the growth of ice as distinct lenses, layers, veins, and masses in soils commonly but not always, oriented normal to direction of heat loss.

Well-bonded signifies that the soil particles are strongly held together by the ice and that the frozen soil possesses relatively high resistance to chipping or breaking.

Poorly-bonded signifies that the soil particles are weakly held together by the ice and that the frozen soil consequently has poor resistance to chipping or breaking.

Friable denotes extremely weak bond between soil particles. Material is easily broken up.

Excess Ice signifies ice in excess of the fraction that would be retained as water in the soil voids upon thawing.

For a more complete list of terms generally accepted and used in current literature on Frost and Permafrost see Hennion, F. "FROST AND PERMAFROST DEFINITIONS", Highway Research Board, Bulletin 111, 1955.

APPENDIX A

SAMPLE FORMS FOR PERMAFROST FIELD RECORDS

I. EXPLORATION & TERRAIN NOTES

1. LOCATION: Thunder River, N.W.T. HOLE No. T.P. 24
   SITE: Centre Proposed Hostel—Site 4 DEPTH: 22'
   AIR PHOTO: A 18635–49; N 1.7, W 4.3
   NA & NR. Plan—TR-A-1
   ELEVATION: 28' above river water level (hand level)
   NOTES BY: John Smith
   DATE: START a.m. 14/8/56
   END p.m. 17/8/56

2. METHOD OF EXPLORATION: Portable gasoline powered jackhammer.
   Pit Size—4' x 6'—3 local labourers.
   REMARKS: No difficulties, log cribbing from 14'–22'.
   Rain all day 15/8/56

3. VEGETATION COVER SYMBOL—SITE FEI
   AREA IF
   DESCRIPTION: At Site—irregular distribution of grass hummocks and sedges with moss covering most of surface—odd low shrub. Area—predominantly moss covered with irregular distribution of grasses and sedges.

4. RELIEF
   REGION: Lowland, flat, recent alluvium.
   SITE: 6" high grass tussocks, some mounds 4' in diameter and 1' high.

5. DRAINAGE: Poor—many puddles of scum covered water. During spring run off overflow probably runs to small creek 200' E. (which is now dry) and thence to river.

6. GENERAL
   DEPTH OF THAW—HOLE-AVERAGE 20" Max. 26" Min. 10" DATE 16/8/56
   AREA-AVERAGE 18" Max. 27" Min. 10" DATE 16/8/56
   REMARKS: Local inhabitants report wind packed snow drifts up to 5' deep cover site.

II. PERMAFROST — SUBSURFACE FEATURES

Dth ft.	Hole Log	Depth, ft.	Soil Description	Depth, ft.	Ice Description	Soil Samples	Photo	Remarks
	Pt		Cat. #8—light to dark brown		THAWED			Photos taken on north wall of pit
		1.2						
2	Pt			1.6				
4	Pt Nbn		Peat—category #13—reddish brown to dark brown—1 branch at 3.5 ft.—4 in. in diameter		Frozen—no visible ice seg., well bonded—material breaks in slabs 12" long x 3" thick		1	
6	Pt Vs in Nbn			4.6	Hairline ice lenses, about 1" spacing in Nbn		1	
		6.8		6.8				
8	SM Vs		Light brown silty fine sand		H.L. hor. lenses ⅛" to ½" spacing, visible ice = 15% of total volume	2—M/C 1—G.S.	1	
		8.5		8.5				
10	CH Vs		Grey clay, high plasticity, random small (¼" dia) rounded pebbles		1" hor. ice lenses spaced about 8 in.—odd diagonal h.l. ice lens (2-3 in. long)	1—G.S. 2—M/C	1	
12, 14	CH Nbn			10.8	No visible ice segregation, well bonded	3—M/C 1—G.S.	1	
		14.3		14.3				
16	ICE				Ice with clay inc.—ice soft, cloudy, milky white; clay incl.—angular, avge. 1" long, ¼" thick		1	
18				17.7	Ice soft, cloudy, milky white		1	
		19.0		19.0				
20	GP Vc		Gravel, poorly graded, mostly rounded stones ½"–2" in diameter		Ice coating stones up to ½" thick, average thickness about ⅛"	1—G.S.	1	
22		22.0	BOTTOM OF EXPLORATION					

Location—Thunder R., N.W.T. Site—Hostel—Site #4 Hole No.—T.P. 24	Boring—Start—14.8.56 End —17.8.56 Notes by—J. Smith	Org. Terrain—F.E.I. Topography—Flat lowland Elevation—28′ above river level

GUIDE

to the

FIELD DESCRIPTION

of

SOILS

for

Engineering Purposes

Guide to the Field Description of Soils for Engineering Purposes

The purpose of this document is to enable field men to describe soils as they are encountered and used for engineering purposes. It is not intended to be a soil classification system. Wherever possible the terms conform with those of the Unified Soil Classification System (in use in the United States) and with the British Standard Code of Practice for Site Investigation.

2. WHAT IS MEANT BY "SOIL"

The word soil, as used in an engineering sense, refers to that portion of the earth's crust which is fragmentary, or such that some individual particles may be readily separated by the agitation in water of a dried sample. Soil has been derived from bed-rock or organic matter by natural processes of chemical decomposition and physical disintegration and may have been subsequently modified by atmospheric or biological agencies.

3. MAJOR SOIL DIVISIONS

Soil may be grouped into three major divisions: coarse-grained, fine-grained, and organic.

(a) *Coarse-grained soils* may be described briefly as those soils made up largely of particles visible to the naked eye. Further subdivisions may be made according to the particle size as follows:

Cobbles and Boulders.—particles larger than 3 inches in diameter:
Cobbles 3 to 8 inches; boulders greater than 8 inches;

Gravel.—particles smaller than 3 inches in diameter and larger than the No. 4 sieve (approx. ¼ inch);

Sand.—particles smaller than the No. 4 sieve and larger than the No. 200 sieve (particles smaller than the No. 200 sieve are not visible to the naked eye).

(b) *Fine-grained soils* are made up of particles not visible to the naked eye. Plasticity and particle size, therefore, cannot be judged accurately without the use of refined testing techniques. For field identification, fine-grained soils may be classed as silt or clay by their behaviour in a few simple indicator tests described later (under the field identification procedures).

(c) *Organic soils* are placed in a separate group because of their appreciable content of organic matter. Soils which are mostly organic may be described as organic material, a term which includes peat, muskeg and peat moss. Partly organic soils which are largely mineral types are described as the predominant soil modified by the word "organic" e.g., organic silt.

4. DESCRIPTION OF SOILS

(a) *Coarse-grained soils*

For adequate description of coarse-grained or cohesionless soils, reference should be made to the *density, grading,* and *grain shape* of the soil.

Density.—Density is described by the terms "dense", "medium dense" and "loose" and should refer only to the density in place (i.e. in the ground). It is difficult to drive a 2- by 2-inch wooden picket into dense soil for more than a few inches. A 2- by 2-inch picket can be easily driven into loose soils. If the grains are "cemented" together, density cannot be estimated by this simple method.

Grading.—Grading is the term applied to the particle-size distribution of the soil. A uniform soil has a predominance of particles of one size, whereas a well-graded material has sizes assorted over a wide range, with no one size predominating. The word "uniform" is applied where it is obvious that one size is predominant, and "graded" if this is not the case.

Grain shape.—The terms used to describe grain shape are "angular", "subangular" and "rounded".

Angular particles have sharp edges and relatively plane sides with unpolished surfaces; subangular particles are similar to angular but have rounded edges; rounded particles have smoothly curved sides and no edges.

Additional descriptive notes.—Note should be made if the soil is stratified or contains any organic matter. If the soil contains some fine material, but not sufficient to cause cohesion, this should also be noted.

(b) *Fine-grained soils*

The descriptive terms for fine-grained or cohesive soils are obtained by reference to *consistency* in the undisturbed and remoulded states, *plasticity, structure, colour,* and *odour.*

Consistency.—Consistency varies mainly with water content and density and is described by the adjectives "hard", "stiff", "firm", and "soft". Occasionally, cohesive soils are "sensitive", i.e., they undergo a great loss of strength when disturbed or remoulded. It is necessary, when describing consistency, to state whether it is consistency in the undisturbed or remoulded states. The proper adjectives for consistency may be determined by attempting to penetrate the soil with the thumb. It is difficult to indent hard clays or silts with the thumb-nail. Stiff soils are readily indented with the thumb. Firm soils can be penetrated by moderate thumb pressure. Soft soils are penetrated easily with the thumb, and can be remoulded under light finger pressure.

Plasticity.—Plasticity is the ability to change shape and to retain the impressed shape when the stress is removed. The degree of plasticity of soils is the range in moisture content through which the soil remains plastic or is capable of being moulded. An indication of plasticity can be gained by manipulating the soil with the fingers when it is near the plastic limit. The plastic limit of a soil is defined as the moisture content at which a thread of soil one-eighth inch in diameter will begin to crumble when rolled further. Near the plastic limit, highly plastic soils will require considerable pressure to roll threads by hand, medium plastic soils a noticeable pressure, and soils weakly plastic can be rolled with little effort. The dry strength test is another indication of plasticity. Highly plastic soils are very hard when dry and cannot be broken by finger pressure. Medium plastic soils have a medium dry strength and can be crumbled only with difficulty. Weakly plastic soils have low dry strength and can be easily crumbled between thumb and forefinger.

Structure.—Structure is the term applied to the nature of the soil mass. The following terms are commonly used in describing special soil structures: "stratified", "fissured", "lensed", and "friable" or "blocky". The appearance of a fresh fracture may be used as an indication of structure. Stratification is evident when the soil has definite bedding planes and when these bedding planes are roughly parallel to one another. When there are definite stratifications, closely spaced, of alternating material the structure of the mass is described as "varved" or "laminated". Fissures are indicated when the soil breaks along definite planes of fracture, developing very little strength

TABLE 1

General Basis for Field Description of Soils

Major Divisions	Subdivisions	Field Identification	Information for Description
COARSE-GRAINED SOILS	COBBLES AND BOULDERS	Larger than 3 inches diameter —cobbles 3 to 8 inches —boulders greater than 8 inches	Density Particle Shape
	GRAVEL	Smaller than 3 inches but larger than No. 4 sieve (approx. $\frac{1}{4}$ inch)	Grading Density Particle Shape Stratification
	SAND	Smaller than No. 4 sieve but larger than No. 200 sieve. Particles smaller than No. 200 sieve are not visible to the naked eye.	Grading Density Particle Shape Stratification Organic Matter
FINE-GRAINED SOILS	SILT	Exhibits dilatancy (reacts to the shaking test). Powders easily when dry; only slight dry strength. Gritty to the teeth. Dries rapidly. No shine imparted when moist and stroked with knife blade.	Consistency Undisturbed Remoulded Plasticity Dry Strength Structure
	CLAY	Not dilatant. Possesses appreciable dry strength. When moist, sticks to fingers and does not wash off readily. Not gritty to the teeth. When moist a shiny surface is imparted when stroked with knife blade.	Consistency Undisturbed Remoulded Plasticity Dry Strength Structure
ORGANIC SOILS	PARTLY ORGANIC —organic clay —organic silt etc.	Depending on amount of organic material, these soils usually have some of the characteristics of their inorganic counterparts: usually highly compressible (spongy) usually have characteristic odour	Consistency Undisturbed Remoulded Plasticity Dry Strength Structure
	ORGANIC MATERIAL	Fibrous structure—usually brown or black when moist. Spongy. Usually has characteristic odour.	Organic terrain including muskeg, peat and peat moss

in fracturing. Near the surface, fissures may be indicated by slight discoloration along the planes. When the soil breaks along a fissure, the surface of the fracture will be very clean and glossy. A lensed structure is caused by the inclusion of small pockets of foreign material. For instance, a clay may have small lenses of sand scattered throughout. A friable or blocky structure is that found when a cohesive soil can be broken into small lumps easily with the lumps themselves more difficult to break.

Colour.—Colour indicates the depth of weathering in a soil and may also be helpful in identifying similar soils in the same region.

Odour.—Odour of the soil will normally indicate the presence of organic matter.

(c) *Organic soils*

The descriptive terms used for inorganic soils can be used to describe partly organic soils. For organic material, a separate classification system is necessary. This will be described in a booklet similar to this, based upon studies of Dr. N. W. Radforth.

5. FIELD IDENTIFICATION PROCEDURE

Most soils consist of mixtures of various particle sizes. Therefore the first step is to decide which of the principal fractions or characteristics predominate, then to decide which of these acts as a modifier. For example, a sand containing some silt would be called a silty sand. Table I lists the principal soil divisions with their characteristics which lead to identification.

Boulders, cobbles, gravel, and sand are identified by visual examination as all their particles are visible to the naked eye. Size is the criterion of identification.

Fine-grained soils can only be identified by more indirect means. The tests listed below may be used to establish the identity of these soils:

(a) *Shaking test*

When a wet pat of soil is shaken vigorously in the hand, the surface will become glossy and show free water. If the pat of soil is then squeezed in the fingers, the free water may disappear and the surface become dull, i.e. dilates. With clay soils this phenomenon will not be noticeable but with silts and fine sands a rapid or good reaction will be exhibited;

(b) *Shine Test*

If a moist lump of soil is stroked with considerable pressure with the flat of a pen knife blade or finger-nail, the type of surface imparted is an indication of the soil: if a shiny surface results, the presence of clay is indicated; silt is indicated if a dull surface is produced;

(c) *Dry Strength Test*

If a small piece of dry fine-grained soil is broken or crushed with the fingers, the breaking strength is an indication of the relative amounts of silt or clay. Very low dry strength is indicated when the soil powders readily in the fingers, and may be taken as an indication of a sandy silt or silt. Medium dry strength is shown by difficulty in powdering the soil by finger pressure, but the soil can be broken into small pieces without great difficulty. This state indicates silty clays and clays of medium plasticity. High dry strength is indicated when the pat of dry soil cannot be broken with the fingers. A highly plastic clay is indicated by this condition.

In addition to the tests mentioned above, clay sticks to the fingers when wet, and does not wash off readily, whereas silt will wash away easily or brush off if dry. When a small amount of soil is placed between the teeth, the presence of grit will indicate silt or sand, but if no grit is detected a pure clay is present.

Organic soils are very compressible and spongy. Purely organic soils are easily recognized by their matted or fibrous structure. Partly organic soils may behave as a silt or clay, but are very compressible and usually have a characteristic odour.

6. PARTICULAR SOIL NAMES AND CONDITIONS

Each soil has a definite origin, and many of its characteristics depend upon the environment under which it was formed. In some cases, the geological origin can only be determined after study by the specialist. In other cases, the nature of the soil is indicative of the origin, and the soil can be described most adequately by using a special name.

(a) *Topsoil*

Topsoil is the layer of soil on the surface which will support plant life. It is characterized by the presence of organic material. Topsoil should be modified by reference to the predominant inorganic soil.

(b) *Fill*

Fill is a man-made deposit of natural soils or waste materials. It can usually be identified by the inclusion of grass, twigs, cinders, bricks, glass, etc., and by a layer of topsoil or profile development *under* the fill. To describe fill, an adjective indicating the predominant soil should be used, i.e. sand and gravel fill, clay fill, rubbish fill, or cinder fill.

(c) *Local names*

Frequently soils in one area are given local names by the inhabitants. These names give a vivid description of the soil, e.g. "bull's liver". To promote uniformity in soil terminology, such local names should be omitted or used only to supplement the description of the soil.

(d) *Permafrost*

In northern parts of Canada, the soil remains perennially frozen. These areas are known as permafrost regions. In such regions, the same soils exist as in other areas, but it is necessary not only to identify the soil, but to note the presence of permafrost, and if possible the depth of the "active zone", i.e., the depth to which the soil thaws during the summer, and the thickness of organic cover if any.

7. OTHER FACTORS IN SOIL DESCRIPTION

If the vertical section of a boring or test pit is being examined, such data as the date of observation, depth below surface, elevation of surface, level of groundwater, and location of the boring or test pit must be recorded. A brief description of the method of sampling is necessary to show whether the sample can be regarded as undisturbed.

8. CHECK LIST FOR FIELD DESCRIPTION OF SOILS

General

The check list below may be used as a guide in a soil description. It includes the terms necessary for an adequate description of the soil. Any additional descriptive terms, which the user may think necessary, should be included to give a more complete description.

(a) *Environmental*

Sample No. *Site*

Detailed Location *Date*

Depth Below Surface *Surface Elevation*

Boring *Test Pit* *Excavation* *Other*

Remarks on Method of Sampling

Groundwater Level

(b) *Check list for coarse-grained soils*

Soil Subdivision	Boulders and Cobbles, Gravel, Sand		
Size of Maximum Particles			
Grain Shape	Angular	Subangular	Rounded
Grading	Uniform	Graded	
	Fine	Medium	Coarse
Density	Loose	Medium	Dense
Structure	Stratified	Nonstratified	
Colour			
Odour			
Organic Material			
Presence of Fines			

(c) *Check list for fine-grained soils*

Soil Subdivision

Sandy Silt	Silt	Clayey Silt	Silty Clay	Clay

Consistency	Hard	Stiff	Firm	Soft
Dry Strength	None	Low	Medium	High
Reaction to Shaking Test	Rapid	Slow	None	
Reaction to Shine Test	No clay		Clay present	
Reaction to Taste Test	Silt or sand present		No Silt or Sand	
Toughness at Plastic Limit	Weakly plastic	Medium plastic	Highly plastic	
Structure	Stratfied		Fissured	
	Friable or Blocky	Lensed	Nonstratified	
Odour				
Colour	Mottled			

GUIDE

to a

FIELD DESCRIPTION OF

MUSKEG

(Based on the Radforth Classification System)

Foreword

Muskeg (or "Organic Terrain") comprises about 12 per cent of the terrain of Canada. It creates considerable difficulties for surface transportation and often interferes with engineering works. As a start in the solution of the problems caused by muskeg, it is desirable that everyone use the same terms to refer to this type of terrain. Standardization of terminology can best be furthered by an adequate classification or description of the terrain. Dr. N.W. Radforth, Professor of Botany, McMaster University, has developed a descriptive system for muskeg; this booklet is a condensed version of information contained in several technical papers authored by Dr. Radforth. These papers are listed on the inside back cover of this booklet and may be obtained from the National Research Council.

The Associate Committee on Soil and Snow Mechanics is anxious to assist in the standardization of muskeg terminology and methods in muskeg research and practice; this publication is but one step toward this goal. It is hoped that the descriptive system will be widely used by those engaged in engineering practice in muskeg areas in Canada. This booklet is issued in a preliminary form to permit revision as the need arises. Comments on its usefulness would be appreciated by the Associate Committee.

1. What is Meant by "Organic Terrain" and "Organic Material"

"Organic terrain" is a term used to describe what is commonly known as "muskeg". The surface of this terrain is composed of a living organic mat of mosses, sedges and/or grasses, with or without tree and shrub growth. Underneath the surface there is a mixture of partially decomposed and disintegrated organic material, commonly known as "peat" or "muck". As a rule, this subsurface material is highly compressible compared to most mineral soils. Organic terrain is characterized by its very high water content and its extremely low bearing capacity.

2. Basis of the Descriptive System

Because of its biological origin, organic terrain is extremely complex. Owing to this complexity it was thought at first that perhaps no constant relationship existed between various factors of the terrain. However, extensive examination of the fossilized pollen and spores preserved in peat samples from various locations across Canada proved that certain qualitative relationships do exist and this furnished a basis for the development of the descriptive system.

This descriptive system attempts to record a three-dimensional problem and is based on surface vegetation which occurs above the ground, topographic features which occur along the ground, and on composition and structure of the subsurface material which occurs in the ground. All of these factors must be taken into account to obtain a reasonable evaluation of the terrain. Tables IV and V at the end of this booklet show the relationship between these various factors.

3. Pattern of Surface Vegetation

Surface vegetation is the first factor to be observed in a particular muskeg area and is also the easiest factor to assess.

Table I presents the necessary information to describe nine vegetal coverage classes. Photographs depicting these classes appear in Figures 1 to 9. Note that the properties mentioned in Table I do not refer to species of plants but rather to qualities of vegetation such as stature, degree of woodiness, external texture, and certain easily recognized growth habits.

Pure classes seldom exist by themselves but rather are in combination with other classes. Only 18 such combinations occur most frequently in Northern Canada and are listed in Table V. The complete description of a particular area may be given by two or three letters, never by four. If one coverage class property is not present to the extent of 25 per cent of the terrain, it is not abundant enough to be included in the composite cover description. In the combination of letters, that letter which represents the most prominent set of properties is placed first, and other letters involved follow in order of prominence.

This system can be applied to a complex area consisting of several distinctly different combinations of vegetative classes and equally well to an area of uniform coverage made up of two or three vegetative classes.

Fig. 1 <u>Class "A"</u> - Woody; 15 feet or over

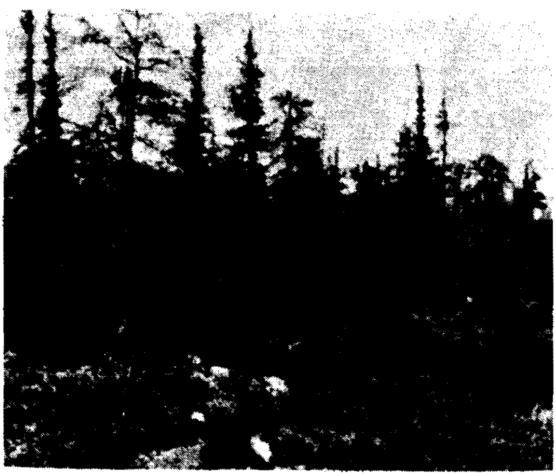


Fig. 2 <u>Class "B"</u> - Woody; 5 feet to 15 feet

Fig. 3 Class "C" - Non-woody; 2 feet to 5 feet

Fig. 4 Class "D" - Woody; 2 feet to 5 feet

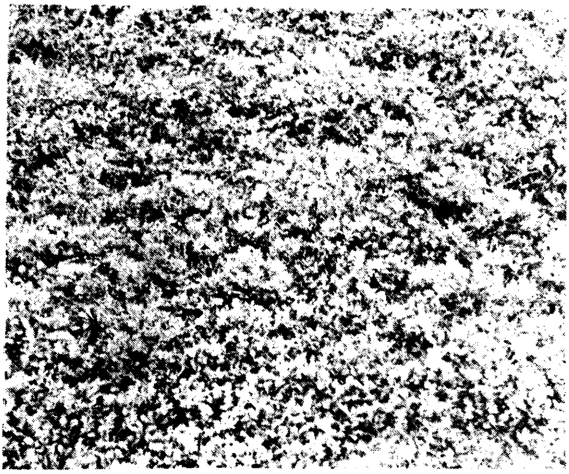


Fig. 5 Class "E" - Woody; up to 2 feet

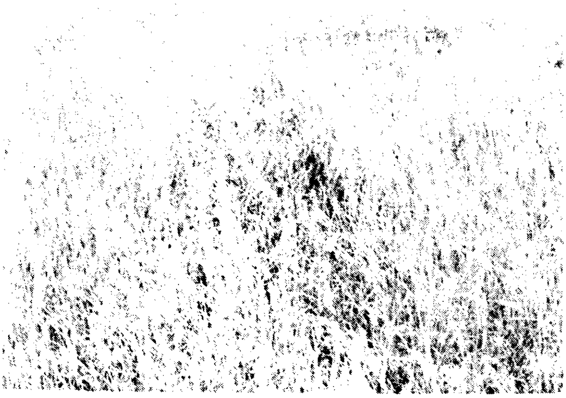


Fig. 6 Class "F" - Non-woody; up to 2 feet

Fig. 7 Class "G" - Non-woody; up to 2 feet

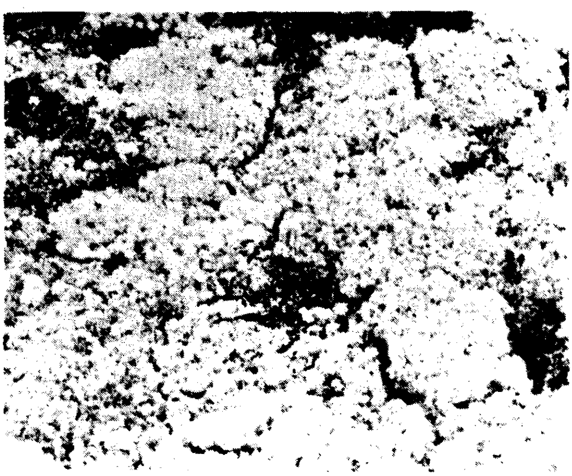


Fig. 8 Class "H" - Non-woody; up to 4 inches

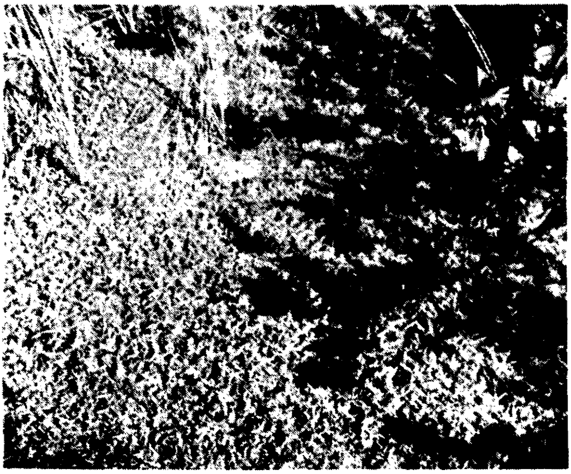


Fig. 9 <u>Class "I"</u> - Non-woody; up to 4 inches

4. Topographic Features

Terrain unevenness is important in the appraisal of organic terrain. Changes in topography are sometimes caused by irregularities in the mineral substrata but much of the unevenness of the surface is due to structural changes within the organic material itself. Table II gives the descriptive information for identifying topographic features of organic terrain. Several of these features are not peculiar to muskeg areas, but do occur and therefore should be described.

5. Subsurface Characteristics

In addition to describing muskeg by its surface features, it is equally necessary to describe the subsurface material (i.e. peat). Based on examination of peat samples from various sites, sixteen categories of peat were established. These categories vary in accordance with variation in the organic terrain (see Table V). The description of organic material is based on the extent to which wood and fibres are present. Organic material can be roughly grouped into three types:

(1) Material composed chiefly of soils of an amorphous-granular base;

(2) Material chiefly made up of fine fibres. These fibres may be woody or non-woody;

(3) Material predominantly of wood particles and coarse fibres. The coarse fibres are always woody.

Table III lists these sixteen categories. Figures 10 to 25 show photographically the general appearance of these sixteen categories of organic material.

These categories are qualitative only. Therefore, a successful application of this system will necessarily involve comparing a particular peat sample with the photographs and selecting the appropriate category.

6. Application of the System

To integrate all the information that has been collected on muskeg and peat from field observations, all details should be recorded on data sheets. Suggested sheets for recording surface and subsurface investigations are included in this booklet. They include most of the specific details required; other pertinent information may be added. Naturally the amount and type of information required will depend largely upon the use for which it is intended.

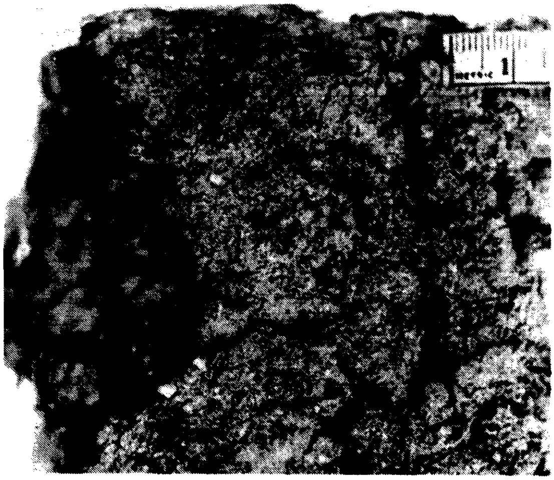


Fig. 10 Category 1

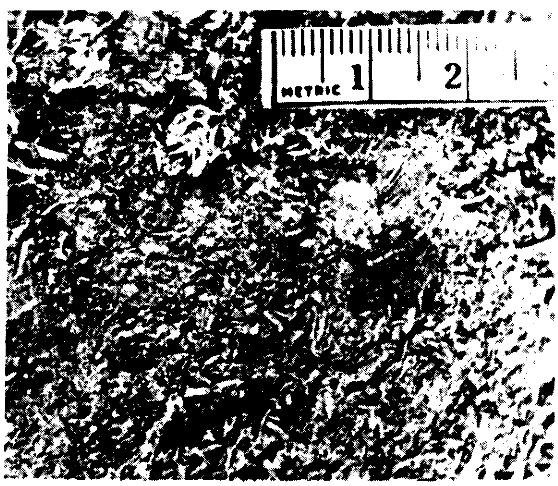


Fig. 11 Category 2

Fig. 12 Category 3

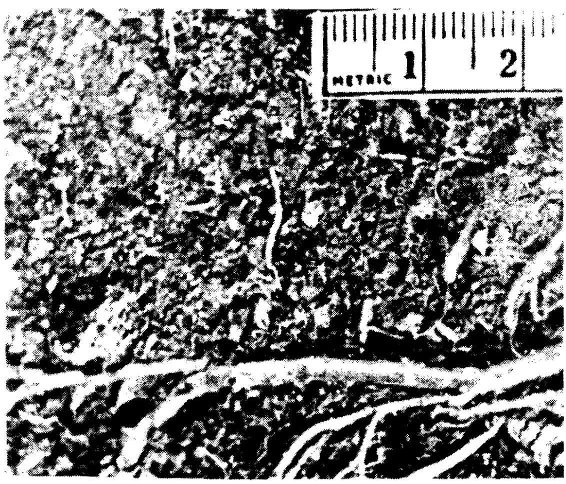


Fig. 13 Category 4

Fig. 14 Category 5

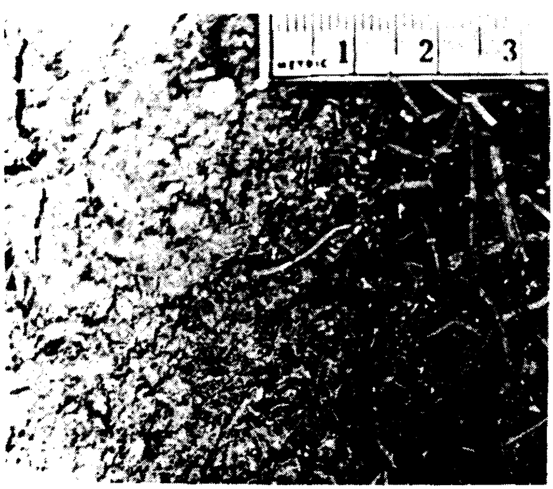


Fig. 15 Category 6

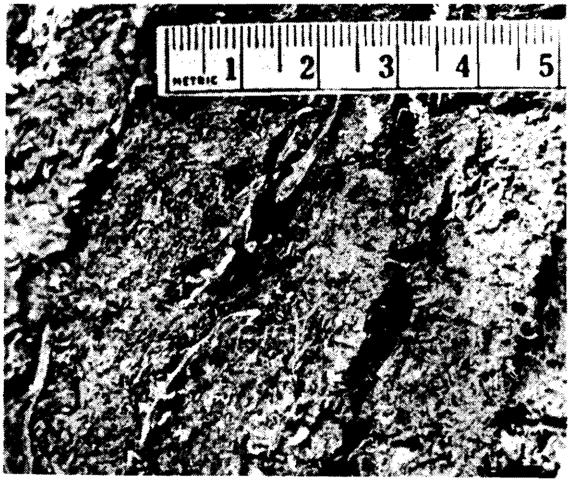


Fig. 16 Category 7

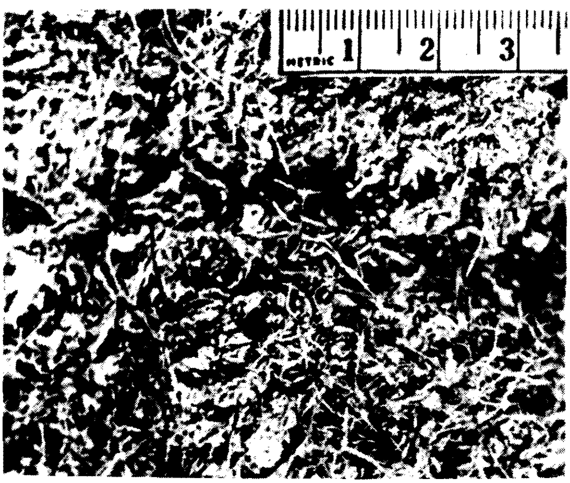


Fig. 17 Category 8

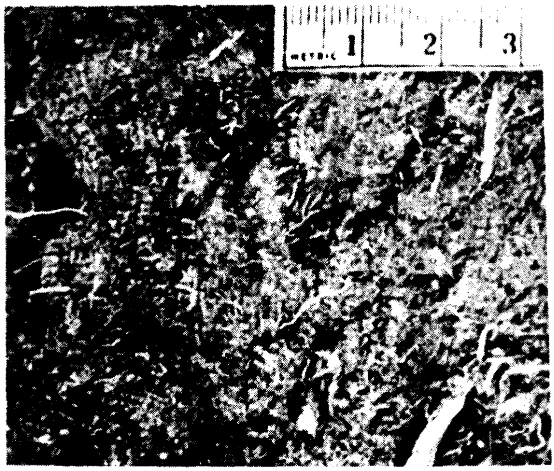


Fig. 18 Category 9

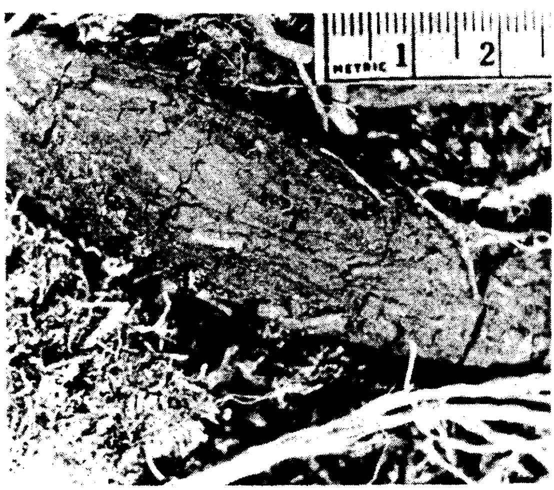


Fig. 19 Category 10

Fig. 20 Category 11

Fig. 21 Category 12

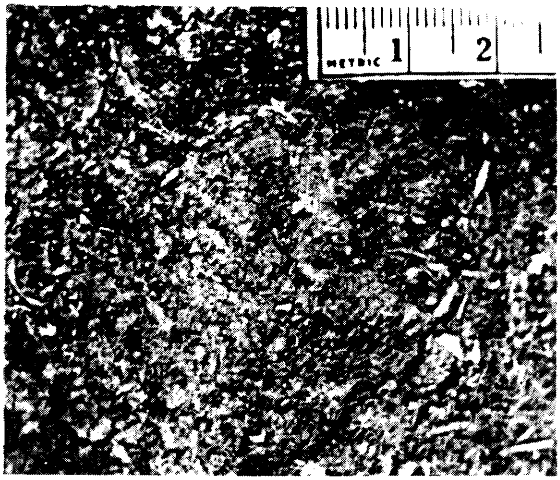


Fig. 22 Category 13

Fig. 23 Category 14

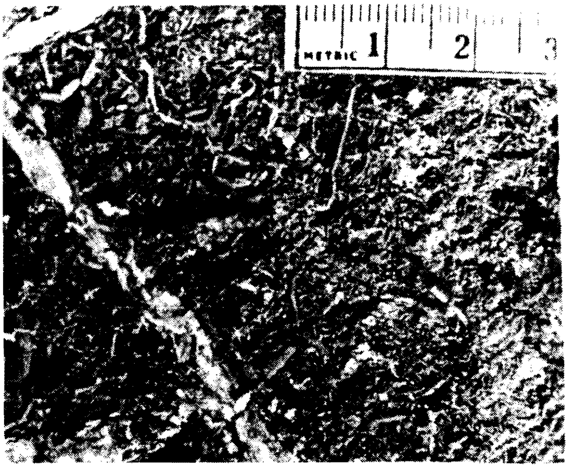


Fig. 24 Category 15

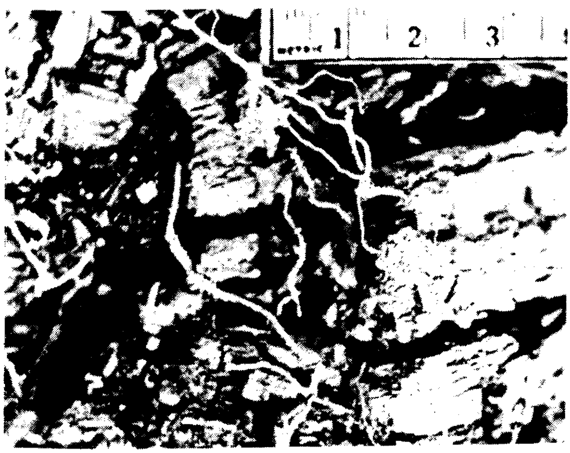


Fig. 25 Category 16

7. Muskeg Field Investigation Record - Surface Investigations

Site:

Date:

Detailed Location:

Map -

Aerial Photos -

Approx. Area of Terrain:

Surface Elevation:

Physiographic Features:

Water Conditions:

Evidence of drainage pattern

Depth to water table

Colour of water

p^H value (acidity)

Remarks

Notes on Climatic Conditions:

Description:

Surface Coverage	Topographic	Remarks

Photographs:

Number	Description

General Remarks:

8. Muskeg Field Investigation Record - Subsurface Investigations

Site: Date:

Location of Sample(s): Hole No(s):

Surface Elevation: Sample No(s): Depth:

Type of Sample:

Colour of Peaty Soil:

Type of Mineral Subsoil:

Peat Profile Peat Category

Depth to Mineral Subsoil:

Depth to Frost Level:

Photographs:

Number Description

General Remarks:

TABLE I

Summary of Properties Designating Nine Pure Coverage Classes

Coverage Type (Class)	Woodiness vs. Non-woodiness	Stature (approx. height)	Texture (where req'd)	Growth Habit	Example
A	woody	15 ft. or over	------	tree form	Spruce Larch
B	woody	5 to 15 ft.	------	young or dwarfed tree or bush	Spruce Larch Willow Birch
C	non-woody	2 to 5 ft.	------	tall grass-like	Grasses
D	woody	2 to 5 ft.	------	tall shrub or very dwarfed tree	Willow Birch Labrador tea
E	woody	up to 2 ft.	------	low shrub	Blueberry Laurel
F	non-woody	up to 2 ft.	------	mats, clumps or patches, sometimes touching	Sedges Grasses
G	non-woody	up to 2 ft.	------	singly or loose association	Orchid Pitcher plant
H	non-woody	up to 4 in.	leathery to crisp	mostly continuous mats	Lichens
I	non-woody	up to 4 in.	soft or velvety	often continuous mats, sometimes in hummocks	Mosses

TABLE II

TOPOGRAPHIC FEATURES

Contour Type	Feature	Description
a	Hummock	includes "tussock" and "nigger-head", has tufted top usually vertical sides, occurring in patches, several to numerous
b	Mound	rounded top, often elliptic or crescent-shaped in plane view
c	Ridge	similar to Mound but extended, often irregular and numerous; vegetation often coarser on one side
d	Rock gravel plain	extensive exposed areas
e	Gravel bar	eskers and old beaches (elevated)
f	Rock enclosure	grouped boulders overgrown with organic deposit
g	Exposed boulder	visible boulder interrupting organic deposit
h	Hidden boulder	single boulder overgrown with organic deposit
i	Peat plateau (even)	usually extensive and involving sudden elevation
j	Peat plateau (irregular)	often wooded, localized and much contorted
k	Closed pond	filled with organic debris, often with living coverage
l	Open pond	water rises above organic debris
m	Pond or lake margin (abrupt)	
n	Pond or lake margin (sloped)	
o	Free polygon	forming a rimmed depression
p	Joined polygon	formed by a system of banked clefts in the organic deposit

TABLE III

SUBSURFACE CONSTITUTION

PREDOMINANT CHARACTERISTIC	CATEGORY	NAME
AMORPHOUS-GRANULAR	1.	Amorphous-granular peat
	2.	Non-woody, fine-fibrous peat
	3.	Amorphous-granular peat containing non-woody fine fibres
	4.	Amorphous-granular peat containing woody fine fibres
	5.	Peat, predominantly amorphous-granular, containing non-woody fine fibres, held in a woody, fine-fibrous framework
	6.	Peat, predominantly amorphous-granular containing woody fine fibres, held in a woody, coarse-fibrous framework
	7.	Alternate layering of non-woody, fine-fibrous peat and amorphous-granular peat containing non-woody fine fibres
FINE-FIBROUS	8.	Non-woody, fine-fibrous peat containing a mound of coarse fibres
	9.	Woody, fine-fibrous peat held in a woody, coarse-fibrous framework
	10.	Woody particles held in non-woody, fine-fibrous peat
	11.	Woody and non-woody particles held in fine-fibrous peat
COARSE-FIBROUS	12.	Woody, coarse-fibrous peat
	13.	Coarse fibres criss-crossing fine-fibrous peat
	14.	Non-woody and woody fine-fibrous peat held in a coarse-fibrous framework
	15.	Woody mesh of fibres and particles enclosing amorphous-granular peat containing fine fibres
	16.	Woody, coarse-fibrous peat containing scattered woody chunks

TABLE IV

Topographic Feature	Topographic Symbol	Location by Coverage	Occurrence Distribution	Peat Category
Hummock	a	FI background hummock coverage – F	in groups commonest near peat plateaus or ponds	non-woody, fine-fibrous (2)
Mound	b	FI background mound coverage – EH	random, common where ill-drained	non-woody, fine-fibrous – mound itself, coarse-fibrous (8)
Ridge	c	FI background ridge coverage – HE	regularly associated common on ill-drained plains	coarse-fibrous, traversing fine-fibrous (13)
Rock gravel plain	d	HEB where covered	infrequent interruptions	amorphous granular, with woody, fine-fibrous held in coarse-fibrous (6)
Gravel bar	e	HEB	coastal plain	
Rock enclosure	f	EHB	uncommon, on elevated rock ridge or plateau, often near ponds	coarse-fibrous, woody (12)
Exposed boulder	g	EHB	random, common in EHB background of FI	
Hidden boulder	h	EH	random, common under EHB background of FI	woody, fine-fibrous, held in coarse-fibrous (9)
Peat plateau (even)	i	HE	spreading, usually equidimensional, common interrupting FI	amorphous granular in fine-fibrous (3)
Peat plateau (irregular)	j	HFE	spreading, usually linear, common traversing mixed background	amorphous granular fine-fibrous non-woody in woody, fine-fibrous (5)
Closed pond	k		random, in HE occasionally FI, common usually associated with ridge margin	amorphous granular (1)
Open pond	l		in FI, common	
Pond or lake margin (abrupt)	m	EH	often part of drainage route in F, common, often with marginal ridge of EA	non-woody and woody, fine-fibrous, held in coarse-fibrous (14)
Pond or lake margin (Sloped)	n	F	random, in flooded plains, common, in F	non-woody, fine-fibrous (2)
Free polygon	o	EH	random, uncommon in EH or FI background	woody, fine-fibrous held in coarse-fibrous (9)
Joined polygon	p	HE, FI	random areas, common on peat plateaus or confined FI	non-woody, fine-fibrous covering amorphous granular in fine-fibrous (7)

TABLE V

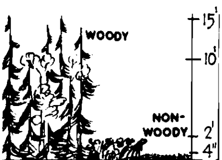
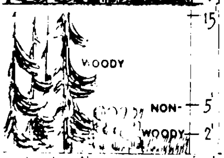
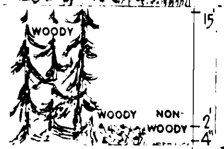
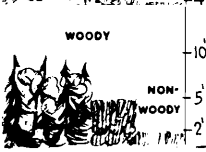
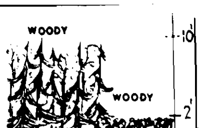
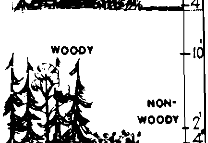
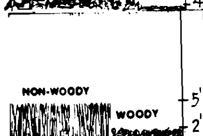
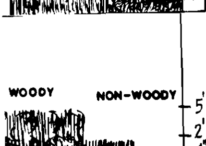
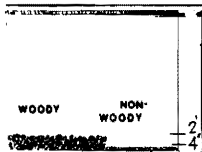
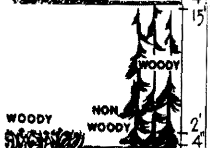
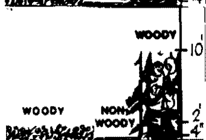
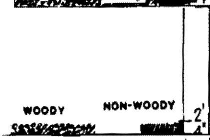
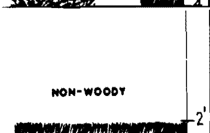
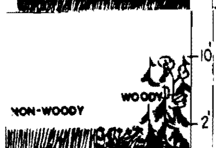
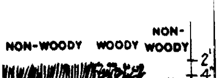
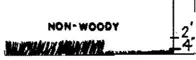
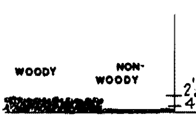
Sketch	Ground Form Description	Location by Coverage	Occurrence Distribution	Coverage Formula	Peat Category
	woody coverage highly irregular in stature and mixed forms; intermediate woody and lowest non-woody layers mixed and abruptly changing	better drained areas where tree crown coverage is open	frequent, dispersed and ill-defined	A<->B,E,H<->I	woody, fine-fibrous held in coarse-fibrous (9)
	tree crowns not overlapping; undergrowth often impassable, interrupted only by clumped non-woody member	following river courses	broken distribution in forested terrain generally in areas less than ½ sq. mile	ADF	woody, coarse and fine-fibrous (9, 13)
	spotted to impassable tree growth; undergrowth broken to continuous, even as to height	commonly on localized divides in relatively good drainage	often continuous for hundred square miles, but sometimes around finger-like processes with sharp definition	AEH	woody, fine-fibrous held in coarse-fibrous (9)
	often clear, eye-level vision occasionally impassable woody mesh interrupted by clumped non-woody growth	following river and creek courses	often predominating, dispersed in linear fashion	BDF	woody, coarse and fine-fibrous (9, 13)
	undulating layering on very uneven terrain, the condition continuous	on broken terrain	widespread and merging with several classes	BE	woody, coarse-fibrous (12)
	as for BE with relatively structureless H class smoothing irregularities and intermittently a pure class	on moderately rough patches in rougher terrain as background	widespread and less frequent than BE	BEH	woody, fine-fibrous held in coarse fibrous (9)
	interrupted islands of even height woody growth in background mosaic of other classes	crowns of divides sometimes well-drained shoulders of eskers	frequent interruptions each a few metres square	BHE	woody, with amorphous granular in fine-fibrous (15)
	non-woody member in continuous mesh, with low woody class dispersed	commonly on old beach lines	infrequent, isolated, localized	CE	woody, and non-woody, fine-fibrous held in coarse-fibrous (14)
	woody member marking a dispersed higher contour often merging with low non-woody classes arranged irregularly	usually traversing FI where very localized drainage is slightly improved	frequent, dispersed	DFI	woody, in non-woody, fine-fibrous (10)

TABLE V

Sketch	Ground Form Description	Location by Coverage	Occurrence Distribution	Coverage Formula	Peat Category
	random irregular woody groups, low and open branched framed in relatively structureless folded ground layer	common interrupting FI background in treeless areas	often covering extensive areas of elevated contour, several to many square miles	EH	woody, fine-fibrous held in coarse-fibrous (9)
	as for EH, with folded condition accentuated and scattered tree forms	irregular plateaus near poorly drained areas in FI background	continuous, in widely separated areas	EHA	woody, coarse-fibrous with scattered woody erratics (16)
	as for EHA, with tree stature reduced	irregular plateaus near poorly drained areas in FI background	continuous, in widely separated areas	EHB	woody, coarse-fibrous with scattered woody erratics (16)
	as for EH except for sunken variously shaped interruptions of non-woody organized growth	associated with boundaries of EH and FI	occupying areas of several square miles	EHF	woody, fine-fibrous held in coarse-fibrous (9)
	slightly elevated areas with diffuse margins grading into FI	often occurring at margins of HE plateaux before grading into FI, and in ponds	infrequent, isolated and widely separated	F	non-woody, fine-fibrous (2)
	frequent islands of uniform non-woody, interrupted by irregular masses of low woody growth	as islands interrupting FI areas with ponds	examples closely associated but may be isolated	FEB	woody and non-woody in fine-fibrous (11)
	irregular expanses with roughness accentuated by randomly distributed low woody member	near ponds in low lying areas	infrequent, localized	FEI	woody and non-woody, fine-fibrous (5)
	meadow-like expanses with appressed class I, often water soaked or submerged, often clumping	in poorly drained areas – usually associated with ponds	serves frequently as background for other class combinations – very common	FI	non-woody, fine-fibrous (2)
	folded continuous areas of uniform surface texture	often as polygon coverage in treeless areas	common as coverage for plateaus, often as islands with FI as background	HE	amorphous granular in fine-fibrous (3)

FIRE PERFORMANCE RATINGS 1965

SUPPLEMENT No. 2
TO THE NATIONAL BUILDING CODE
OF CANADA

PREFACE

The Associate Committee on the National Building Code set up in 1962 a small technical committee, the Fire Test Board. It is directly responsible to the Associate Committee for the contents of NBC Supplement No. 2 and for the preparation of any related material that may be published by the Associate Committee.

This Board considered the revision of Supplement No. 2 in accordance with its terms of reference. Appendix 4.1.B "Fire Resistance Rating" as it was originally called, was first produced in 1953 in order to bring together the test information needed to make the performance requirements of the National Building Code workable. It was intended to be a list of fire tests on specific assemblies. In fact, because of the scarcity of fire test reports, it did contain a proportion of entries based on interpolation and calculation.

In reassessing the available test data, the Fire Test Board found that, where a number of test reports existed describing essentially the same assemblies, the results would vary over a significant range. Since the publishing of multiple results for what is apparently the same construction leaves the problem of establishing single ratings still unresolved, the Fire Test Board has decided it must use its own judgment and select reasonable values which will in most instances be equalled or exceeded by constructions falling within the described categories. The Fire Performance information in this document is therefore presented in a new form closely linked to the fire performance requirements and the minimum material specifications of the National Building Code.

All available published test information on assemblies of common building materials adequately identified by description has been carefully studied. Ratings which are considered reasonable in the light of available information have been assigned and included in the series of tables in this Supplement.

Where a general basis for rating cannot be established, some of the individual ratings formerly listed in Supplement No. 2 have been retained to provide as wide a coverage as possible. The Board hopes this will be a temporary measure. Subsequent research and testing may make it unnecessary to include individual fire test results in future Supplements.

N. B. Hutcheon, Chairman,
Fire Test Board.

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Fire Performance Ratings

PART 1 - INTRODUCTION

1.1.1 (1) The fire performance ratings set out in this document are approved by the Associate Committee on the National Building Code on the advice of the Fire Test Board for use with the National Building Code of Canada. The ratings apply to materials and assemblies of materials which comply in all essential details with the minimum standards described in Parts 4 and 5 of the National Building Code. Additional requirements, where needed, are described in detail in each Section of this Supplement.

(2) Part 2 covers Fire Resistance Ratings for walls, floors, roofs, columns and beams related to the Standard Methods of Test CSA B54.3–1964, ASTM E119–61 and BS 476 Part 1–1953. Part 3 describes Flame Spread Ratings for surface materials related to the Standard Method of Test ASTM E84–61.

1.1.2 The standard fire tests are the basis for compliance with the National Building Code requirements. The ratings shown in this document apply if no more specific test values are available. The construction of an assembly that is the subject of an individual test report, must be followed in all essential details if the fire endurance period reported is to be applied as a Fire Resistance Rating for use in the National Building Code.

1.1.3 The assigning of a Fire Resistance Rating on the basis of a test on a specific construction must remain the responsibility of the authority having jurisdiction who alone is in a position to determine whether the construction as built will be identical in all essential features to that which was tested.

1.1.4 The authority having jurisdiction may allow higher fire resistance ratings than those covered in this Supplement in cases where the construction can be identified more specifically than is possible under the generic descriptions in this Supplement and related closely to supporting evidence which in his opinion justifies a higher rating.

1.1.5 Summaries of all available published fire test information have been or are being prepared by the Division of Building Research as follows:

(1) "Flame Spread Performance of Common Building Materials" by M. Galbreath. Technical Paper No. 170. Division of Building Research, National Research Council, Ottawa, April 1964 NRC 7820; price 75 cents.

(2) "Fire Endurance of Protected Steel Columns and Beams", in preparation

(3) "Fire Endurance of Concrete Assemblies", in preparation.

(4) "Fire Endurance of Unit Masonry Assemblies", in preparation.

(5) "Fire Endurance of Light Frame and Miscellaneous Assemblies", in preparation.

Assemblies of proprietary materials, which cannot be fully identified by specification, are not included herein. Many such assemblies have been rated by Underwriters Laboratories of Canada. This information is published in their List of Equipment and Materials, Volume II, Building Construction. Copies of this document may be obtained without charge on request to Underwriters Laboratories of Canada, Crouse Road, Scarborough, Ontario.

1.2 Interpretation of Test Results

1.2.1 The Fire Performance Ratings set out in this Supplement must always be related to results obtained or to be expected from the Standard Methods of Test described in the National Building Code. The test methods are essentially a means of comparing the performance of one building component or assembly with another in relation to its performance in fire.

1.2.2 Since it is not practicable to measure the fire endurance of constructions in situ they must of necessity be evaluated under some agreed test conditions. A specified Fire Resistance in the National Building Code is not strictly speaking, the endurance period expected in situ, in a real fire, but is the fire endurance which the particular construction to be used must equal or exceed under the specified methods of test.

1.2.3 Considerations arising from departures in use from the conditions established in the standard test methods may in some circumstances have to be taken into account by the designer and the authority having jurisdiction. Some of these conditions are covered at present by the provisions of the National Building Code.

1.3 Aggregates Used in Concrete

1.3.1 The nature of the aggregate used has a significant effect on the fire endurance of concrete. Concretes containing a high proportion of quartz

(SiO_2) have shown a tendency to disintegrate when exposed to fire. It is known that quartz undergoes a change of form at a temperature above 1000°F. The resultant change in shape of the crystals induces stresses that may be responsible for the disruptive effects noted. The consequences of this effect are not fully known. It appears to have been of greatest significance in hollow concrete masonry units where a thin face shell is exposed to the fire giving little opportunity for the stresses to be taken up in the material.

1.3.2 In these tables, concretes having coarse aggregates that contain more than 65 per cent quartz, have been excluded because the Fire Test Board is not prepared, at present, to establish ratings for these concretes. The fire endurance of such concretes may however be determined, for a specific purpose, by the standard fire test as described in the National Building Code. Concretes having coarse aggregates containing 30 per cent to 65 per cent quartz are included in the tables.

1.3.3 Limestone concretes exhibit good characteristics in fire. Limestone consists essentially of calcium and magnesium carbonates. When exposed to fire these tend to break down into lime (CaO) (MgO) and water. The heat absorbed during the chemical change and the water released in the material both tend to delay temperature rise and consequently to prolong the fire endurance period. The remaining natural stone aggregates are mostly silicates in one form or another and their behaviour in fire lies between that of the quartz and the limestone aggregates.

1.3.4 Lightweight aggregate concretes exhibit better fire behaviour than the natural stone aggregates. This may be attributable partly to lower thermal conductivity. The better thermal behaviour may however in some circumstances be countered by the lesser strength of the lightweight concrete.

1.3.5 For purposes of this document concretes are described as Type S, N or L as follows:

(1) Type S Concrete is that type in which the coarse aggregate is granite, quartzite, siliceous gravel or other dense materials containing 30 per cent but not more than 65 per cent of quartz, chert or flint.

(2) Type N Concrete is that type in which the coarse aggregate is cinders, broken brick, blast furnace slag, limestone, calcareous gravel, trap rock, sandstone or similar dense material containing not more than 30 per cent of quartz, chert or flint.

(3) Type L concrete is that type in which all the aggregate is expanded slag, expanded clay, expanded shale or pumice.

1.3.6 The descriptions of the aggregates in Type S and Type N concretes above apply to the coarse aggregates only. Coarse aggregate for this purpose means aggregate retained on a #4 sieve (4.76 mm.). The use of siliceous sand is not considered to affect the fire enduring properties of these concretes. In Type L concrete, all the aggregates both coarse and fine, must be of the lightweight material in order to justify the fire resistance ratings given. The use of increasing proportions of sand as fine aggregates in Type L concrete may produce fire endurance periods approaching that of Type N concrete as the proportion increases. Aggregates for Type L concrete used in load bearing components must conform to ASTM C330–60T "Lightweight Aggregates for Structural Concrete."

1.3.7 Non load bearing lightweight components of vermiculite and perlite concrete in the absence of other test evidence, should be rated on the basis of the values shown for Type L concrete.

1.4 Equivalent Thickness

1.4.1 The thickness of solid unit masonry and concrete described in this document is the thickness of solid material in the unit or component thickness. For units that contain cores or voids the figures refer to the "equivalent thickness" determined as follows:

1.4.2 Equivalent thickness of a wall, floor, column or beam protection is equal to the sum of the equivalent thicknesses of the units and plaster finish in the wall, floor, column or beam protection, measured at the point that will give the least value of equivalent thickness.

1.4.3 Equivalent thickness of a hollow masonry unit is equal to the actual overall thickness of a unit in inches multiplied by the net volume of the unit in cubic inches and divided by the gross volume of the unit in cubic inches.

Net Volume is determined as follows:

(a) for concrete masonry units by the method described in ASTM C140–62 "Standard Methods of Sampling and Testing Concrete Masonry Units".

(b) for cored bricks by direct measurement as referred to in CSA A82.2–1954 "Specifications for Standard Methods for Sampling and Testing Brick".

(c) for hollow clay tiles by direct measurement as referred to in CSA A82.6–1954 "Specification for Standard Methods for Sampling and Testing Standard Clay Tile".

Gross Volume is equal to

Length of Unit (in.) × Height of Unit (in.) × Thickness of Unit (in.)

1.4.4 Equivalent Thickness of Plaster Finish is equal to: True thickness of plaster on one or both faces multiplied by the factor shown in Table 1.5.1 depending on the material to which the plaster is applied.

1.5 Contribution of Plaster Finish

1.5.1 The true thickness of the plaster finish applied direct to concrete or masonry on one or both faces of a wall and on the fire exposed faces of floors, beams, and columns, is multiplied by the factor shown in Table 1.5.1 depending on the material to which the plaster is applied. The corrected thickness is then included in the "Equivalent Thickness" as described in Section 1.4. Gypsum plaster to be in accordance with CSA A82.30, "Specification for Gypsum Plastering, Interior Furring and Interior Lathing." Portland cement-sand plaster is as follows: First (scratch) coat — one part portland cement to two parts sand by volume, second (brown) coat one part portland cement to three parts sand by volume.

TABLE 1.5.1
Contribution to Fire Resistance Rating of Plaster Finish on Masonry and Concrete

Description of Plaster Finish	Multiplying Factor when Plaster is Applied to—		
	Type S Concrete	Type N Concrete Solid Brick Units	Cored Brick Units Hollow Clay Tile Type L Concrete
(i) Portland cement sand	1¼	1	¾
(ii) Gypsum sand	1½	1¼	1
(iii) Gypsum vermiculite or perlite	1¾	1½	1¼

To be used only in assessing the contribution to the Fire Resistance Rating provided by normal plaster thickness up to 1½ in. applied direct to masonry or concrete.

1.6 Tests on Floors

1.6.1 All tests relate to the performance of a floor or floor and ceiling assembly above a fire. It has been assumed on the basis of experience that fire on top will take a longer time to penetrate the floor than one below and that the fire endurance in such a situation will be at least equal to that obtained from below in the standard test.

1.6.2 The new "Methods of Fire Tests" CSA B54.3–1964 recognized by the National Building Code provides that in the case of a roof assembly the temperature rise criterion shall not apply. This means that the criterion for failure of roofs is collapse only. The provision does not affect significantly, the ratings set out in Section 2.3 or Section 2.4. In concrete roofs (Section 2.2) the minimum thickness shown inTable 2.2.1 for floors may be neglected. The fire resistance for roofs will be determined on the basis of cover to reinforcing steel (Table 2.2.2) alone and the minimum thickness will be that required by the National Building Code for structural reasons.

1.7 Moisture Content

1.7.1 The moisture content of building materials at the time of fire test may have a significant influence on the fire endurance recorded. In general an increase in the moisture content should result in an extension of the fire endurance period, though in some materials the presence of moisture may produce disruptive effects and early collapse of the assembly.

1.7.2 Moisture content is now controlled in standard fire test methods and is generally recorded in the test reports. In earlier tests moisture content was not always adequately determined.

1.8 Permanence and Durability

1.8.1 The ratings in this document relate to tested assemblies and do not take into account possible changes, or deterioration in use, of the materials tested. The Standard Fire Test measures the fire endurance of a sample building assembly as it is erected for purposes of test. No judgment is required by the test method as to the permanence or durability of the assembly. Such matters must remain the concern of the authority having jurisdiction.

1.9 Definition

1.9.1 When the word membrane is used in this document it means the whole of the facing applied to or suspended from the structural members so as to form a continuous wall or ceiling surface that protects the members from exposure to fire on the side on which it is located.

PART 2 - FIRE RESISTANCE RATINGS

2.1 Masonry Walls

2.1.1 The minimum thickness of solid masonry walls complying with the requirements of the National Building Code as described in Clause 1.1.1 for fire resistance ratings from ½ hour to 4 hours is shown in Table 2.1.1. Concrete is referred to in the Table as Type S, N or L depending on the aggregate used. Types of concrete are described in Section 1.3. Hollow units are rated on the basis of "equivalent thickness" as described in Section 1.4.

2.1.2 Ratings obtained as described in 2.1.1 apply to either load bearing or non load bearing walls, with the following exceptions:

(a) Gypsum Tile Walls are non load bearing.

(b) Walls less than the minimum thickness prescribed for load bearing walls in the National Building Code are non load bearing.

(c) Cavity walls, consisting of two masonry wythes tied together by metal ties will have a fire resistance at least as great as a solid wall of the same equivalent thickness, provided the maximum design compressive stress as described in Part 4.4 Masonry of the National Building Code does not exceed 55 lb./sq. in. of the masonry.

2.1.3 Where a wall consists of two wythes of masonry material bonded together, such as concrete block and brick, the Fire Resistance Rating may be assumed to be the rating that would apply if the whole of the wall were of the material that gives the lesser rating.

2.1.4 If wood joists are built into a masonry wall the fire resistance will be reduced. The thickness of masonry material between the end of the joist and the fire exposed side of the wall should be not less than that shown in the tables for the fire resistance required.

2.1.5 On monolithic walls and walls of unit masonry the full plaster finish on one or both faces, multiplied by the factor shown in Table 1.5.1, may be included in the wall thickness shown in Table 2.1.1 except as follows:

> On walls of hollow clay tile* and hollow units of Type S Concrete, plaster on the fire exposed side or on both sides may be included but if there is no plaster on the fire exposed side, any plaster finish on the non exposed side must be disregarded.

*This refers to hollow clay tile as described in CSA A-82.4–1954 and CSA A-82.5–1954 not to cored brick.

2.1.6 Short reinforced concrete walls or portions of walls, that may be exposed to fire on both sides simultaneously, and are required to carry a load during fire exposure should be of minimum dimensions and have minimum cover to steel reinforcement as shown in Tables 2.8.1 and 2.8.2 (Section 2.8).

TABLE 2.1.1

Minimum Thickness of Masonry Walls
Load Bearing and Non Load Bearing

	Minimum Thickness in Inches for Fire Resistance Rating of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
(i) Solid Brick Units (80 per cent solid and over) Actual Overall Thickness	2.5	3.0	3.5	4.3	5.0	6.0	7.0
(ii) Cored Brick Units and Hollow Tile Units (less than 80 per cent solid) Equivalent Thickness	2.0	2.4	2.8	3.4	4.0	4.8	5.6
(iii) Concrete Masonry Units, Solid or Hollow, and Monolithic Concrete Type S Concrete Equivalent Thickness	2.8	3.2	3.7	4.6	5.5	6.7	8.0
(iv) Type N Concrete Equivalent Thickness	2.5	3.0	3.5	4.3	5.0	6.0	7.0
(v) Type L Concrete Equivalent Thickness	1.7	2.2	2.7	3.3	4.0	4.8	5.7
(vi) Gypsum Partition Tile or Block[(1)] Solid or Hollow Units Non Load Bearing Equivalent Thickness	1.3	1.7	2.0	2.5	3.2	4.1	5.0

[(1)]Gypsum partition tile is wood fibred gypsum in accordance with CSA A82.25–1950, "Specification for Gypsum Partition Tile or Block".

2.2 Reinforced Concrete Floors

2.2.1 The minimum thickness of concrete floors complying with the requirements of the National Building Code as described in Subsection 1.1.1 for fire resistance ratings from ½ hour to 4 hours is shown in Table 2.2.1.

Minimum thickness of concrete cover required as protection to the principal reinforcement in order that these ratings may apply is shown in Table 2.2.2.

The fire resistance of concrete roofs is dependent on minimum cover to principal reinforcement (Table 2.2.2) alone when the temperature rise criterion is not applied. See Clause 1.6.2.

2.2.2 Floors may fail either by heat transfer so that a temperature rise of 250°F is recorded on the unexposed side, or by collapse. The thickness of concrete shown in Table 2.2.1 is required to resist the transfer of heat during the fire resistance period indicated.

The cover to the reinforcement shown in Table 2.2.2 is required to maintain the integrity of the structure and prevent collapse during the same period.

2.2.3 The concrete is referred to in the Tables as type S, N or L depending on the aggregate used. These types of concrete are described in Section 1.3. The fire resistance of floors containing hollow units may be determined on the basis of "Equivalent thickness" as described in Section 1.4.

2.2.4 Concrete floor topping and fill may be included in the floor thicknesses shown in Table 2.2.1.

The contribution of plaster finish, securely fastened to the underside of the concrete may be included, as described in Section 1.5, in the floor thickness shown in Table 2.2.1 and in the thickness of cover shown in Table 2.2.2. It should be noted, however, that CSA A82.30, "Specification for Gypsum Plastering, Interior Furring and Lathing", does not permit plaster exceeding ½ in. thick applied direct to concrete floors unless it is reinforced or held in place by metal lath.

2.2.5 Minimum protection to reinforcement in prestressed concrete slabs is shown in Table 2.2.2.

Minimum dimensions and cover to reinforcement of prestressed concrete beams are shown in Section 2.10.

TABLE 2.2.1

Minimum Thickness of Reinforced Concrete Floor Slabs

	Minimum Thickness in Inches for Fire Resistance Rating of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
(i) Type S & N Concrete	2.5	3.0	3.5	4.3	5.0	6.0	7.0
(ii) Type L Concrete	1.7	2.2	2.7	3.3	4.0	4.8	5.7

TABLE 2.2.2

Minimum Protection to Reinforcement in Concrete Slabs

	Minimum Thickness of Cover to Principal Reinforcement in Inches for Fire Resistance Rating of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
(i) Types S, N or L Concrete	⅝	⅝	¾	¾	1	1¼	1½
(ii) Prestressed Concrete Slabs Type S, N or L Concrete	¾	1	1	1¼	1½	2	2½

2.3 Wood and Steel Framed Walls, Floors and Roofs

2.3.1 The Fire Resistance Rating of walls, floors and roofs, incorporating wood, steel, light gauge steel members and open web steel joists, that comply with the requirements of the National Building Code as described in Subsection 1.1.1 for ratings up to and including 1½ hours may be determined by the use of Tables 2.3.1 to 2.3.7 inclusive.

2.3.2 The ratings apply to both load bearing and non load bearing walls and to load bearing floors and roofs.

2.3.3 The Fire Resistance Rating of a framed assembly is equal to the sum of:

(a) A time assigned in Tables 2.3.1 or 2.3.2 for the endurance of the fire exposed membrane.

(b) A time assigned in Table 2.3.3 for the contribution of the framing members.

(c) A time assigned in Table 2.3.4 for additional protection if used.

2.3.4 Fire Resistance Ratings derived from these tables give time to collapse of a load bearing assembly. The fire resistance by the criterion of temperature rise on the unexposed surface or by penetration of flame, may be considered to be at least equal to the time to collapse if the membrane on the non fire exposed side is one of the following:

(a) A wall membrane having a time assigned in Tables 2.3.1 or 2.3.2 of not less than 15 min.

(b) An exterior wall membrane as described in Table 2.3.5.

(c) A floor construction as described in Table 2.3.6.

(d) A roof construction including a combination of sub-floor and structure as described in columns (b) and (c) of Table 2.3.6 and a finish roofing material approved by the National Building Code.

2.3.5 It is common for there to be the possibility of fire on either side of an interior wall and in this case the fire resistance rating will be determined by the membrane that contributes least to the fire endurance.

2.3.6 The values shown in these tables apply only if the supports for the fire exposed membrane are at not more than 16 in. o.c. Wood studs are assumed to be not less than 2 in. by 4 in. nom. wood joists not less than 2 in. nom. thickness. Plaster thickness is measured from the face of gypsum lath and from the back of metal lath.

2.3.7 The fastening of the membrane to the supporting construction is of the greatest importance if the assigned fire resistance rating is to be attained. Fastening to wood and metal supports may be not less than that specified in CSA A82.30 standard "Specifications for Gypsum Plastering, Interior Furring and Lathing" and not less than the minimum nail sizes and spacing set out in Table 2.3.7.

2.3.8 The membrane method may seriously under value the fire resistance of certain assemblies including some with open web steel joists. Ratings higher than those provided by the method described above may be justified by reference to test data.

2.3.9 Supplementary ratings based on individual tests are included in Tables 2.3.8. and 2.3.9. These are derived from reports of individual tests carried out in accordance with the Standard Method of Test as required by the National Building Code. The values shown in these tables are higher than the fire resistance ratings obtained by the method described above and apply directly only to constructions which conform in all essential details to the descriptions given. They may also be used as a basis for judgement on the part of the authority having jurisdiction in assigning ratings for similar constructions.

2.3.10 The notes appended to Tables 2.3.8 and 2.3.9 provide the available pertinent evidence as to the assemblies which were tested. Attention is drawn particularly to the working stresses which were stated to be 18,000 psi. It is recognized that current practice is based on improved steels and correspondingly higher working stresses.

There is test evidence that steels in common use will retain the same proportion of their original yield and ultimate strengths when heated to temperatures up to 1200°F. Since it is not known what the ratio of working stress to yield stress was for the tests on which Tables 2.3.8 and 2.3.9 were based it is not possible to say with certainty that other steels stressed in accordance with current practice will provide the same fire endurance as those tested. Consideration must be given to this before applying the ratings shown to other steels and working stresses. Similar consideration should be given to this point in test evidence from other sources.

2.3.11 Ratings derived in accordance with the provisions of Tables 2.3.1 to 2.3.7 may be assumed to apply regardless of the type of steel, provided the assembly is designed in accordance with the requirements of the National Building Code.

2.3.12 Where a beam is included with an open web steel joist or similar construction and is protected by the same continuous ceiling, the beam may be assumed to have at least the Fire Resistance Rating assigned to the rest of the assembly.

This may be assumed to apply in the case of ratings given in this Supplement and to ratings assigned on the basis of test evidence, subject to the reservations as to steel quality and steel stresses noted in Clause 2.3.10 and provided the construction to which the beam is related is a normal one and does not derive any unusual load carrying capacity from the floor or slab above.

TABLE 2.3.1

Time Assigned to Wallboard Membranes

Description of Finish	Time Assigned to Membrane in Minutes
(i) ½ in. Fibreboard	5
(ii) ⅜ in. Douglas Fir Plywood phenolic bonded	5
(iii) ½ in. Douglas Fir Plywood phenolic bonded	10
(iv) ⅝ in. Douglas Fir Plywood phenolic bonded	15
(v) ⅜ in. Gypsum Wallboard	10
(vi) ½ in. Gypsum Wallboard	15
(vii) ⅝ in. Gypsum Wallboard	30
(viii) Double ⅜ in. Gypsum Wallboard	25
(ix) ½ + ⅜ in. Gypsum Wallboard	35
(x) Double ½ in. Gypsum Wallboard	50[(1)]
(xi) 3/16 in. Asb. Cem. + ⅜ in. Gypsum Wallboard	40[(2)]
(xii) 3/16 in. Asb. Cem. + ½ in. Gypsum Wallboard	50[(2)]
(xiii) Composite ⅛ in. Asb. Cem. 7/16 in. Fibreboard	20

[(1)]No. 16 s.w.g. 1 in. sq. wire mesh must be fastened between the two sheets of wallboard.
[(2)]Values shown apply to walls only.

TABLE 2.3.2

Time Assigned to Plaster Membranes

		Plaster Thickness in inches	Finish Material: a. Portland Cement — Sand or Lime — Sand	b. Portland Cement — Sand and asbestos fibre (3 lb/bag cement)	c. Gypsum — Sand	d. Gypsum Wood Fibred	e. Gypsum Perlite or Gypsum — Vermiculite
			Time Assigned to Membrane in Minutes				
Supporting Material	(i) Wood Lath	½	5	10	20	20	—
	(ii) ½ in. Fibreboard	½	—	—	20	20	—
	(iii) ⅜ in. Gypsum Lath	½	—	—	35	35	55
	(iv) ⅜ in. Gypsum Lath	⅝	—	—	40	40	65
	(v) ⅜ in. Gypsum Lath	¾	—	—	50	50	80(1)
	(vi) Metal Lath	¾	20	35	50	50	80(1)
	(vii) Metal Lath	⅞	25	40	60	65	80(1)
	(viii) Metal Lath	1	30	50	80	80	80(1)

Plaster and supporting material to be in accordance with CSA A82.30—1953, "Specifications for Gypsum Plastering, Interior Furring and Lathing".

(1) The values shown for these membranes have been limited to 80 min. because the fire resistance rating derived from these tables must not exceed 1½ hr.

(2) For mixture for portland cement sand-plaster see Clause 1.5.1.

TABLE 2.3.3

Time Assigned for Contribution of Wood or Light Steel Frame

Description of Frame	Time Assigned to Frame in Minutes
(i) Wood Stud Walls	20
(ii) Steel Stud Walls	10
(iii) Wood Joist Floors and Roofs	10
(iv) Open Web Steel Joist Floors and Roofs	10

TABLE 2.3.4

Time Assigned for Additional Protection

Description of Additional Protection	Fire Resistance Period
(i) Add to the Fire Resistance Rating of wood stud walls if the spaces between the studs are filled with mineral wool batts complying with the provisions of CSA A101–1952, Specification for Mineral Wool Thermal Building Insulation and weighing not less than ¼ lb/per sq. ft. of wall surface.	15
(ii) Add to Fire Resistance Rating of plaster on gypsum lath ceilings if 1 in. square 20 gauge wire mesh, or 16 gauge diagonal wire reinforcing at 10 in. o.c. is placed between lath and plaster.	30
(iii) Add to Fire Resistance Rating of plaster on gypsum lath ceilings if 3 in. wide metal lath strips are placed over joints between lath and plaster.	10
(iv) Add to Fire Resistance Rating of ½ in. plaster on gypsum lath ceilings (Table 2.3.1 entries iii, iv and v) if supports are at 12 in. o.c.	10

* * *

TABLE 2.3.5

Membrane on Exterior Face of Wood or Light Steel Stud Walls

Sheathing (a)	Building paper (b)	Exterior Finish (c)
⅝ in. t & g lumber		Lumber siding
5/16 in. exterior grade plywood	Building paper	wood shingles and shakes
½ in. gypsum wallboard		¼ in. plywood exterior grade
		¼ in. hardboard
		metal siding
		stucco on metal lath
		masonry veneer

Exterior membrane may be any combination of (a), (b) and (c) or ⅜ in. exterior grade plywood without sheathing.

TABLE 2.3.6

Flooring over Wood, Light Gauge Steel Members, or Open Web Steel Joists

Finish Flooring (a)	Sub Floor (b)	Structure (c)
(1) Hardwood or softwood flooring on building paper (2) Flexible flooring on 3/8 in. plywood on building paper (3) Ceramic tile on 1¼ in. mortar bed	½ in. plywood or 11/16 in. t & g softwood	Wood joists or light steel joists
(4) Not required with concrete sub floor	2 in. reinforced concrete or 2 in. concrete on metal lath or formed steel sheet or 1½ in. reinforced gypsum-fibre concrete on ½ in. gypsum wallboard	Light steel joists

Floor construction may be a combination of (a), (b) and (c).

* * *

TABLE 2.3.7

Minimum Fastening of Wallboard or Lath to Wood Frame

Surface	Minimum Nail Sizes	Maximum Spacing
(i) Gypsum lath	Ceiling 1½ in. 13 gauge nails 3/8 in. head Wall 1¼ in. 13 gauge nails 19/64 in. head	4 in. o.c. 5 in. o.c.
(ii) Metal lath	Ceiling 1½ in. 10 gauge nails 7/16 in. head Wall 1 in. large head asphalt roofing nails	6 in. o.c. 7 in. o.c.
(iii) Gypsum wallboard	Ceiling 1½ in. 13 gauge nails 7/32 in. head Wall 1½ in. 13 gauge nails 7/32 in. head	6 in. o.c. 8 in. o.c.
(iv) Fibreboard lath	Ceiling 1¼ in. 13 gauge nails 19/64 in. head Wall 1¼ in. 13 gauge nails 19/64 in. head	4½ in. o.c. 4½ in. o.c.

Note to Table 2.3.7 — Fastening of these materials to wood and metal frame construction to be in all other respects in accordance with CSA A82.30, Specification for Gypsum Plastering, Interior Furring and Lathing.

TABLE 2.3.8

Fire Resistance Rating of Open Web Steel Joist Floors and Roofs

Type of Construction	Top Slab or Floor	Ceiling: Perlite or Vermiculite Plaster on ⅜-inch Perforated Gypsum Lath (d)				Fire Resistance Rating
		Spacing of ¾ in. (c) Furring Channels	Plaster Mix (a)	Plaster Thickness (in.) (b)	Plaster Reinforcement	
Steel(h) Joist Floors	2-in. portland cement concrete slab reinforced by 6 in. x 6 in., 8 x 8 ga. wire mesh over ribbed metal lath supported by bar joists spaced 24 in. on centres	16 in.	(i)	½	14-gauge diagonal wire(f) 11.3 in. o.c.	2 hr.
			(i)	½	1-in. 20-gauge(g) hex. wire mesh	3 hr.
		12 in.	(ii)	⅝	14-gauge(f) diagonal wire 10 o.c.	3 hr.
			(ii)	1	1-in. 20-gauge(g) hex. wire mesh	4 hr.
		12 in.	(ii)	⅝	Extra clips passed through lath along each channel at 5⅓ in. o.c.(e)	3 hr.

NOTES TO TABLE 2.3.8

(a) Plaster Mix
- (i) 100 lb. gypsum plaster to 2½ cu. ft. aggregate.
- (ii) Scratch coat — 100 lb. gypsum plaster to 2 cu. ft. aggregate. Brown coat — 100 lb. gypsum plaster to 3 cu. ft. aggregate.

(b) Thickness includes finish coat and is measured from face of lath.
(c) Furring channels — ¾ in. steel channels fastened to joists by double strand wire ties.
(d) Gypsum lath — ⅜ in. perforated gypsum lath secured to furring channels by 14 gauge galvanized wire clips tied to the furring channels at 12 or 16 in. o.c. depending on the spacing of the latter, and under the lath so as to provide continuous support for the lath.
(e) Extra clips — Additional looped wire clips 14 gauge galvanized wire passed through the lath and tied to the furring channels to provide extra support.
(f) Diagonal wire — 14 gauge galvanized wire placed diagonally under the lath, tied to the wire clips at the point of junction with the furring channels.
(g) Galvanized wire mesh — 1 in. mesh galvanized 20 gauge wire fastened under the lath and tied back to the furring channels at 12 or 16 in. o.c. depending on the spacing of the latter.
(h) The design tensile stress in the open web steel joists of the tested assemblies did not exceed 18,000 psi.

The ratings in Table 2.3.8 and the notes above are taken from
Fire Endurance of Open Web Steel Joist Floors with Concrete Slabs and Gypsum Ceilings by James V. Ryan and E. W. Bender.
Building Materials and Structures Report No. 141
National Bureau of Standards, Washington, 1954.

TABLE 2.3.9

Fire Resistance Rating of Open Web Steel Joist Assemblies for Roofs and Floors

Type of Construction	Top Slab or Floor	Ceiling or Soffit Protection on Metal Lath	Fire Resistance Rating
Steel Joist Floors	2¼ in. reinforced concrete or 2 in. reinforced gypsum tile with ¼ in. mortar finish 1 in. by 2 in. pine flooring on 1 in. by 2 in. nailing strips set ½ in. into 2 in. concrete on rib lath or 1 in. portland cement mortar finish on 2 in. concrete on rib lath	¾ in. gypsum sand plaster 1:2, 1:3	2 hours
	2 in. reinforced concrete or 2 in. reinforced gypsum tile with ¼ in. mortar finish	¾ in. gypsum-vermiculite or gypsum-perlite plaster scratch coat 1 bag (100 lb.) gypsum to 2 cu. ft. vermiculite or perlite, brown coat 1 bag (100 lb.) gypsum to 3 cu. ft. vermiculite or perlite	2 hours
	2½ in. reinforced concrete or 2 in. reinforced gypsum tile with ½ in. mortar finish	¾ in. gypsum-vermiculite or gypsum-perlite plaster scratch coat 1 bag (100 lb.) gypsum to 2 cu. ft. vermiculite or perlite, brown coat 1 bag (100 lb.) gypsum to 3 cu. ft. vermiculite or perlite	3 hours
	2½ in. reinforced concrete or 2 in. reinforced gypsum tile with ½ in. mortar finish	1 in. gypsum-vermiculite or gypsum-perlite plaster scratch coat 1 bag (100 lb.) gypsum to 2 cu. ft. vermiculite or perlite, brown coat 1 bag (100 lb.) gypsum to 3 cu. ft. vermiculite or perlite	4 hours
	2 in. reinforced concrete or 2 in. precast reinforced portland cement concrete or gypsum slabs the precast slabs to be finished with top coating of mortar ¼ in. thick	2 in. precast reinforced gypsum tile, well anchored into beams with metal ties or clips and covered with ½ in. 1:3 gypsum sand plaster	4 hours

NOTES TO TABLE 2.3.9

The ratings given in Table 2.3.9 apply to the floor constructions indicated when supported on open-web steel joists, pressed steel joists, or rolled steel beams, which are not stressed beyond 18,000 psi in flexure for open-web or pressed or light rolled steel joists and 20,000 psi for American Standard or heavier rolled beams and are bridged in accordance with accepted requirements. The ratio of weight of portland cement to that of fine and coarse aggregates combined for the floor slab shall not be less than 1:6½. The plaster for the ceiling shall be applied on metal lath (expanded metal, woven wire, or paper-backed wire lath) of appropriate weight for the spacing of the supports. The lath shall be tied to the supports to give the equivalent of single No. 18 gauge steel-wire ties on 5 in. centres. The thickness of plaster shall be the depth from the back side of flat lath and to the back of the flat portion of ribbed lath.

The slab thicknesses are measured from the top flange of the joists and unless otherwise indicated are for monolithic poured construction. To obtain the fire-resistance ratings herein given, the average thickness of the slabs cast in place should be ¼ in. greater than at the joists. This greater average thickness usually results from the sag of metal lath forming or the placing of the more rigid forms under the top flange of the joists.

The ratings in Table 2.3.9 and the notes above are taken directly from
Fire Resistance Classifications of Building Construction
Building Materials and Structures Report BMS92
National Bureau of Standards, Washington.
The reservations expressed in Subsection 2.3.10 regarding the use of improved steels and higher working stresses apply equally to the constructions described in this Table.

2.4 Solid Wood Walls, Floors and Roofs

2.4.1 The minimum thickness of solid wood walls, floors and roofs complying with the requirements of the National Building Code as described in Clause 1.1.1 for fire resistance ratings from ½ hour to 1½ hours is shown in Table 2.4.1.

2.4.2 The ratings apply to walls that are either load bearing or non load bearing as noted and to floors and roofs that are load bearing.

2.4.3 The assemblies described with the exception of item (i) . (b) Table 2.4.1 are of 2 in nominal members laid side by side and fastened together by 4 in. common wire nails 6 ga.(1) (0.192 in. diameter) at 16 in. o.c. staggered top and bottom. The 2⅝ in. floor described in item (i) . (b) is of 3 in. by 8 in. nominal planks, either tongued or grooved or with ¾ in. by 1½ in. splines set in the joints, fastened together by 3½ in. common wire nails 7 gauge(1) (0.176 in. diameter) at 16 in. o.c.

2.4.4 The fire resistance rating of the assemblies described in Table 2.4.1 may be increased by 15 minutes, if one of the following is applied on the fire exposed side

(a) ½ in. gypsum wallboard
(b) ¾ in. gypsum-sand plaster or metal lath
(c) ½ in. gypsum-sand plaster on ⅜ in. gypsum lath.

Plaster and wallboard should be as specified in the National Building Code. Fastening of the plaster to the wood structure should be at least as described in Section 2.3.

2.4.5 Supplementary ratings based on individual tests are included in Table 2.4.2. These are reports of tests carried out in accordance with the Standard Method of Fire Test required by the National Building Code. The ratings given apply to constructions that conform in all essential details with the descriptions given. They may also be used as a basis for judgement by the authority having jurisdiction in assigning ratings for similar constructions.

(1)Nail gauges refer to CSA G111–1952, Specifications for Wire Nail Spikes and Staples.

TABLE 2.4.1

Minimum Thickness of Solid Wood Walls, Floors or Roofs

	Minimum Thickness in Inches for Fire Resistance Rating of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
(i) Solid wood floor with building paper and finish flooring on top							
(a) Mill floor	3⅝	3⅝	5½	7½	—	—	—
(b) Splined or tongued and grooved	2⅝	2⅝	—	—	—	—	—
(ii) Solid wood walls							
(a) Vertical plank load bearing	3⅝	3⅝	5½	7½	—	—	—
(b) Horizontal plank non-load bearing	3⅝	3⅝	3⅝	5½	—	—	—

TABLE 2.4.2

Fire Resistance Ratings on Non Bearing Built Up Solid Wood Partitions

Construction Details	Overall Thickness (In.)	Fire Resistance Rating (Hr.)
Solid panels of ¾ in. wood boards 2½ to 6 in. wide grooved and joined with wood splines, nailed together, boards placed vertically with staggered joints. 3 boards thick.	2¼	½
Solid panels with 3/16 in. plywood facings* glued to 1¾ in. solid wood core of glued T & G construction for both sides and ends of core pieces with T & G rails in the core about 2½ ft. apart.	2⅛	1

*Ratings for plywood faced panel are based on phenolic resin glue being used for gluing facings to wood frames. If other types of glue are used for this purpose, the ratings can be taken to apply if the facings are nailed to the frames in addition to being glued.

The ratings and notes in Table 2.4.2 are taken from
Fire Resistance Classifications of Building Constructions
Building Materials and Structures Report BMS 92
National Bureau of Standards, Washington, 1942.

2.5 Solid Plaster Partitions

2.5.1 The minimum thickness of solid plaster partitions complying with the requirements of the National Building Code as described in Subsection 1.1.1 for fire resistance ratings from ½ hour to 4 hours is shown in Table 2.5.1.

2.5.2 The ratings obtained from Table 2.5.1 are conditional upon the following:

(a) The partitions are non load bearing.

(b) The plaster described is applied on both sides of expanded metal lath or welded woven wire fabric.

(c) The lath is supported on ¾ in. vertical light steel channel studs at not more than 24 in. o.c.

2.5.3 The limiting dimension of 2 in. in Table 2.5.1 is determined by the provisions of CSA A82.30 that do not permit solid plaster partitions to be less than 2 in. in thickness.

TABLE 2.5.1

Minimum Thickness of Solid Plaster Partitions
(Non Load Bearing)

	Minimum Thickness in Inches for Fire Resistance Ratings						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
Plaster on Metal Lath							
(i) Portland cement-sand, Portland cement-lime-sand	2	—	—	—	—	—	—
(ii) Gypsum-sand	2	2	2½	—	—	—	—
(iii) Gypsum-vermiculite, Gypsum-perlite, Portland cement-vermiculite, Portland cement-perlite	2	2	2	2¼	2½	3¼	4

(1)For mixture for portland cement sand-plaster see Clause 1.5.1.

2.6 Protected Steel Columns

2.6.1 The minimum thickness of protective covering to steel columns complying with the requirements of the National Building Code as described in Subsection 1.1.1 is shown in Tables 2.6.1 and 2.6.2 for fire resistance ratings from ½ hour to 4 hours.

2.6.2 For hollow unit masonry column protection the thickness shown is equivalent thickness as described in Section 1.4.

2.6.3 Concrete is referred to as Type S, N or L depending on the nature of the aggregate used. This is described in detail in Section 1.3.

2.6.4 The addition of plaster to masonry and monolithic concrete column protection may be taken into account in assigning fire resistance ratings as described in Section 1.5.

2.6.5 As the size of a column increases the fire endurance becomes greater for the same thickness of cover. The fire resistance ratings obtained from Tables 2.6.1 and 2.6.2 apply to columns of the minimum size permitted by the structural requirements of the National Building Code. Increased values of fire resistance may be obtained for larger columns but these should be justified by test.

2.6.6 Where there is a note in Table 2.6.1 "column spaces filled" this means that the space between the unit masonry protective covering and the web or flange of the column is filled with concrete or cement mortar or a mixture of cement mortar and broken bricks.

TABLE 2.6.1

Minimum Thickness of Concrete or Masonry Protection to Steel Columns

Description of Cover	Minimum Thickness of Cover in Inches for Fire Resistance Rating of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
Monolithic Concrete							
(i) Type S Concrete[1] (Column spaces filled)	1	1	1	1	1½	2½	3½
(ii) Type N & L Concrete[1] (Column spaces filled)	1	1	1	1	1¼	2	3
Concrete Masonry Units[5] or Precast Reinforced Concrete Units							
(iii) Type S Concrete (Column spaces not filled)	2	2	2	2	2½	3½	4½
(iv) Type N and L Concrete (Column spaces not filled)	2	2	2	2	2	3	4
(v) Clay or Shale Brick[2] (Column spaces filled)	2	2	2	2	2	2½	3
(vi) Clay or Shale Brick[2] (Column spaces not filled)	2	2	2	2	2	3	4
(vii) Gypsum Partition Tile or Block[3] (Column spaces not filled)	2	2	2	2	2	3	4
(viii) Hollow Clay Tile[4] (Column spaces filled)	2 nom[6]	2 nom[6]	2 nom[6]	2 nom[6]	—[7]	—[7]	—[7]
(ix) Hollow Clay Tile[4] (Column spaces not filled)	2 nom[6]	2 nom[6]	2 nom[6]	—	—	—	—

[1]Applies to cast in place concrete reinforced by No. 5 s.w.g. wire wrapped around column spirally at 8 in. o.c. or 4 in. No. 16 s.w.g. wire mesh.

[2]Brick cover 3 in. thick or less reinforced with 13 s.w.g. wire or ⅜ in. No. 18 s.w.g. wire mesh laid in every second course.

[3]Gypsum partition tile or block laid in gypsum-sand mortar with ⅜ in. No. 18 s.w.g. wire mesh laid in every horizontal joint and lapped at corners. Gypsum partition tile is wood fibred gypsum in accordance with CSA A82.25–1950, Specification for Gypsum Partition Tile or Block.

[4]Hollow clay tiles laid in masonry mortar with ⅜ in. No. 18 s.w.g. wire mesh laid in every horizontal joint and lapped at corners.

[5]Concrete masonry reinforced with No. 5 s.w.g. wire or ⅜ in. No. 18 s.w.g. wire mesh, laid in every second course.

[6]2 in. nom. is 2 in. ± 3 per cent with cores to the extent permitted by CSA A82.5–1954, Specification for Structural Clay Non Load Bearing Tile.

[7]2 in. nom. hollow clay tile, with ⅜ in. No. 18 s.w.g. wire mesh laid in every horizontal joint and covered with ¾ in. gypsum-sand plaster, limestone concrete fill in column spaces, has 4 hours fire resistance rating.

TABLE 2.6.2
Minimum Thickness of Plaster Protection to Steel Columns

Description	Minimum Thickness of Cover in Inches for Fire Resistance Rating of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
(i) Gypsum sand plaster on ⅜ in. gypsum lath[1]	½	½	½	¾	—	—	—
(ii) Gypsum perlite or vermiculite plaster on ⅜ in. gypsum lath[1]	½	½	½	¾	1	—	—
(iii) Gypsum perlite or vermiculite plaster on ½ in. gypsum lath[1]	½	½	½	¾	1[2]	1½[2]	2[2]
(iv) Gypsum perlite or vermiculite plaster on double ½ in. gypsum lath[1]	½	½	½	¾	1[2]	1[2]	1½[2]
(v) Portland cement sand plaster on metal lath[3]	1	1	1	—	—	—	—
(vi) Gypsum sand plaster on metal lath[3]	¾	¾	¾	—	—	—	—
(vii) Gypsum perlite or vermiculite plaster on metal lath[3]	¾	¾	¾	1	1	1½	2[2]

(1)Lath held in place by 18 s.w.g. wire wrapped around lath at 18 in. o.c.
(2)Wire mesh 2 in. No. 16 s.w.g. placed midway between inner and outer faces of plaster.
(3)Expanded metal lath 3.4 lb/sq. yard fastened to ⅜ in. by ¾ in. steel channels held in vertical position around column by 18 gauge wire ties.
(4)For mixture for portland cement sand-plaster see Clause 1.5.1.

NOTE: Thickness of plaster is measured from the face of gypsum lath and from the back of metal lath.
Plaster and supporting materials to be in accordance with CSA A82.30, "Specification for Gypsum Plastering, Interior Furring and Lathing".

2.7 Individually Protected Steel Beams

2.7.1 The minimum thickness of protective covering to steel beams exposed to fire on three sides complying with the requirements of the National Building Code as described in Subsection 1.1.1 for fire resistance ratings from ½ hour to 4 hours is shown in Table 2.7.1.

2.7.2 The first two entries in Table 2.7.1 (concrete protection) are derived directly from fire tests on beams. The remainder of the entries are the same as the values for column protection. The fire resistance ratings for the latter entries are conservative, because a beam is exposed to fire on three sides while a column is exposed on four sides. They do represent, however, the best values that can be assigned at present.

2.7.3 Concrete is referred to as Type S, N or L depending on the nature of the aggregate used. This is described in detail in Section 1.3.

2.7.4 The addition of plaster to concrete or masonry beam protection may be taken into account in assigning fire resistance ratings as described in Section 1.5.

2.7.5 The fire resistance of protective cover to steel beams depends on the means used to hold the protection in place. Because of the importance of this factor no ratings have been assigned in Table 2.7.1 to masonry units used as protective cover to steel beams. These however may be determined on the basis of comparison with column protection at the discretion of the authority having jurisdiction if satisfactory means of fastening can be provided.

2.7.6 A steel beam or steel joist assembly that is entirely above a horizontal ceiling membrane will be protected from fire below the membrane and will resist structural collapse for a period equal to the fire resistance rating derived from Section 2.3. The support for this membrane must be equivalent to that described in Section 2.3. The rating on this basis may not exceed 1½ hours. (See also Subsection 2.3.12.)

TABLE 2.7.1
Minimum Thickness of Cover to Individually Protected Steel Beams

Description of Cover	Minimum Thickness of Cover in Inches for Fire Resistance Ratings of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
(i) Type S concrete[(1)] (beam spaces filled solid)	1	1	1	1	1¼	2	2½
(ii) Type N & L concrete[(1)] (beam spaces filled solid)	1	1	1	1	1	1½	2
(iii) Gypsum sand plaster on ⅜ in. gypsum lath[(3)]	½	½	½	¾	—	—	—
(iv) Gypsum perlite or vermiculite plaster on ⅜ in. gypsum lath[(3)]	½	½	½	¾	1[(2)]	—	—
(v) Gypsum perlite or gypsum vermiculite on ½ in. gypsum lath[(3)]	½	½	½	¾	1[(2)]	1½[(2)]	2[(2)]
(vi) Gypsum perlite or vermiculite plaster on double ½ in. gypsum lath[(3)]	½	½	½	¾	1[(2)]	1[(2)]	1½[(2)]
(vii) Portland cement sand on metal lath[(4)]	1	1	1	—	—	—	—
(viii) Gypsum sand on metal lath[(4)]	¾	¾	¾	—	—	—	—
(ix) Gypsum perlite or gypsum vermiculite on metal lath[(4)]	¾	¾	¾	1	1	1½	2[(2)]

[(1)]Applies to cast in place concrete reinforced by No. 5 s.w.g. wire at 8 in. o.c. or 4 in. No. 16 s.w.g. wire mesh.
[(2)]Wire mesh No. 16 s.w.g. at 2 in. o.c. placed midway between inner and outer faces of plaster.
[(3)]Lath held in place by 18 s.w.g. wire wrapped around the gypsum lath at 18 in. o.c.
[(4)]Expanded metal lath 3.4 lb/sq. yard fastened to ⅜ in. × ¾ in. steel channels held in position by 18 gauge wire ties.
[(5)]For mixture for portland cement sand-plaster see Clause 1.5.1.

NOTE: Thickness of plaster is measured from the face of gypsum lath and from the back of metal lath.
Plaster and supporting materials to be in accordance with CSA A82.30, "Specification for Gypsum Plastering, Interior Furring and Lathing".

2.8 Reinforced Concrete Columns

2.8.1 The minimum overall dimension and minimum cover to steel reinforcement in reinforced concrete columns complying with the requirements of the National Building Code as described in Subsection 1.1.1 are shown in Tables 2.8.1 and 2.8.2 for Fire Resistance Ratings from ½ hour to 4 hours.

2.8.2 The ratings shown are for columns loaded to the safe design loads specified in the National Building Code. Any increase in the applied load may result in a decrease in the fire endurance.

2.8.3 Concrete is referred to as Type S, N or L depending on the nature of the aggregate used. This is described in detail in Section 1.3.

2.8.4 The addition of plaster to the concrete column may be taken into account in determining cover to steel reinforcement as described in Section 1.5. The addition of plaster does not however justify any decrease in the minimum column sizes shown.

2.8.5 The values in Tables 2.8.1 and 2.8.2 may be applied to short reinforced concrete walls or portions of walls (see Subsection 2.1.6).

2.8.6 The Fire Resistance Rating of a reinforced concrete column that is built into a masonry or concrete wall so that not more than one face may be exposed to the possibility of fire at one time is determined on the basis of cover to reinforcing steel alone (see Table 2.8.2). In order to meet this condition the wall must be of the minimum dimension provided in Section 2.1 for the fire resistance period required.

TABLE 2.8.1

Minimum Dimensions of Reinforced Concrete Columns

	Minimum Dimension of Column in Inches for Fire Resistance Rating of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
Type S, N or L Concrete	6	6	6	8	10	12	16

TABLE 2.8.2

Minimum Cover to Reinforcement in Concrete Columns

	Minimum Cover to Reinforcement in Inches for Fire Resistance Rating of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
Type S Concrete	1½	1½	1½	1½	2 1½*	2½ 1½*	2½ 2*
Type N and L Concrete	1½	1½	1½	1½	1½	1½	1½

*Reinforcing steel enclosed in wire mesh or steel ties.

2.9 Reinforced Concrete Beams

2.9.1 The minimum thickness of cover to steel reinforcement in reinforced concrete beams complying with the requirements of the National Building Code as described in Clause 1.1.1 is shown in Table 2.9.1 for fire resistance ratings from ½ hour to 4 hours.

2.9.2 The Fire Resistance Ratings derived from Table 2.9.1 may be applied to a concrete beam or to concrete joist floor construction as described in Part 4.5 of the National Building Code provided the width of the beam or joist is not less than 4 in.

No rating over 2 hours shall be assigned on the basis of Table 2.9.1 to a beam or joist where the average width of the part that projects below the slab is less than 5½ in. and no rating over 3 hours shall be assigned where the average width of the part that projects below the slab is less than 6½ in.

2.9.3 For purposes of these ratings, a beam may be either independent of or integral, with a floor or roof slab assembly.

2.9.4 Attention is drawn to the provisions of the National Building Code that require minimum cover to steel reinforcement to be 1½ in. in beams and ¾ in. in joists and to the limitations on concrete joist floors as follows:

(a) the joists shall be not farther apart than 30 in. face to face.

(b) the ribs shall be not less than 4 in. wide and of a depth not more than 3 times the width.

2.9.5 Where the upper extension or top flange of a joist or Tee-beam in a floor assembly contributes wholly or partly to the thickness of the slab above, the total thickness at any point must be not less than the minimum thickness described in Table 2.2.1 for the Fire Resistance Rating required.

TABLE 2.9.1

Minimum Cover to Steel Reinforcement in Reinforced Concrete Beams

	Minimum Thickness of Concrete Cover in Inches for Fire Resistance Ratings of						
	½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
Type S, N or L Concrete	¾	¾	¾	1	1	1½	2

2.10 Prestressed Concrete Beams

2.10.1 The minimum cross sectional area and minimum thickness of cover to steel reinforcement in prestressed concrete beams complying with the requirements of the National Building Code as described in Subsection 1.1.1 for Fire Resistance Ratings from ½ hour to 4 hours are shown in Table 2.10.1.

2.10.2 These ratings apply to a beam that is either independent of or integral with a floor or roof slab assembly. Minimum thickness of slab and minimum cover to steel reinforcement in prestressed concrete slabs are shown in Section 2.2.

TABLE 2.10.1

Minimum Area and Thickness of Cover to Steel Reinforcement in Prestressed Concrete Beams

	Area of Beam in sq. inches	Minimum Thickness of Cover in Inches for Fire Resistance Ratings of						
		½ hr.	¾ hr.	1 hr.	1½ hr.	2 hr.	3 hr.	4 hr.
Type S or N Concrete	40–150	1	1½	2	2½	—	—	—
	150–300	1	1	1½	1¾	2½	—	—
	over 300	1	1	1½	1½	2	3	4
Type L Concrete	over 150	1	1	1	1½	2	3	4

NOTE: Where the thickness of concrete cover required for prestressed concrete is 2½ in. or more, a light mesh reinforcement should be incorporated in the beams to retain the concrete in position around the tendons. This mesh reinforcement should have a concrete cover of 1 in.

PART 3 - FLAME SPREAD RATINGS

3.1 Interior Finish Materials

3.1.1 Table 3.1.1 shows flame spread values for combinations of some common interior finish materials and applied surface coatings complying with the requirements of the National Building Code as described in Subsection 1.1.1. The values are based on all the evidence available at present. Materials not included have been omitted because of lack of test evidence or because of inability to classify or describe the material in general terms for the purpose of assigning ratings.

3.1.2 The ratings are shown in groups corresponding to the provisions of the National Building Code, namely over 150, 150 and less but more than 75, 75 and less but more than 25, and 25 and less. The ratings apply to materials falling within the general categories indicated. More specific test evidence may be used when available.

3.1.3 Thin surface coatings can significantly modify flame spread characteristics either upward or downward. Table 3.1.1 includes a number of thin coatings that increase the flame spread rating of the base material, so that these may be considered where more precise control over flame spread hazard is desired.

3.1.4 Information on flame spread ratings of proprietary materials and fire retardant treatments that cannot be described in sufficient detail to ensure reproducibility is available through the listing and labelling service of Underwriters' Laboratories of Canada. A summary of all available published flame spread test results has been prepared by the Division of Building Research and is available as Technical Paper No. 170 (See 1.1.5).

TABLE 3.1.1

Flame Spread Ratings for Combinations of Common Interior Finish Materials and Surface Coatings

SYMBOLS USED X = over 150 150 = 150 and less but more than 75 75 = 75 and less but more than 25 25 = 25 and less	SURFACE COATING	Unfinished	Pigmented Paint	Varnish	Shellac or Lacquer	Wax or Oil	Printed Wallpaper One Layer	Jute Fibre, Burlap
BASE MATERIAL		a	b	c	d	e	f	g
Fibreboard Low Density Board	(i)	X	X	X	X	X	X	X
Cork	(ii)	X	X	X	X	X		
Linoleum	(iii)	X	X	X	X	X		
Hardboard to CGSB 11-GP-3	(iv)	150	150[1]	150[1]	X	X	150	X
Particle Board to CGSB 11-GP-1	(v)	150	150[1]	150[1]	X	X	150	X
Douglas Fir Plywood Exterior Grade[3]	(vi)	150	150[1]	150[1]	X	X	150	X
Dressed Wood	(vii)	150	150[1]	150[1]	X	X	150	X
Gypsum Plaster or Wallboard	(viii)	25	25[1]	25[1]	25[1]	25	25[2]	150
Metal Sheet	(ix)	25	25[1]	25[1]	25[1]	25	25[2]	150
Masonry Surfaces incl. Concrete and Stucco	(x)	25	25[1]	25[1]	25[1]	25	25[2]	150
Asbestos-Cement	(xi)	25	25[1]	25[1]	25[1]	25	25[2]	150

(CGSB = Canadian Government Specifications Board.)

[1]The flame spread values apply to normal paint thicknesses, not exceeding .010 ins.

[2]Five layers of wallpaper on surfaces of low flame spread rating may increase the rating to 75.

[3]Other plywoods, without special treatment, will have ratings greater or less than 150 depending on the adhesive, the wood species, and the thickness of face veneer. Well bonded plywoods, particularly those with phenolic adhesives with face veneers of substantial thickness, are likely to be 150 or less. Open grain low density woods may give higher ratings.

INDEX

FIRE AND SOUND RESISTANCE

TABLE I

A-1. FIRE AND SOUND RESISTANCE OF WALLS

Type of Wall	Description	Finish on each side See Note 1	Fire Resistance (Note 4)	Sound Rating (See Note 2)
1 Brick	4 in. thick walls of shale, clay, concrete or sand lime brick—at least 75 per cent solid	None	1 hr.	II
2 Brick	4 in. thick walls of clay or shale brick	A	2 hr.	II
3 Brick	6 in. thick walls of clay or shale brick—at least 80% solid	A	4 hr.	II
4 Brick	8 in. thick walls—same as in 1	None	4 hr.	I
5 Hollow Tile	8 in. thick clay or shale tile with min. face shell thickness of ⅝ in., two cells in wall thickness	None	1 hr.	III
6 Hollow Tile	Same as above, and at least 37% solid	A	2 hr.	II
7 Hollow Tile	Same as above, and at least 47% solid	A	3 hr.	II
8 Hollow Concrete Block	4 in. thick with at least 1 in. face shell with natural stone, gravel or lightweight aggregate with a low proportion of quartz with a total wall weight less than 40 lb./sq. ft.	A	1 hr.	III
9 Hollow Concrete Block	Same as above but with a total wall weight of 40 lb./sq. ft. or more	A	1 hr.	II
10 Hollow Concrete Block	6" hollow concrete block of expanded slag, expanded clay or shale aggregate concrete, with finish applied over furring strips. Units at least 48% solid.	H (at least one side)	1 hr.	II
11 Hollow Concrete Block	Same as above, but with units at least 59% solid	H (at least one side)	1½ hr.	II
12 Hollow Concrete Block	6 in. hollow concrete block of limestone aggregate units at least 63% solid	None	1 hr.	II
13 Hollow Concrete Block	8 in. thick with at least 1 in. face shell, weighing at least 40 lb./sq. ft. made of natural stone or gravel aggregate with a low proportion of quartz	None	1 hr.	II
14 Hollow Concrete Block	Same as above but with lightweight aggregate, units weighing less than 40 lb./sq. ft.	None	1 hr.	III
15 Hollow Concrete Block	8 in thick made with expanded slag aggregate—units at least 65% solid	A, H, N	3 hr.	II
16 Hollow Concrete Block	8 in. thick made with air cooled slag or cinder aggregate. Units at least 66% solid	A, H, N	2 hr.	II
17 Hollow Concrete Block	8 in. thick made with limestone aggregate. Units at least 47% solid	None	1 hr.	II
18 Hollow Concrete Block	Same as above, but with units at least 57% solid	None	1½ hr.	II
19 Hollow Concrete Block	Same as above, but with units at least 66% solid	None	2 hr.	I
20 Reinforced Concrete	4 in. thick made with natural stone, gravel or lightweight aggregate	None	1 hr.	I
21 Natural Stone	8 in thick	None	1 hr.	II

TABLE I (continued)

FIRE AND SOUND RESISTANCE OF WALLS

Type of Wall	Description	Finish on each side See Note 1	Fire Resistance (Note 4)	Sound Rating (See Note 2)
22 Brick Faced	4 in. face brick bonded to 4 in. hollow concrete block or 4 in. hollow clay tile	None	1 hr.	II
23 Cavity Walls	2 wythes of shale, clay, concrete or sand lime brick with 2 in. cavity	None	1 hr.	I
24 Cavity Walls	2 wythes of 4 in. thick hollow clay tile at least 40 per cent solid, or hollow concrete block at least 62 per cent solid provided the maximum load does not exceed 80 psi.	None	1 hr.	I
25 Cavity Walls (Non Load Bearing)	8 in. wall thickness with two-2 in. thick wythes of solid gyp. block—4 in. space; tied together with non-corroding metal ties	Z	3 hr.	II
26 Cavity Walls	Same as above but with 2 in. mineral wool in cavity	Z	3 hr.	I
27 Gypsum Block	3 in. thick hollow gypsum block at least 70 per cent solid.	None	1 hr.	III
28 Gypsum Block	2 in. thick solid gypsum block	None	1 hr.	III
29 Gypsum Block	3 in. thick solid gypsum with acceptable resilient clips on one side to attach metal lath	T on one sideand Z on other side	2 hr.	I
30 Gypsum	5 in. thick solid block	Z	4 hr.	II
31 Wood Stud	Two rows of staggered 2" by 4" studs with 2" by 6" top and bottom plates	B Q	1 hr.	II
32 Wood Stud	Same as above	D F O	1 hr.	I
33 Wood Stud	Same as above but with mineral wool blanket at least 1 in. thick weighing at least 2.2 lb. per cu. ft. threaded between studs or 2 in. mineral wool batts applied between studs on both sides.	I	1 hr.	II
34 Wood Stud	Same as above	J	% hr.	II
35 Wood Stud	Same as above but with at least 2" mineral wool batts between studs on at least one side	K B	1 hr.	II
36 Wood Studs	Single row of 2" by 4" studs	B D G L K F O Q U V W	1 hr.	III
37 Wood Studs	Same as above but with full thick mineral wool batts completely filling the stud spaces	I J	1 hr.	III
38 Plank Wall	2 layers of 2" by 6" fir placed vertically with joints staggered	H	1 hr.	III
39 Steel Stud	Single row of steel studs 16 in. o.c. Non load bearing	U V W	1 hr.	III
40 Steel Stud	Same as above	D P R	1 hr.	II
41 Steel Stud	Same as above but with 2 in. mineral wool in cavity	D P R U V W	1 hr.	I

TABLE 2

FIRE RESISTANCE RATING OF EXTERIOR WOOD STUD WALLS

Type of Wall	Description	Interior Finish (see note 1)	Fire Resistance
1 Wood Stud	2" by 4" studs with mineral wool batts with ⅝ in. T & G sheathing or ½ in. gypsum board sheathing or .. in. plywood sheathing plus building paper and siding stucco or masonry veneer.	D F K	1 hr.
2 Wood Stud	Same as 1 except ⅜ in. plywood siding without sheathing	D F K	1 hr.
3 Wood Stud	Same as 1 with mineral wool batts of at least 1.2 lb. sq. ft. or glass wool at least 0.6 lb. sq. ft.	I	1 hr.
4 Wood Stud	Same as 1	B	% hr.
5 Wood Stud	Same as 3	H	% hr.
6 Wood Stud	Same as 1 but with mineral wool batts weighing at least o.86 lb. sq. ft.	M	% hr.

TABLE 3

FIRE AND SOUND RESISTANCE OF FLOORS

Type of Ceiling	Description	Ceiling Finish (Note 1)	Fire Resistance (Note 4)	Sound Rating	
				Airborne Noise (Note 2)	Impact Noise (Note 3)
1 Concrete Slab	5 in. reinforced concrete having ¾ in. minimum cover over reinforcing steel	None	1 hr.	I	III
2 Concrete Slab	Same as 1 but with 4 in. slab	None	1 hr.	II	III
3 Concrete Slab	3½ in. reinforced concrete with ¾ in. minimum cover over reinforcing steel	None	1 hr.	II	III
4 Concrete Slab	3 in. reinforced concrete with ⅝ in. minimum cover over reinforcing—Limestone aggregate	None	¾ hr.	III	III
5 Concrete Joists	3 in. reinforced concrete (gravel aggregate) on pre cast concrete joists (expanded shale aggregate) with 1 in. minimum cover over reinforcing steel in joists. Two inch wood furring wired to underside of joists to attach ceiling	J	1 hr.	I	II
6 Open Web steel joists	2 in. reinforced concrete on metal lath on open web steel joists with ceiling secured to underside of joists	E	1 hr.	I	II
7 Open Web steel joists	Same as 6, but ceiling secured by metal screws to ¾ in. furring channels or 1¼ in nails to ⅞ in. nailing channels	K	1 hr.	III	III
8 Open Web steel joists	Same as 6, but ceiling secured to ¾ in. furring channels	G	1 hr.	II	III
9 Open Web steel joists	2 in. reinforced concrete on metal lath over open web steel joists with ¾ in. steel channels spaced 12" O.C. secured to bottom of joists with double strand wire ties with ceiling attached with suitable metal clips	A-A	1 hr.	II	II
10 Open Web steel joists	Same as above but with ¾ in. steel channels spaced 16" O.C.	B-B	1 hr.	II	III
11 Heavy Timber	1 in. nominal finish flooring or ⅝ in. phenolic bonded plywood on nominal 6 in. laminated plank deck	None	¾ hr.	—	—
12 Heavy Timber	1 in. nominal finish flooring or ⅝ in. phenolic bonded plywood on nominal 3 in. T and G plank or 4 in. laminated plank deck	None	¾ hr.	—	—
13 Heavy Timber	1 in. nominal finish flooring or ⅝ in. phenolic bonded plywood on 4 in. laminated plank deck treated with fire retardant chemicals or a heavy coating of fire retardant compound on underside	None	1 hr.	—	—
14 Wood Joists	1 in. nominal T & G or ⅝ in. phenolic bonded plywood on 1" by 3" furring strips on asbestos paper weighing at least 14 lb. 100 sq. ft. on ½ in. fibreboard on 1 in. nominal T and G or ⅝ in. phenolic bonded plywood subfloor on wood joist at 16 in. O. C.No nails are to pass through the fibreboard into the subfloor	C, E, K	1 hr.	II	III

TABLE 3 (continued)

FIRE AND SOUND RESISTANCE OF FLOORS

Type of Ceiling	Description	Ceiling Finish (Note 1)	Fire Resistance (Note 4)	Sound Rating	
				Airborne Noise (Note 2)	Impact Noise (Note 3)
15 Wood Joists	Double wood floor of nominal 1 in. T and G subfloor or ⅝ in. phenolic bonded plywood subfloor with asbestos cement paper weighing at least 14 lb./100 sq. ft. between, on wood joists 16 in. O.C.	C, K ("E" with 1⅛ in. barbed roofing nails ⅞ in. head diameter spaced 6 in. O.C.)	1 hr.	III	III
16 Wood Joists	Same as 15	E, D ("I" with 1½" long nails spaced 6" O.C.)	½ hr.	III	III
17 Wood Joists	Nominal 1 in. T & G subfloor or ⅝ in. phenolic bonded plywood subfloor with 2 in. mineral wool insulation on bottom between joists	D, K, S, U, V, X	1 hr.	III	III
18 Wood Joists	Nominal 1 in. T and G lumber or ⅝ in. thick phenolic bonded plywood subflooring on wood joists 16 in. O.C. with ceiling suspended on mild steel hangers with 3 in. mineral wool fill between joists	T	1 hr.	III	III
19 Wood Joists	Nominal 1 in. T and G lumber or ⅝ in. phenolic bonded plywood subfloor on wood joists 16 in. O.C., with metal ceiling supports spaced 18 in. O.C., 1½ in. by 3 in. steel channel sections 3′ O.C. hung with mild steel hangers	¾" Gypsum and sand plaster on ⅜" gypsum board	1 hr.	III	III
20 Staggered Wood Joists	Nominal 1 in. T and G lumber or ⅝ in. phenolic bonded plywood subfloor on wood floor joists 16 in. O.C. with separate ceiling joists at least 1 in. below the bottom of the floor joists. With 2 in. insulation between floor or ceiling joists	C, D, E, K	1 hr.	II	II

NOTE 1 The finishes designated by letter in the Tables refer to the following. The finishes shall be nailed in accordance with the requirements in the Residential Standards* unless otherwise specified.

- A ⅝ in. Gypsum and Sand plaster — 1 part gypsum to 3 parts sand.
- B ½ in. gypsum and sand plaster — 1 part gypsum to 2 parts sand on ⅜ in. perforated gypsum lath or plain gypsum lath with lath pads.
- C Same as B but with 3 in. wide strips of expanded metal over all joints.
- D ¾ in. gypsum and sand plaster — 1 part gypsum to 2 parts sand over metal lath.
- E ¾ in. gypsum and sand plaster — 1 part gypsum to 2 parts sand for first coat, 1 part gypsum to 3 parts sand for second coat over metal lath.
- F ⅞ in. portland cement-gypsum plaster — 1 part portland cement to 2 parts sand for first coat and 1 part gypsum to 3 parts sand for second coat over metal lath.
- G ⅝ in. gypsum and perlite plaster — 100 lb. gypsum to 2½ cu. ft. of aggregate on ⅜ in. perforated gypsum lath.
- H ⅜ in. gypsum board.
- I Double layer of ⅜ in. gypsum board, joints staggered.
- J ½ in. gypsum board — taped joints.
- K ⅝ in. special fire retardant gypsum board approved by Underwriters Laboratories Inc. for 1 hr. fire resistance.
- L $^{3}/_{16}$ in. asbestos cement board on ⅜ in. gypsum board.
- M ½ in. phenolic bonded douglas fir plywood.
- N 2 coats of resin emulsion or other coating providing equivalent seal.
- O ⅞ in. portland cement sand plaster on metal lath with 3 lb. asbestos fibre per bag of cement.
- P 1 in. portland cement sand plaster on metal lath with 3 lb. asbestos fibre per bag of cement.
- Q ⅝ in. gypsum sand plaster on ⅜ in. gypsum lath.
- R ¾ in. gypsum sand plaster on ⅜ in. gypsum lath.
- S ½ in. gypsum sand plaster on ⅜ in. gypsum lath with No. 16 S.W.G. 1" sq. wire mesh between lath and plaster.
- T ⅞ in. gypsum sand plaster on metal lath.
- U ½ in. gypsum perlite on gypsum vermiculite plaster on ⅜ in gypsum lath.
- V ¾ in. gypsum perlite or gypsum vermiculite plaster on metal lath.
- W Double layer of ½ in. gypsum wallboard.
- X Double layer of ½ in. gypsum wallboard with No. 16 S.W.G. 1 in. sq. wire mesh between sheets.
- Z ½ in. gypsum and sand plaster—1 part gypsum; 3 parts sand.
- A-A ⅝ in. acoustic plaster approved by Underwriters Laboratory for a one hour fire rating plus ½ in. of gypsum perlite plaster (1½ parts of gypsum to 2½ parts of perlite by vol.). Applied to ⅜ in. perforated gypsum lath and with 14 g. wire placed diagonally at 10 in. o.c. or 20 g. 1 in. wire mesh reinforcement beneath the lath.
- B-B ⅝ in. of gypsum perlite plaster—1½ parts of gypsum to 2½ parts of perlite by vol. applied over ⅜ in. perforated gypsum lath.

NOTE 2

Rating I for airborne sound transmission signifies constructions with a sound transmission class rating of 50 or more and is considered to provide very good performance in resisting airborne sound.

Rating II for airborne sound transmission signifies constructions with a sound transmission class rating of 45 to 50 and is considered to provide fair performance in resisting airborne sound.

Rating III for airborne sound transmission signifies constructions with a sound transmission class rating of less than 45 and is not acceptable where sound resistant construction is required.

NOTE 3

Rating I for impact sound transmission signifies constructions with very good resistance to impact sound transmission, such as is caused by walking.

Rating II for impact sound transmission signifies constructions with fair resistance to impact sound transmission.

Rating III signifies constructions with a poor resistance to impact noise transmission and while permitted in the Residential Standards is not recommended where a sound resistance is required. The ratings for impact sound transmission were estimated assuming bare floors or floors with typical thicknesses of resilient flooring. Where cork tile is installed as a finish flooring the impact sound rating should be increased from II to I or from III to II. Where carpeting is used the impact sound rating should be increased from III to I.

There is as yet no minimum requirements for impact and the information given here is for guidance only.

NOTE 4

The fire resistance ratings in Table 1 and 3 were based on tests conducted at a number of fire testing laboratories. The ratings in Table 2 are estimated as no test results are available for exterior stud walls. The figures are based on comparison with test results on interior load bearing wood stud walls shown in Table I.

*Supplement No. 5 National Building Code of Canada.

Section 9

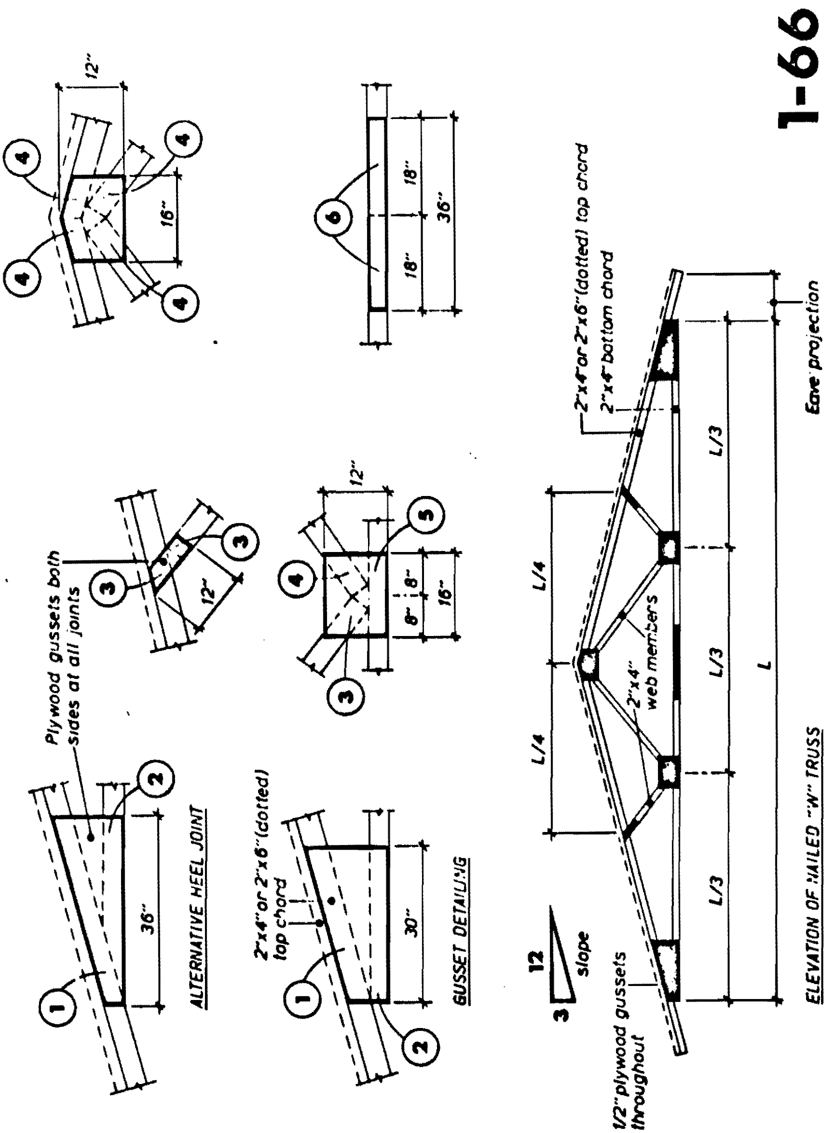
TRUSS DESIGNS

Prepared Jointly By

Division of Building Research—NRC

The Forest Products Laboratory, Ottawa, of the Department of Forestry and Rural Development

Central Mortgage and Housing Corporation


Plywood gussets both sides at all joints
12"
16"
36"
ALTERNATIVE HEEL JOINT
2"x4" or 2"x6" (dotted) top chord
30"
8"
18"
GUSSET DETAILING
12
3
slope
L/4
L/3
L
2"x4" web members
2"x4" or 2"x6" (dotted) top chord
2"x4" bottom chord
Eave projection
1/2" plywood gussets throughout
ELEVATION OF NAILED "W" TRUSS

1-66

NAILED "W" TRUSS DESIGN: 1/66

SLOPE: 3/12 only
SPANS: 16'-4" to 28'-4"
GUSSETS: ½" plywood

Nailing Schedule:

Roof Snow Load	Slope	Span "L"		Joint Location					
		ft.	in.	1	2	3	4	5	6
22.5 (2x4 top chord)	3/12	16	4	17	17	4	6	6	12
		18	4	20	18	4	6	6	13
		20	4	22	21	4	7	7	14
		22	4	24	24	4	8	8	16
		24	4	26	26	4	9	9	17
		26	4	29	28	5	9	9	19
		28	4	31	30	5	9	9	20
30 (2x4 top chord)	3/12	16	4	21	21	4	7	7	14
		18	4	24	23	4	7	7	16
		20	4	27	26	5	8	8	17
		22	4	29	29	5	9	9	19
		24	4	32	31	5	10	10	21
		26	4	35	34	6	11	11	23
		28	4	37	36	6	11	11	24
22.5 (2x6 top chord)	3/12	16	4	13	13	3	5	5	9
		18	4	15	14	3	5	5	10
		20	4	16	16	3	5	5	11
		22	4	18	18	3	6	6	12
		24	4	20	19	3	6	6	13
		26	4	21	21	4	7	7	14
		28	4	22	22	4	7	7	15
30 (2x6 top chord)	3/12	16	4	16	16	3	5	5	11
		18	4	18	17	3	5	5	12
		20	4	20	19	4	6	6	13
		22	4	22	22	4	7	7	14
		24	4	24	23	4	8	8	16
		26	4	26	25	5	8	8	17
		28	4	27	27	5	8	8	18
37.5 (2x6 top chord)	3/12	16	4	18	18	4	6	6	12
		18	4	21	20	4	6	6	14
		20	4	24	23	5	7	7	15
		22	4	26	25	5	8	8	17
		24	4	28	27	5	9	9	18
		26	4	30	30	6	10	10	20
		28	4	32	32	6	10	10	21

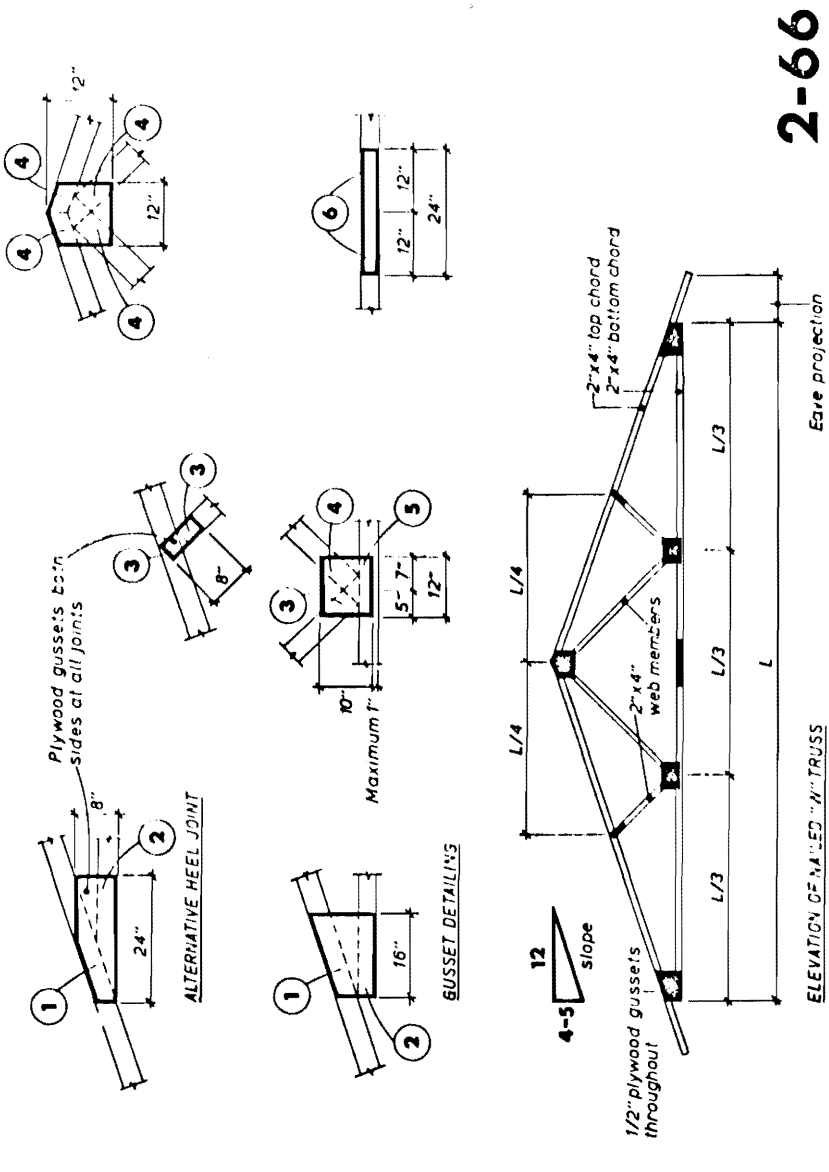
Notes:

LUMBER:
—Construction Grade Spruce or equivalent.

NAILS:
—All nails to be 3" common steel wire.
—All rows of nails to be staggered in direction of grain to keep splitting to a minimum.
—Nails may be clinched or unclinched.
—Solid blocking to be used under gusset plates during nailing.

PLYWOOD:
—½" sheathing grade Douglas Fir throughout.
—Grain direction of plywood faces to be parallel to bottom chord excepting plates joining web to top chord at quarter points.

GENERAL:
—To ensure maximum stiffness, the upper chords must be in good bearing contact at peak.
—Trusses with spans different than those listed may be used provided the nailing is not less than that shown for the next larger span.


Plywood gussets both sides at all joints
ALTERNATIVE HEEL JOINT
GUSSET DETAILING
24"
8"
16"
12"
10"
5" 7"
Maximum 1"
24"
2"x4" top chord
2"x4" bottom chord
2"x4" web members
L/4
L/4
L/3
L/3
L/3
L
Eave projection
12
4-5
slope
1/2" plywood gussets throughout
ELEVATION OF NAILED "W" TRUSS
2-66

NAILED "W" TRUSS DESIGN: 2/66

SLOPES: 4/12 and 5/12

SPANS: 16'-4" to 28'-4"

GUSSETS: ½" plywood

Nailing Schedule:

Roof Snow Load	Slope	Span "L"		Joint Location					
		ft.	in.	1	2	3	4	5	6
22.5	4/12	16	4	9	8	2	3	3	5
		18	4	10	9	2	3	4	6
		20	4	11	10	2	3	4	7
		22	4	12	11	2	4	4	7
		24	4	13	12	3	4	5	8
		26	4	14	13	3	4	5	9
		28	4	15	14	3	4	5	9
22.5	5/12	16	4	7	7	2	2	3	5
		18	4	8	7	2	3	3	5
		20	4	9	8	2	3	4	6
		22	4	10	9	2	3	4	6
		24	4	10	10	2	3	4	7
		26	4	11	10	3	4	5	7
		28	4	12	11	3	4	5	8
30	4/12	16	4	12	11	2	4	4	7
		18	4	13	12	3	4	5	8
		20	4	15	13	3	4	5	9
		22	4	16	14	3	5	6	10
		24	4	17	16	4	5	6	11
		26	4	19	17	4	6	7	11
		28	4	20	18	4	6	7	12
30	5/12	16	4	10	9	2	3	4	6
		18	4	11	10	3	4	4	7
		20	4	12	11	3	4	5	8
		22	4	13	12	3	4	5	8
		24	4	14	13	3	4	6	9
		26	4	15	14	4	5	6	10
		28	4	16	15	4	5	6	10
37.5	4/12	16	4	17	16	3	5	6	11
		18	4	19	18	4	5	7	12
		20	4	21	20	4	6	7	13
		22	4	23	21	4	7	8	14
		24	4	25	23	5	7	9	16
		26	4	27	25	5	8	10	17
		28	4	29	27	5	8	10	18
37.5	5/12	16	4	14	13	3	4	5	9
		18	4	16	14	4	5	6	10
		20	4	17	16	4	5	7	11
		22	4	19	17	4	6	7	12
		24	4	20	19	4	6	8	13
		26	4	22	20	5	7	9	14
		28	4	24	22	5	7	9	15

Notes:

LUMBER:

—Construction grade spruce or equivalent.

NAILS:

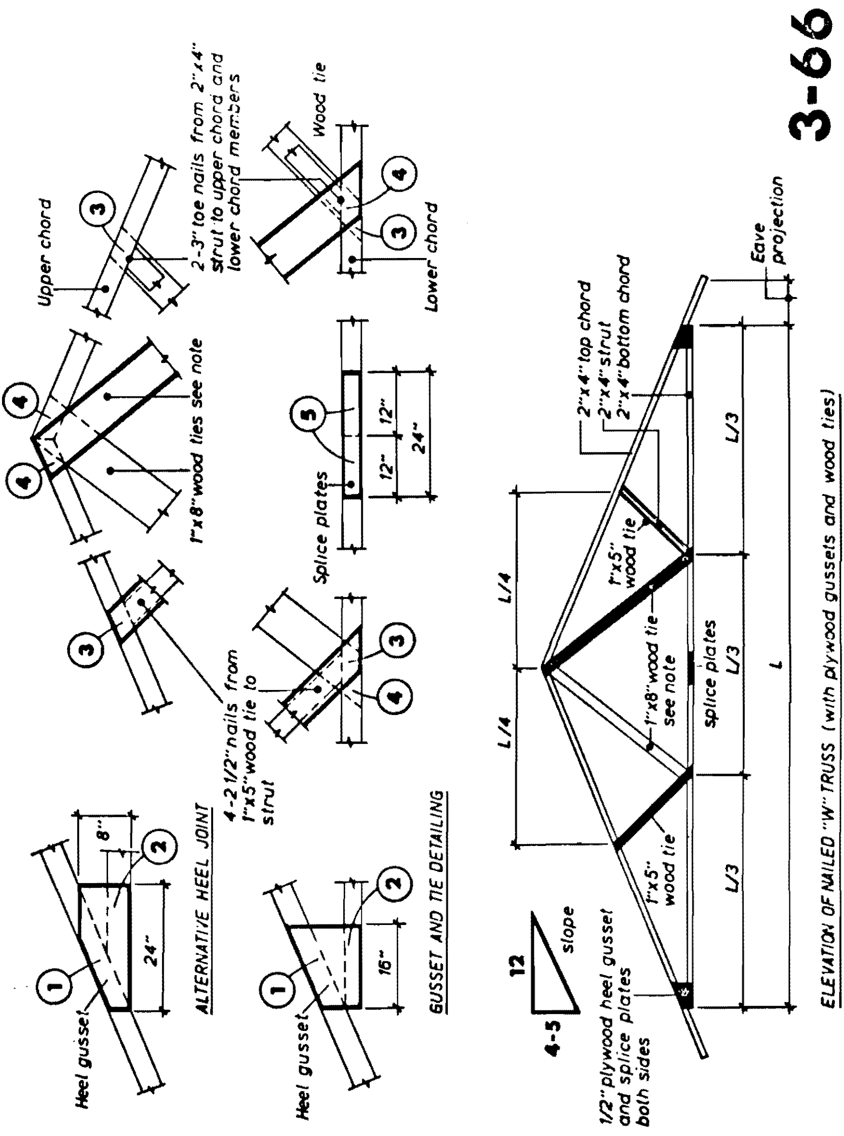
—All nails to be 3" common steel wire.
—All rows of nails to be staggered in direction of grain to keep splitting to a minimum.
—Nails may be clinched or unclinched.
—Solid blocking to be used under gusset plates during nailing.

PLYWOOD:

—½" sheathing grade Douglas Fir throughout.
—Grain direction of plywood faces to be parallel to bottom chord excepting plates joining web to top chord at quarter points.

GENERAL:

—To ensure maximum stiffness, the upper chords must be in good bearing contact at peak.
—Trusses with spans different than those listed may be used provided the nailing is not less than that shown for the next larger span.


Heel gusset
1
2
24"
8"
ALTERNATIVE HEEL JOINT
Heel gusset
16"
GUSSET AND TIE DETAILING
3
4
4-2 1/2" nails from 1"x5" wood tie to strut
1"x8" wood ties see note
Splice plates
5
12"
12"
24"
Upper chord
2-3" toe nails from 2"x4" strut to upper chord and lower chord members
Wood tie
Lower chord
12
4-5
slope
1/2" plywood heel gusset and splice plates both sides
1"x5" wood tie
L/4
L/4
1"x8" wood tie see note
splice plates
1"x5" wood tie
2"x4" top chord
2"x4" strut
2"x4" bottom chord
L/3
L/3
L/3
L
Eave projection
ELEVATION OF NAILED "W" TRUSS (with plywood gussets and wood ties)

3-66

NAILED "W" TRUSS DESIGN: 3/66

SLOPES: 4/12 and 5/12
SPANS: 16'-4" to 28'-4"
GUSSETS: ½" plywood

Nailing Schedule:

Roof Snow Load	Slope	Span "L"		Joint Location				
		ft.	in.	1	2	3	4	5
22.5	4/12	16	4	9	8	5	5	5
		18	4	10	9	5	6	6
		20	4	11	10	5	7	7
		22	4	12	11	5	7	7
		24	4	13	12	5	8	8
		26	4	14	13	5	9	9
		28	4	15	14	5	9	9
22.5	5/12	16	4	7	7	5	5	5
		18	4	8	7	5	6	5
		20	4	9	8	5	6	6
		22	4	10	9	5	7	6
		24	4	10	10	5	8	7
		26	4	11	10	5	8	7
		28	4	12	11	5	9	8
30	4/12	16	4	12	11	5	7	7
		18	4	13	12	5	8	8
		20	4	15	13	5	9	9
		22	4	16	14	5	10	10
		24	4	17	16	5	11	11
		26	4	19	17	5	11	11
		28	4	20	18	5	12	12
30	5/12	16	4	10	9	5	7	6
		18	4	11	10	5	8	7
		20	4	12	11	5	8	8
		22	4	13	12	5	9	8
		24	4	14	13	5	10	9
		26	4	15	14	5	11	10
		28	4	16	15	5	12	10
37.5	4/12	16	4	17	16	5	11	11
		18	4	19	18	5	12	12
		20	4	21	20	5	13	13
		22	4	23	21	5	14	14
		24	4	25	23	5	16	16
		26	4	27	25	5	17	17
		28	4	29	27	5	18	18
37.5	5/12	16	4	14	13	5	10	9
		18	4	16	14	5	11	10
		20	4	17	16	5	12	11
		22	4	19	17	5	14	12
		24	4	20	19	5	15	13
		26	4	22	20	5	16	14
		28	4	24	22	5	17	15

Notes:

LUMBER:

—Construction grade Spruce or equivalent.

NAILS:

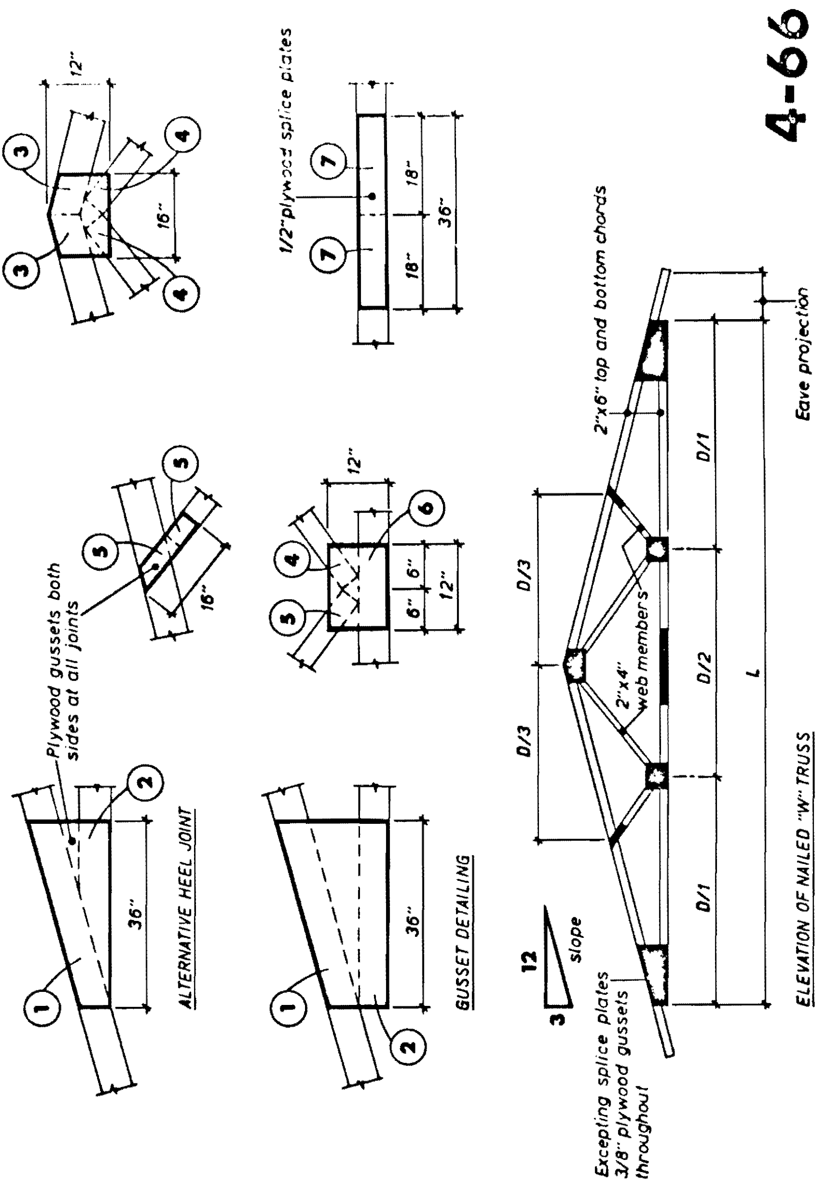
—All nails to be 3" common steel wire except as otherwise shown.
—All rows of nails to be staggered in direction of grain to keep splitting to a minimum.
—Nails may be clinched or unclinched.
—Solid blocking to be used under gusset plates during nailing.

PLYWOOD:

—½" sheathing grade Douglas Fir throughout.
—Grain direction of plywood faces to be parallel to bottom chord excepting plates joining web to top chord at quarter points.

GENERAL:

—To ensure maximum stiffness, the upper chords must be in good bearing contact at peak.
—Trusses with spans different than those listed may be used provided the nailing is not less than that shown for the next larger span.
—1" x 6" diagonal may be used when the number of nails in 4 is 12 or less.


4-66
ALTERNATIVE HEEL JOINT
GUSSET DETAILING
ELEVATION OF NAILED "W" TRUSS
Plywood gussets both sides at all joints
1/2" plywood splice plates
2"x6" top and bottom chords
2"x4" web members
Excepting splice plates 3/8" plywood gussets throughout
Eave projection
12
3
slope
D/3
D/1
D/2
L
36"
16"
12"
18"
6"
1
2
3
4
5
6
7

NAILED "W" TRUSS DESIGN: 4/66

SLOPE: 3/12 only
SPANS: 30'-4" and 32'-4"
GUSSETS: ⅜"-½" plywood

Nailing Schedule:

Roof Snow Load	Slope	Span "L"		Joint Location						
		ft.	in.	1	2	3	4	5	6	7
22.5	3/12	30	4	24	23	6	6	4	7	16
		32	4	26	25	6	6	5	8	17
30	3/12	30	4	30	29	7	7	6	9	20
		32	4	32	31	7	7	6	10	21
37.5	3/12	30	4	35	34	8	8	7	11	24
		32	4	37	36	8	8	7	11	25

Dimension Schedule:

Span		L-30'-4"	L-32'- 4"
Dimensions	D/1	11'-0"	11'- 9"
	D/2	8'-4"	8'-10"
	D/3	6'-9"	7'- 2"

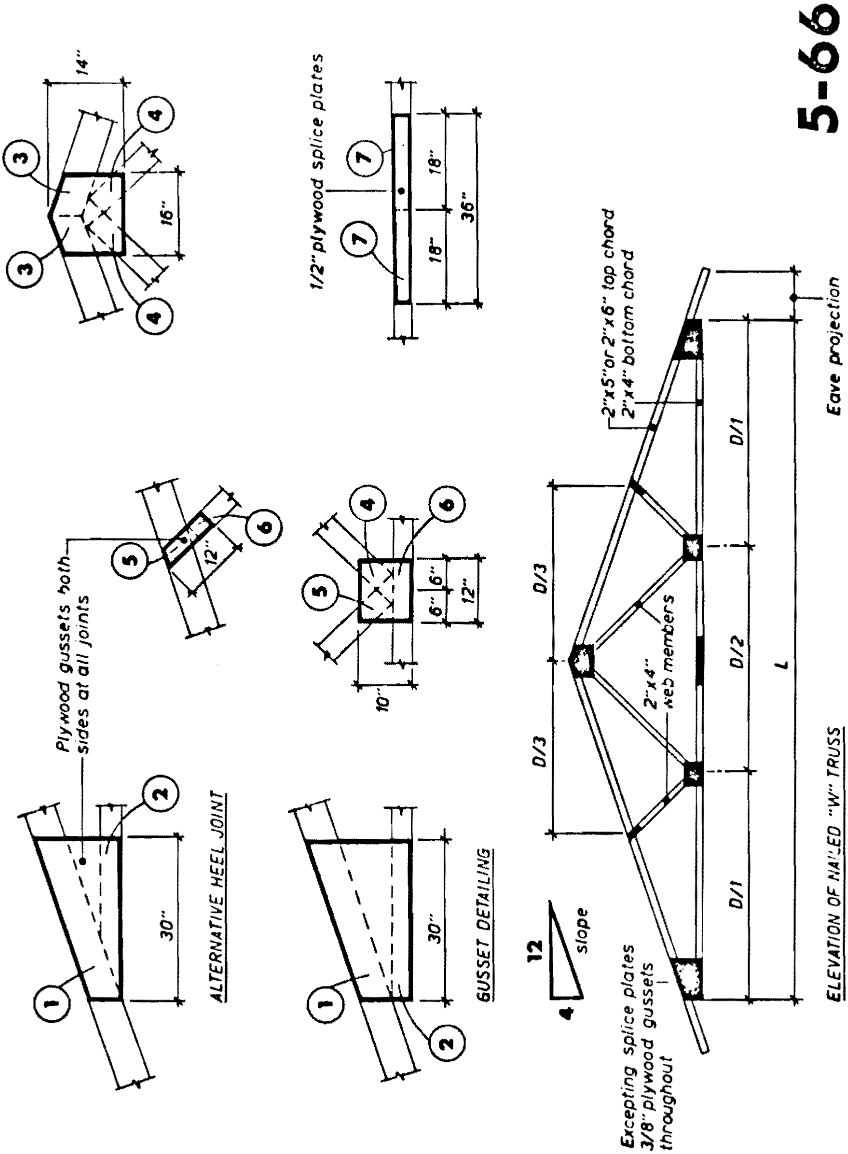
Notes:

LUMBER:
—Construction grade Spruce or equivalent.

NAILS:
—All nails to be 3" common steel wire.
—All rows of nails to be staggered and clinched perpendicular to direction of plywood face.
—Solid blocking to be used under gusset plates during nailing.

PLYWOOD:
—½" sheathing grade Douglas Fir at centre splice bottom chord, all other locations to be ⅜" thick plywood of the same grade.
—Grain direction of plywood faces to be parallel to bottom chord excepting plates joining web to top chord at quarter points.

GENERAL:
—To ensure maximum stiffness, the upper chords must be in good bearing contact at peak.
—Trusses with spans between those listed may be used provided the nailing is not less than that shown for the larger span.



Plywood gussets both sides at all joints
30"
ALTERNATIVE HEEL JOINT
30"
GUSSET DETAILING
12"
10"
6"
6"
12"
14"
16"
1/2" plywood splice plates
18"
18"
36"
12
4
slope
Excepting splice plates 3/8" plywood gussets throughout
D/3
D/3
2"x4" web members
2"x5" or 2"x6" top chord
2"x4" bottom chord
D/1
D/2
D/1
L
Eave projection
ELEVATION OF NAILED "W" TRUSS
5-66

NAILED "W" TRUSS DESIGN: 5/66

SLOPE: 4/12 only
SPANS: 30'-4" to 32'-4"
GUSSETS: 3/8"-1/2" plywood

Nailing Schedule:

Roof Snow Load	Slope	Span "L"		Joint Location						
		ft.	in.	1	2	3	4	5	6	7
22.5	4/12	30	4	15	14	4	4	3	5	10
		32	4	16	15	4	4	3	5	11
30	4/12	30	4	18	17	5	5	4	6	12
		32	4	20	19	5	5	4	6	13
37.5	4/12	30	4	22	21	6	6	5	7	15
		32	4	23	22	6	6	5	7	16

Dimension Schedule:

Span		L-30'-4"	L-32'- 4"
Dimensions	D/1	11'-0"	11'- 9"
	D/2	8'-4"	8'-10"
	D/3	6'-9"	7'- 2"

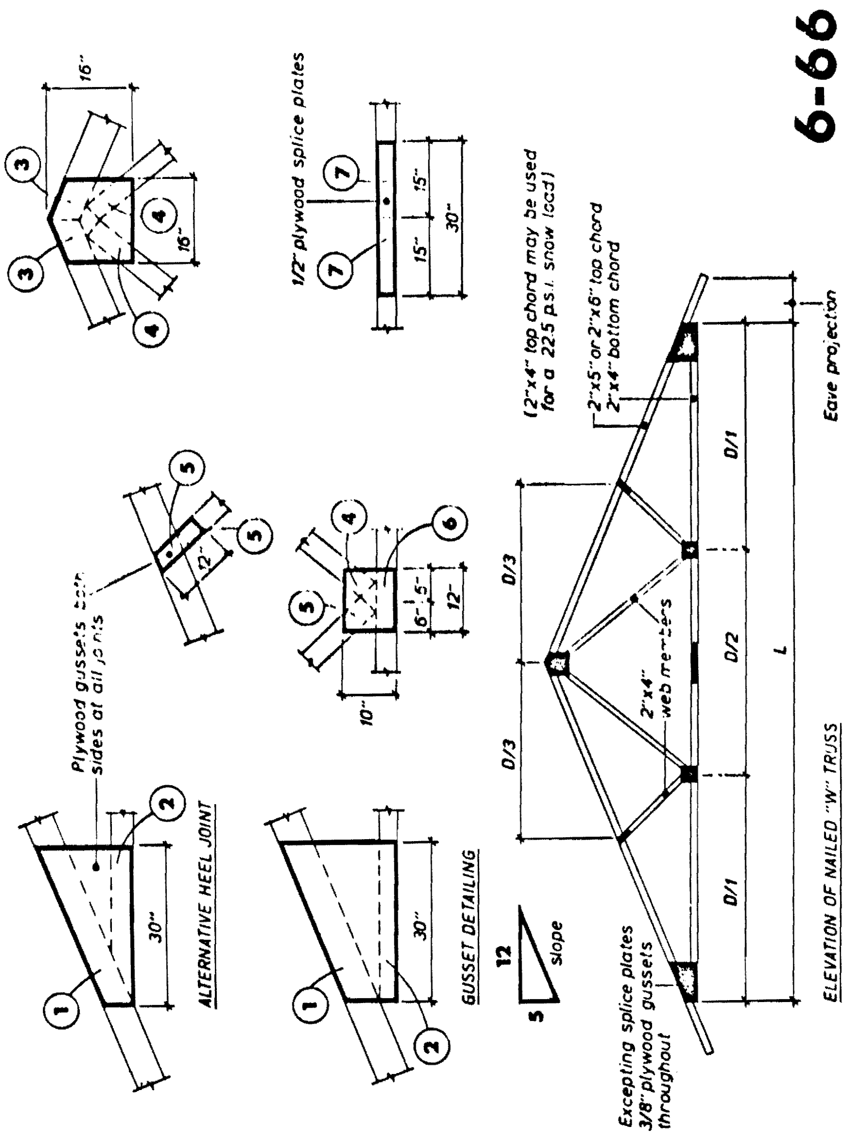
Notes:

LUMBER:
—Construction grade Spruce or equivalent.

NAILS:
—All nails to be 3" common steel wire.
—All rows of nails to be staggered and clinched perpendicular to direction of plywood face.
—Solid blocking to be used under gusset plates during nailing.

PLYWOOD:
—½" sheathing grade Douglas Fir at centre splice bottom chord, all other locations to be ⅜" thick plywood of the same grade.
—Grain direction of plywood faces to be parallel to bottom chord excepting plates joining web to top chord at quarter points.

GENERAL:
—To ensure maximum stiffness, the upper chords must be in good bearing contact at peak.
—Trusses with spans between those listed may be used provided the nailing is not less than that shown for the larger span.


6-66
ALTERNATIVE HEEL JOINT
Plywood gussets
sides at all joints
GUSSET DETAILING
1/2" plywood splice plates
16"
30"
15"
12"
10"
(2"x4" top chord may be used
for a 22.5 p.s.i. snow load)
2"x5" or 2"x6" top chord
2"x4" bottom chord
2"x4"
D/3
D/1
D/2
L
Eave projection
12
5
slope
Excepting splice plates
3/8" plywood gussets
throughout
ELEVATION OF NAILED "W" TRUSS

NAILED "W" TRUSS DESIGN: 6/66

SLOPE: 5/12 only
SPANS: 30'-4" to 32'-4"
GUSSETS: ⅜"-½" plywood

Nailing Schedule:

Roof Snow Load	Slope	Span "L"		Joint Location						
		ft.	in.	1	2	3	4	5	6	7
22.5	5/12	30	4	12	12	4	4	3	4	8
		32	4	13	12	4	4	3	4	8
30	5/12	30	4	15	14	5	5	4	5	10
		32	4	16	15	5	5	4	5	11
37.5	5/12	30	4	18	17	5	5	4	5	12
		32	4	19	18	6	6	5	6	13

Dimension Schedule:

Span		L-30'- 4"	L-32'-4"
Dimensions	D/1	10'-10"	11'-7"
	D/2	8'- 8"	9'-2"
	D/3	6'- 9"	7'-2"

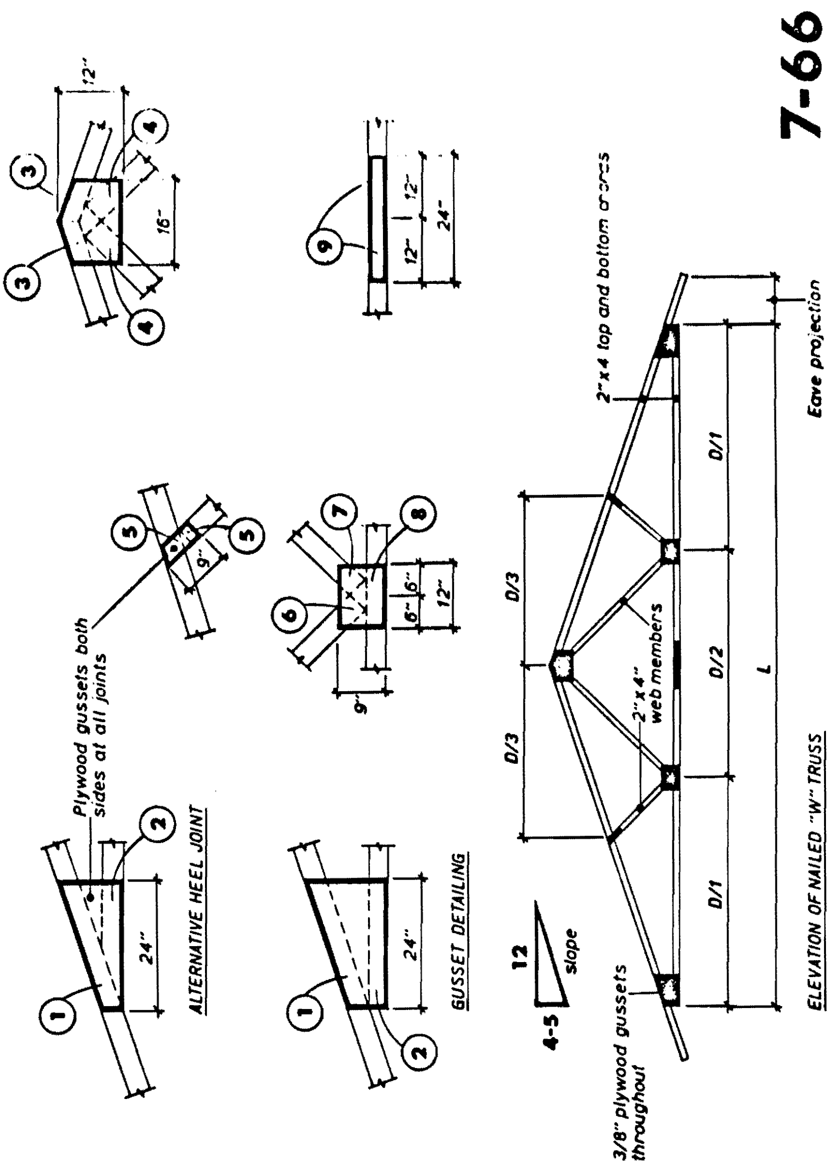
Notes:

LUMBER:
- —Construction grade Spruce or equivalent.

NAILS:
- —All nails to be 3" common steel wire.
- —All rows of nails to be staggered and clinched perpendicular to direction or plywood face.
- —Solid blocking to be used under gusset plates during nailing.

PLYWOOD:
- —½" sheathing grade Douglas Fir at centre splice bottom chord, all other locations to be ⅜" thick plywood of the same grade.
- —Grain direction of plywood faces to be parallel to bottom chord excepting plates joining web to top chord at quarter points.

GENERAL:
- —To ensure maximum stiffness, the upper chords must be in good bearing contact at peak.
- —Trusses with spans between those listed may be used provided the nailing is not less than that shown for the larger span.


7-66
ALTERNATIVE HEEL JOINT
Plywood gussets both sides at all joints
24"
16"
12"
9"
GUSSET DETAILING
6"
6"
12"
9"
24"
12"
12"
24"
ELEVATION OF NAILED "W" TRUSS
12
4-5
slope
3/8" plywood gussets throughout
D/1
D/3
D/3
D/2
D/1
2"x 4" web members
L
Eave projection

NAILED "W" TRUSS DESIGN: 7/66

SLOPES: 4/12 and 5/12
SPANS: 24'-4", 26'-4" and 28'-4"
GUSSETS: ⅜" plywood

Nailing Schedule:

Roof Snow Load	Slope	Span "L"		Joint Location								
		ft.	in.	1	2	3	4	5	6	7	8	9
		24	4	10	10	3	3	2	2	3	4	7
22.5	5/12	26	4	11	11	4	4	3	3	4	4	7
		28	4	12	11	4	4	3	3	4	4	8
		24	4	13	12	4	4	3	3	4	4	8
30	5/12	26	4	14	13	4	4	3	3	4	5	9
		28	4	15	14	5	5	3	3	5	5	9
		24	4	15	14	5	5	4	4	5	5	10
37.5	5/12	26	4	16	15	5	5	4	4	5	5	10
		28	4	18	16	5	5	4	4	5	6	11
		24	4	13	12	3	3	3	3	3	4	9
22.5	4/12	26	4	14	13	3	3	3	3	3	4	10
		28	4	15	14	4	4	3	3	4	5	10
		24	4	16	15	4	4	3	3	4	5	11
30	4/12	26	4	17	16	4	4	3	3	4	5	12
		28	4	18	17	4	4	4	4	4	6	13
		24	4	18	18	4	4	4	4	4	6	13
37.5	4/12	26	4	20	19	5	5	4	4	5	6	14
		28	4	21	20	5	5	4	4	5	7	15

Dimension Schedule:

Span		L-24'-4"	L-26'- 4"	L-28'-4"
Dimensions	D/1	8'-2"	8'-10"	9'-6"
	D/2	8'-0"	8'- 8"	9'-4"
	D/3	6'-0"	6'- 6"	7'-0"

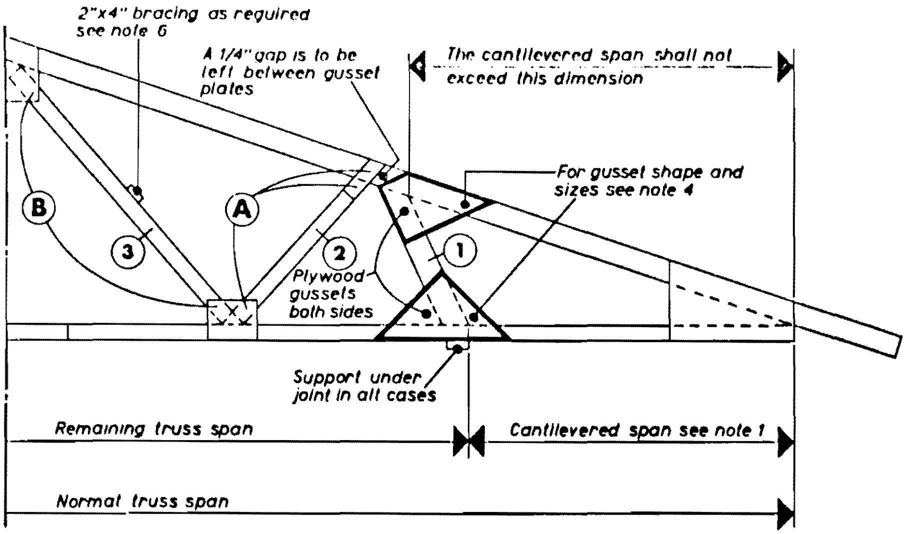
Notes:

LUMBER:
—Construction grade Spruce or equivalent.

NAILS:
—All nails to be 3" common steel wire.
—All rows of nails to be staggered and clinched perpendicular to direction of plywood face.
—Solid blocking to be used under gusset plates during nailing.

PLYWOOD:
—⅜" sheathing grade Douglas Fir throughout.
—Grain direction of plywood faces to be parallel to bottom chord excepting plates joining web to top chord at quarter points.

GENERAL:
—To ensure maximum stiffness, the upper chords must be in good bearing contact at peak.
—Trusses with spans between those listed may be used provided the nailing is not less than that shown for the larger span.



PART ELEVATION OF TYPICAL TRUSS SHOWING CANTILEVER DETAIL

8-66

CANTILEVER DESIGN: 8/66

Method of Reinforcing Cantilevered Nailed "W" Trusses with Plywood Gussets

Reinforcing Requirements:

1. The Cantilevered span is not to exceed 6'-8" for trusses with 2" x 6" or 2" x 5" top chords, or 5'-4" for trusses with 2" x 4" top chords.
2. The additional web member (member 1) should be of the same lumber size as the top chord.
3. Gusset plates and nailing required for additional member (member 1) should be equivalent to those at the heel joint.
4. The shape and size of gusset plates should be chosen with regard to the space limitations and required nailing area for individual designs.
5. Number of nails at connections for member 2 (joint A) to be increased to that used for member 3 (joint B).
6. For trusses having roof slopes of 5/12 and greater lateral bracing should be provided for member 3. (Lateral bracing can be achieved by tying together the mid-points of members 3 of the cantilevered trusses used, with a 2" x 4" extending to at least two normally supported trusses).

General Notes:

If desired, both ends can be Cantilevered, providing the above procedure is followed for each end.

The Cantilever detail may be used for most truss designs when web members are nominal 2" or thicker.

The Cantilever detail shall not be used with truss design 3/66.

LIST OF REFERENCES ON PERMAFROST AND BUILDING IN THE NORTH

The following selected publications on Permafrost and Building in the North are available from the Publications Section, National Research Council, Division of Building Research, Ottawa, Ontario. (Remittances should be made payable to the Receiver General of Canada, credit National Research Council.)

RESEARCH AND TECHNICAL PAPERS

NRC 4056 Protection of Utilities Against Permafrost in Northern Canada by S. C. Copp, C. B. Crawford and J. W. Grainge – reprint from Journal American Water Works Association, Vol. 48, No. 9, September 1956, pp.1155-1168. (25¢)

In 1951, the Division and the Public Health Engineering Division of the Department of National Health and Welfare carried out a study of ground temperatures around water and sewer pipes at Yellowknife, N.W.T. Their observations give a general picture of the changing thermal regime in the ground when municipal services are installed in a region of permafrost.

NRC 5108 Building in Northern Canada by R. F. Legget and H. B. Dickens, First Edition, March 1959, 48pp. (75¢)

This report reviews the major significant factors affecting building in northern Canada. The problems of foundations on permafrost, building design and construction, sewage disposal, water supply, heating, access and costs are all discussed.

NRC 5169 Water Supply and Sewage Disposal in Permafrost Areas of Northern Canada by H. B. Dickens – reprint from The Polar Record, Vol. 9, No. 62, May 1959, pp.421-432. (25¢)

Low temperature and permafrost complicate the provision of sanitary facilities in the North. This paper reviews the ways in which these factors affect water supply and sewage disposal methods in northern regions and presents some of the solutions that are being developed to make adequate sanitation systems feasible.

NRC 5280 Insulation in Northern Building by R. E. Platts, August 1959, 17pp. (25¢)

This report presents one aspect of the Division's studies of the design of housing for the North in terms of service and economy. Among the questions discussed are selection of insulation and insulating manufactured building components. Examples are given of economic thicknesses of insulation for housing in different northern regions.

NRC 5539 Construction in Permafrost: Obstacles of Soil and Climate by H. B. Dickens – reprint from Canadian Consulting Engineer, Vol. 2, No. 1, January 1960, pp.33-37. (10¢)

To cope adequately with the problems of construction in permafrost areas, the engineer requires a clear appreciation of the basic properties of permafrost. This paper discusses these properties in terms of ice content, temperature sensitivity and lack of drainage and indicates the importance of careful site selection in all northern work.

The methods of constructing building foundations, roads and runways in permafrost areas and the problems imposed on water and sewage facilities are briefly reviewed.

NRC 5573 The New Aklavik: Search for the Site by C. L. Merrill, J. A. Pihlainen and R. F. Legget – reprint from The Engineering Journal, Vol. 43, No. 1, January 1960, pp.52-57. (10¢)

This publication records the site survey that was carried out for the relocation of Aklavik, N.W.T. After a brief description of the Mackenzie River Delta, the reasons for the relocation, the requirements of a new site, the organization and field operations of the survey team are described. A brief description of the most favourable site, East Three (now known as Inuvik) is also included.

NRC 5574 Permafrost Aspects of the Hudson Bay Railroad by J. L. Charles – reprint from Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, Vol. 85, No. SM 6, December 1959, pp.125-135. (25¢)

This paper describes permafrost conditions along the route of the Hudson Bay Railroad and their effect on construction and maintenance of this railway line.

NRC 5902 Housing in Northern Canada – Some Recent Developments by H. B. Dickens and R. E. Platts – reprint from The Polar Record, Vol. 10, No. 66, September 1960, pp.223-230. (10¢)

A review of the effects of technical and economic factors on northern house design with reference to recent trends in Eskimo housing and the increased use of prefabrication techniques.

NRC 5941 The Distribution of Permafrost and Its Relation to Air Temperature in Canada and the U.S.S.R. by R. J. E. Brown – reprint from Arctic, Vol. 13, No. 3, September 1960, pp.163-177. (25¢)

A comprehensive review of early attempts to draw maps of permafrost distribution in Canada is presented. This is followed by the most recent permafrost distribution map compiled by the Division of Building Research which is based on continuous and discontinuous zones. Permafrost mapping in the U.S.S.R. is also discussed. A detailed survey of air temperature patterns in both countries reveals that there is a broad relationship between the distribution of permafrost and this climatic factor.

NRC 5942 Experience with a Pier-Supported Building Over Permafrost by H. B. Dickens and D. M. Gray – reprint from Journal of the Soil Mechanics and Foundations Division. Proceedings of the American Society of Civil Engineers, Vol. 86, No. SM 5, October 1960, pp.1-14. (25¢)

The construction of a two-storey steel frame building over permafrost at Churchill, Manitoba, during 1948 to 1950 is described and its performance discussed in relation to the construction techniques used. Its apparent satisfactory performance after nine years of occupancy suggests that the concrete pier and spread footing foundation used can be a practicable alternative to embedded foundations for large heated structures in permafrost regions.

NRC 6059 Prefabrication in Northern Housing by R. E. Platts, November 1960. (50¢)

High northern transportation and labour costs and the very short construction season favour full prefabrication to achieve minimum weight and erection time and lower costs. This report studies the factors influencing northern prefabrication design, the technical requirements, and details of proven systems. Panel and joint details are presented, openings and hardware discussed, and improved details and structures are suggested. Potential costs in place are estimated and proper job planning is emphasized.

NRC 6452 Fort Simpson, N.W.T. – Engineering Site Information: Soils and Permafrost Conditions by J. A. Pihlainen, August 1961, 9pp. 10 figs. (25¢)

The Division of Building Research has undertaken as one of its responsibilities and as a contribution to northern development, the collection and publication of engineering site information on northern settlements, as the opportunities arise. A request for assistance with a soil investigation for the foundation of a new hostel at Fort Simpson provided the opportunity to extend the investigation to a general survey of soils and permafrost conditions using special drilling and sampling techniques to produce frozen cores for observation.

NRC 6262 Permafrost Investigations in Canada by R. F. Legget, H. B. Dickens and R. J. E. Brown – reprint from Geology of the Arctic, Vol. II, October 1961, pp.956-969. (25¢)

The Division of Building Research is engaged in mapping permafrost in Canada by means of direct field observations, reviews of the technical literature and the circulation of permafrost questionnaires throughout northern Canada. To improve the ability to predict permafrost conditions, studies of the climatic and terrain factors affecting the distribution of permafrost were initiated. A survey of the thermal characteristics of these factors and possible correlations with the distribution of permafrost is presented in this paper.

NRC 6731 Bench Marks in Permafrost Areas by G. H. Johnston – reprint from The Canadian Surveyor, Vol. XVI, No. 1, January 1962, pp.32-41. (25¢)

Available literature on the problem of establishing permanent bench marks in permafrost areas is reviewed. The factors that influence stability are noted and some of the methods devised to provide reliable bench marks are described. Finally, the design, installation and performance of a bench mark used at Inuvik, N.W.T. by the Division of Building Research is described in detail.

NRC 6757 Inuvik, N.W.T. – Engineering Site Information by J. A. Pihlainen, August 1962, 18pp., 18 figs. (with a supplement by D. W. Boyd). (50¢)

The development of the new townsite of Inuvik, N.W.T. has afforded the Division of Building Research a unique opportunity to observe the effect of a town on permafrost conditions and to record the history of any changes that occur. Members of the Division were privileged to serve on the site survey team which carried out extensive investigations prior to and following the selection of the present townsite in August 1954. This paper summarizes site conditions and terrain features at Inuvik which are of interest to engineers and includes observations of vegetation, soils and permafrost conditions, depth of thaw and ground temperatures.

NRC 7057 Condensation Control in Stressed Skin and Sandwich Panels by R. E. Platts – reprint from Forest Products Journal, Vol. XII, No. 9, September 1962, pp.429-430. (DBR Technical Paper No. 149.) (10¢)

Calculations and experience show that mass air flow, rather than vapour diffusion, is nearly always the cause of severe condensation in building structures. Closed panels should not accumulate significant condensate through a winter season through diffusion, gravity air flow or "pumping". Inspection of older stressed skin panel buildings in the Far North indicated that closed stressed skin panels can remain free from condensation damage without vents or vapour barriers.

NRC 7139 A Review of Permafrost Investigations in Canada by R. J. E. Brown – reprint from The Canadian Geographer, Vol. VI, Nos. 3-4, Winter 1962, pp.162-165. (10¢)

This paper describes the various permafrost research studies carried out by the Division of Building Research since 1950.

NRC 7289 Deep Bench Marks in Clay and Permafrost Areas by M. Bozozuk, G. H. Johnston and J. J. Hamilton – reprint from Field Testing of Soils, ASTM Special Technical Publication No. 322, pp.265-275, September 1963. (DBR Technical Paper No. 166.) (25¢)

This paper describes the design and use of deep bench marks by the Division of Building Research. The bench marks consist of an inner pipe protected by an outer casing from the effects of seasonal ground movements and frost action. In sensitive clays the bench mark is installed by jacking or driving the outer casing with relatively simple equipment. In stiffer clays it is inserted in an augered hole and then turned and pushed to refusal with a drill rig. In permafrost areas, the bench mark is placed in a drilled or steamed hole to a depth at which the lower portion of the inner rod is securely anchored in the perennially frozen ground. Details of bench mark assemblies and installation techniques for soft clays, stiff clays, and frozen ground are described.

NRC 7414 The Temperature Under Heated or Cooled Areas on The Ground Surface by W. G. Brown – reprint from Transactions of the Engineering Institute of Canada, Vol. 6, No. B-14, July 1963, Paper No. EIC-63-MECH 3. (DBR Research Paper No. 208.) (25¢)

Equations and graphical methods are presented which allow calculation of the steady or unsteady temperature in the ground under flat areas of any shape on the ground surface. The equations, some of which are derived by super-position, are applicable to structures such as basementless buildings, shallow lakes and rivers, street intersections and ice-rinks.

NRC 7417 Soil Sampling in Permafrost Areas by G. H. Johnston – Paper presented at the Annual Meeting of the Engineering Institute of Canada, Quebec City, May 1963. (DBR Technical Paper No. 155.) (10¢)

The need for adequate subsurface explorations, particularly with regard to determining the ice content of frozen soils in permafrost areas is stressed. Methods and techniques for obtaining samples of perennially frozen ground are discussed under four main headings: sampling natural exposures, hand borings, test pits and core drilling. The application and limitations of each method are noted and lists of pertinent equipment required are given.

NRC 7568 Permafrost Investigations at Thompson, Manitoba – Terrain Studies by G. H. Johnston, R. J. E. Brown, and D. N. Pickersgill. October 1963, 55pp., 50 figs. (DBR Technical Paper No. 158.) ($1.00)

The new townsite of Thompson, Manitoba, is located near the southern boundary of the zone of discontinuous permafrost where isolated patches of frozen ground occur. The Division of Building Research initiated studies at the Thompson site, therefore, to appraise the climatic and terrain features which appear to affect the occurrence and distribution of perennially frozen ground in this fringe area of Canada's permafrost region. The results of these studies of air temperature, precipitation, snow cover, vegetation, relief, drainage and soils are presented in this paper. A preliminary assessment of the local ground thermal regime is also included.

NRC 7660 Graphical Determination of Temperature under Heated or Cooled Areas on the Ground Surface by W. G. Brown. October 1963, 38pp., 20 figs. (DBR Technical Paper No. 163.) (50¢)

Completely graphical methods are applied to determination of temperature in the ground under any flat area such as a basementless building or a shallow lake on the ground surface. It is shown that the temperature can be obtained as the sum of individual temperatures resulting from areas of simple geometry. Cases treated are: the steady-state, the sudden change in surface temperature and the periodic annual and diurnal ground surface temperature.

NRC 7860 Permafrost and Related Engineering Problems by R. J. E. Brown and G. H. Johnston – reprint from Endeavour, Vol. XXIII, No. 89, May 1964, pp.66-72. (DBR Technical Paper No. 173.) (25¢)

The distribution of permafrost and its thermal characteristics are reviewed followed by a discussion of the influence of climatic and terrain factors. The second half of this paper reviews engineering considerations including site investigation techniques, and the design, construction and maintenance of structures in permafrost regions.

NRC 7885 Permafrost Investigations on the Mackenzie Highway in Alberta and Mackenzie District by R. J. E. Brown. June 1964, 36pp., 27 figs. (DBR Technical Paper No. 175.) (75¢)

The distribution of permafrost on the Mackenzie Highway is described in detail. The relationship of the distribution to climatic and terrain factors is discussed with an analysis of air photo patterns.

NRC 8129 Comparison of Observed and Calculated Ground Temperatures with Permafrost Distribution Under A Northern Lake by W. G. Brown, G. H. Johnston, and R. J. E. Brown – reprint from Canadian Geotechnical Journal Vol. 1, No. 3, July 1964, pp.147-154. (10¢)

Making use of limited ground temperature measurements in the neighbourhood of a small, shallow lake near Inuvik, N.W.T., it was possible with the help of an electronic computer to estimate the entire thermal regime under and about the lake. The results indicated a completely unfrozen zone of roughly hour-glass shape directly under the lake. Field borings under the lake and adjacent to it supported this theoretical finding.

NRC 8213 Some Observations on the Influence of Climatic and Terrain Features on Permafrost at Norman Wells, N.W.T., Canada by R. J. E. Brown – reprint from Canadian Journal of Earth Sciences, Vol. II, February 1965. (25¢)

Measurements of evaporation (including potential evapotranspiration), net radiation at the ground surface, depth of thaw and ground temperatures in the thawed layer and the permafrost were made during the summers of 1959 and 1960 at five sites. Although rather crude measuring devices were used due to field conditions some quantitative information was obtained on the relative importance of the climatic and terrain features in the permafrost environment.

NRC 8252 Some Observations on Permafrost Distribution at a Lake in the Mackenzie Delta, N.W.T., Canada by G. H. Johnston and R. J. E. Brown – reprint from Arctic, Vol. 17, No. 3, September 1964, pp.162-175. (25¢)

The results of a field investigation to determine the distribution of permafrost under and adjacent to a small, shallow lake in the Mackenzie River delta are reported. Permafrost was found to extend to the edge of the lake but was not encountered under the lake. The thawing effect of this body of water has apparently been confined to the ground lying under the lake although ground temperature measurements inland from the lake indicate that its thermal effect extends for some distance beyond the lake perimeter.

NRC 8276 Difficulties Associated With Predicting Depth of Freeze or Thaw, by W. G. Brown – reprint from Canadian Geotechnical Journal, Vol. I, No. 4, November 1964, pp.215-226. (25¢)

Calculations using the Neumann Solution (as modified by Aldrich) and thermal properties of soils (obtained by Kersten) show that the frost penetration depth for the same freezing index for essentially all soils with any moisture content and for dry sand and rock varies by a factor of about 2 to 1. The theoretical calculations and additional experimental data are used as a basis for a small alteration in the slope of the experimentally determined design curve of the U.S. Army Corps of Engineers. This modified design curve is recommended for field used because of (1) inherent imperfections in existing theory and (2) practical limitations to precise specification of field conditions.

NRC 8375 Permafrost Investigations in Saskatchewan and Manitoba by R. J. E. Brown. Sept. 1965, 47pp., 26 figs. (DBR Technical Paper No. 193.) ($1.00)

The distribution of permafrost and the climatic and terrain factors affecting its occurrence in the southern fringe area of the permafrost region in Saskatchewan and Manitoba are described and discussed in detail.

NRC 9269 Pile construction in permafrost by G. H. Johnston – reprint from Proceedings: Permafrost International Conference, November 1963, pp.477-480. (DBR Technical Paper No. 233.)

The use of pile foundations at Inuvik, N.W.T., is described under five headings – site preparation, type of pile, pile placement methods, depth of embedment and refreezing characteristics.

NRC 9270 Engineering site investigations in permafrost areas by G. H. Johnston – reprint from Proceedings: Permafrost International Conference, November 1963, pp.371-374. (DBR Technical Paper No. 234.)

The three main phases (preliminary office studies and planning, field investigations and final laboratory and office studies) which should be considered in conducting engineering site investigations in permafrost areas are discussed in some detail.

NRC 9272 Relation between mean annual air and ground temperatures in the permafrost region of Canada by R. J. E. Brown – reprint from Proceedings: Permafrost International Conference, November 1963, pp.241-246 (DBR Research Paper No. 296.)

Observations in Canada and other countries indicate that the mean annual ground temperature in permafrost at the depth of zero annual amplitude is several degrees warmer than the mean annual air temperature. Values range from about 1°F to 12°F with 6°F being an approximate average. Ground temperature observations and permafrost characteristics are presented for 17 stations in Canada. They indicate the existence of a broad relation between mean annual air and ground temperatures in the permafrost region but many additional observations are required to establish a closer correlation.

NRC 9274 Influence of vegetation on permafrost by R. J. E. Brown – reprint from Proceedings: Permafrost International Conference, November 1963, pp.20-25. (DBR Research Paper No. 298.)

Vegetation influences permafrost by modifying the energy exchange regime at the ground surface. It exerts also an indirect influence by modifying climatic and terrain features which themselves affect the permafrost. The influence of vegetation on depth of thaw, temperature, extent and thickness of permafrost is reviewed.

NRC 9281 The Angirraq: low cost prefabrication in Arctic houses by R. E. Platts – reprint from Arctic, Journal of the Arctic Institute of North America, Vol. 19, No. 2, June 1966. (DBR Technical Paper No. 236.)

Studies to assist with the development of a prefabricated Northern house have led to improvements and simplifications in low-cost stressed skin design. Basic stressed skin panels with full thick insulation and cedar plywood exterior are combined with open-joint detailing to form a simple economical building. Shear dowels and continuous chords tie the assembly to form a grid box. The design features are also applicable to larger Arctic buildings and some are relevant to prefabrication in southern Canada.

NRC 9762 Permafrost investigations in British Columbia and Yukon territory by R. J. E. Brown. December 1967, 74pp., 41 figs. (DBR Technical Paper No. 253.) ($1.00)

The distribution of permafrost in British Columbia and the Yukon Territory is described in detail followed by a discussion of the influence of climate and terrain factors.

Technical Translations

TT 1021 Frost and Foundations. Elementary Conditions for the Planning and Construction of Foundations in Areas with Winter Frost and Permafrost by Nielson and Rauschenberger. From G.T.O. Publikation Nr. 1, 1957, 20pp. ($2.00)

TT 1033 Technical Considerations in Designing Foundations in Permafrost (SN 91-60). State Committee of the Council of Ministers (U.S.S.R.) for Building Problems. State Publishing House of Literature on Building. Architecture and Building Materials, Moscow, 1960, 64pp. ($4.50)

TT 1064 Methodology of Comparing the Economics of Different Construction Projects by V. F. Zhukov. From Thawing of Permafrost Prior to the Erection of Structures, p.21-38, Academy of Sciences, U.S.S.R., V. A. Obruchev Institute of Permafrost Studies, Moscow, 1958, 17pp. ($1.00)

TT 1219 Principles of Geocryology (Permafrost Studies) *Part II*, Engineering Geocryology, *Chapter II, Deformation of Structures Resulting From The Processes of Freezing and Thawing* by A. I. Dement'ev, pp.18-27, Academy of Sciences of the U.S.S.R., V. A. Obruchev Institute of Permafrost Studies, Moscow, 1959.

Deformation of structures caused by (1) seasonal freezing and thawing of the ground, and (2) thawing of permafrost are described and discussed.

TT 1220 Principles of Geocryology (Permafrost Studies) *Part II*, Engineering Geocryology, *Chapter VIII, Beds for Roads and Airfields* by G. V. Porkhaev and A. V. Sadovskiy, pp.231-254, Academy of Sciences of the U.S.S.R., V. A. Obruchev Institute of Permafrost Studies, Moscow, 1959.

Problems caused by permafrost in the construction and use of roads, railroads and airfields are described and deformation of these structures resulting from seasonal freezing and thawing of the active layer and thawing of the permafrost are discussed. Practical methods of obtaining stable conditions are described and compared with theoretical calculations.

TT 1221 Principles of Geocryology (Permafrost Studies) Part II, Engineering Geocryology, *Chapter IX, Underground Utility Lines*, by G. V. Porkhaev, pp.255-266, Academy of Sciences of the U.S.S.R., V. A. Obruchev Institute of Permafrost Studies, Moscow, 1959.

Thermal calculations for pipes laid in frozen ground are discussed. Various methods for installing utility lines underground in permafrost areas are described and the performance of these installations are compared. A brief description of the design and performance of utility lines in the permafrost regions of Canada and Alaska is included.

TT 1232 Principles of Geocryology (Permafrost Studies) Part II, Engineering Geocryology, *Chapter XI, Specific features of the maintenance of structures in permafrost conditions,* pp.285-297 by A. I. Dement'ev. Academy of Sciences of the U.S.S.R., V. A. Obruchev Institute of Permafrost Studies, Moscow, 1959.

This translation of Chapter XI by A. I. Dement'ev discussed the particular problems of maintaining structures in permafrost areas. Problems associated with keeping the site in good condition are presented first. This is followed by three sections each considering a particular construction method and associated maintenance requirements. The first is concerned with the construction method used to preserve the permafrost condition in the foundation soils, the second allows the permafrost to thaw, and the third disregards the permafrost because it does not affect the structure. The chapter concludes with instructions for releasing the completed structure to the occu-
TT 1239. pants, and suggestions for long-term observations on performance.

TT 1246 Heaving force of frozen ground. I. Mainly on the results of field research by S. Kinoshita and T. Ono. Low temperature Science (Teion Kagaku) Ser. A, 21: pp.117-139, 1963.

The heaving pressure caused by frost heaving was measured in the field with small iron pipe footings. The soil contained 35% clay, 51% silt and 14% sand. The maximum adfreezing pressure measured was 2.1 kg/cm^2. The maximum heaving pressure measured beneath a steel plate in the same soil was 29.3 kg/cm^2. The heaving pressures were maintained only during the active heaving period – when the rate of heaving decreased, relaxation in the soil caused the pressures to reduce. In general, when the amount of heaving was restrained, the heaving pressure increased. Experiments were also carried out with small footings made of other materials such as wood and plaster with and without externally painted surfaces.

TT 1249 Principles of Geocryology (Permafrost Studies) Part II, Engineering Geocryology, Chapter IV, Thermal physical principles of controlling the interaction between structures and frozen soils, pp.80-117 by G. V. Porkhaev. Academy of Sciences of the U.S.S.R., V. A. Obruchev Institute of Permafrost Studies, Moscow, 1959.

This translation discusses the thermal regime of the ground in permafrost regions in relation to engineering structures. The chapter begins with a review of the heat exchange between the ground and its surroundings prior to construction. This is followed by a description of the thermal properties of the ground and the possibility of controlling them. Factors affecting the ground thermal regime are also discussed. The chapter concludes with an account of currently available mathematical methods for analyzing the influence of engineering structures on the ground thermal regime in the permafrost region.

TT 1250 Principles of Geocryology (Permafrost Studies) Part II, Engineering Geocryology, Chapter V. Principal methods of moisture-thermal amelioration of the ground over large areas, pp.118-139 by V. P. Bakakin and G. V. Porkhaev. Academy of Sciences of the U.S.S.R., V. A. Obruchev Institute of Permafrost Studies, Moscow, 1959.

This translation reviews the available methods of artificially thawing permafrost areas. It is suggested that greater use could be made of these methods in certain types of construction projects and particularly in open pit mining where large volumes of perennially frozen ground have to be thawed. The heat exchange regime at the ground surface can be altered by modifying the ground surface to increase heat input into the ground. Various methods can be used such as lowering the albedo by colouring or roughening the ground surface, reducing evaporation, removing the vegetation cover or increasing snow accumulation. The thawing of permafrost can be accelerated by injecting water into the ground, flooding the ground surface, or covering the ground surface with artificial snow or various types of thermal insulation.

TT 1287 Principles of Geocryology (Permafrost Studies) Part II, Engineering Geocryology Chapter XII, Methods of investigations in engineering geocryology pp.298-347 by A. I. Dement'ev, et al. Academy of Sciences of the U.S.S.R., V. A. Obruchev Institute of Permafrost Studies, Moscow, 1959. ($3.50)

This translation of Chapter XII by A. I. Dement'ev et al reviews the principal aspects of engineering site investigations in permafrost areas. It begins with a description of the aims and scope of engineering site investigations in permafrost areas and instructions for carrying them out. A considerable portion of the text is devoted to electrical resistivity methods of obtaining information on permafrost. Field and laboratory investigations of the engineering properties of frozen soils are reviewed. Methods are presented for analyzing data obtained in site investigations and the compilation of a report.

TT 1298 Instructions for designing bearing media and foundations in the southern zone of the permafrost region. Research Institute of Foundations and Underground Structures, Academy of Construction and Architecture U.S.S.R. State Publishing House of Literature on Building, Architecture and Building Materials. Moscow, 1962, 77pp. ($3.50)

This translation of the Soviet Building Code dealing with the design of foundations for the southern zone of the permafrost region is of particular interest to the Division of Building Research in its investigations of permafrost and building problems in northern Canada. A similar document dealing with the design of foundations for the entire permafrost region was translated in 1962 – "Technical Considerations in Designing Foundations in Permafrost" (NRC Technical Translation 1033). The Russians have been involved in construction on permafrost for many years in Siberia and their experiences are of great interest to those who are involved in this activity in northern Canada. A building code for northern Canada is currently being prepared.

TT 1314 Guide for Design and Construction of Pile Foundations in Permafrost.

This translation of the Soviet Building Code dealing with the design of pile foundations in permafrost areas is the third such document prepared for the Division of Building Research. (See also TT 1033 and 1298)

TECHNICAL MEMORANDA OF THE ASSOCIATE COMMITTEE ON GEOTECHNICAL RESEARCH

TM 60 Proceedings of the Permafrost Research Conference at the Building Research Centre, Ottawa, 27 March 1958.

The purpose of this meeting was to provide a broad general review of the status of permafrost research in both Canada and Alaska. The proceedings contain in summary form the individual reports of work going on in this field and also a report on the general discussion of permafrost problems which took place.

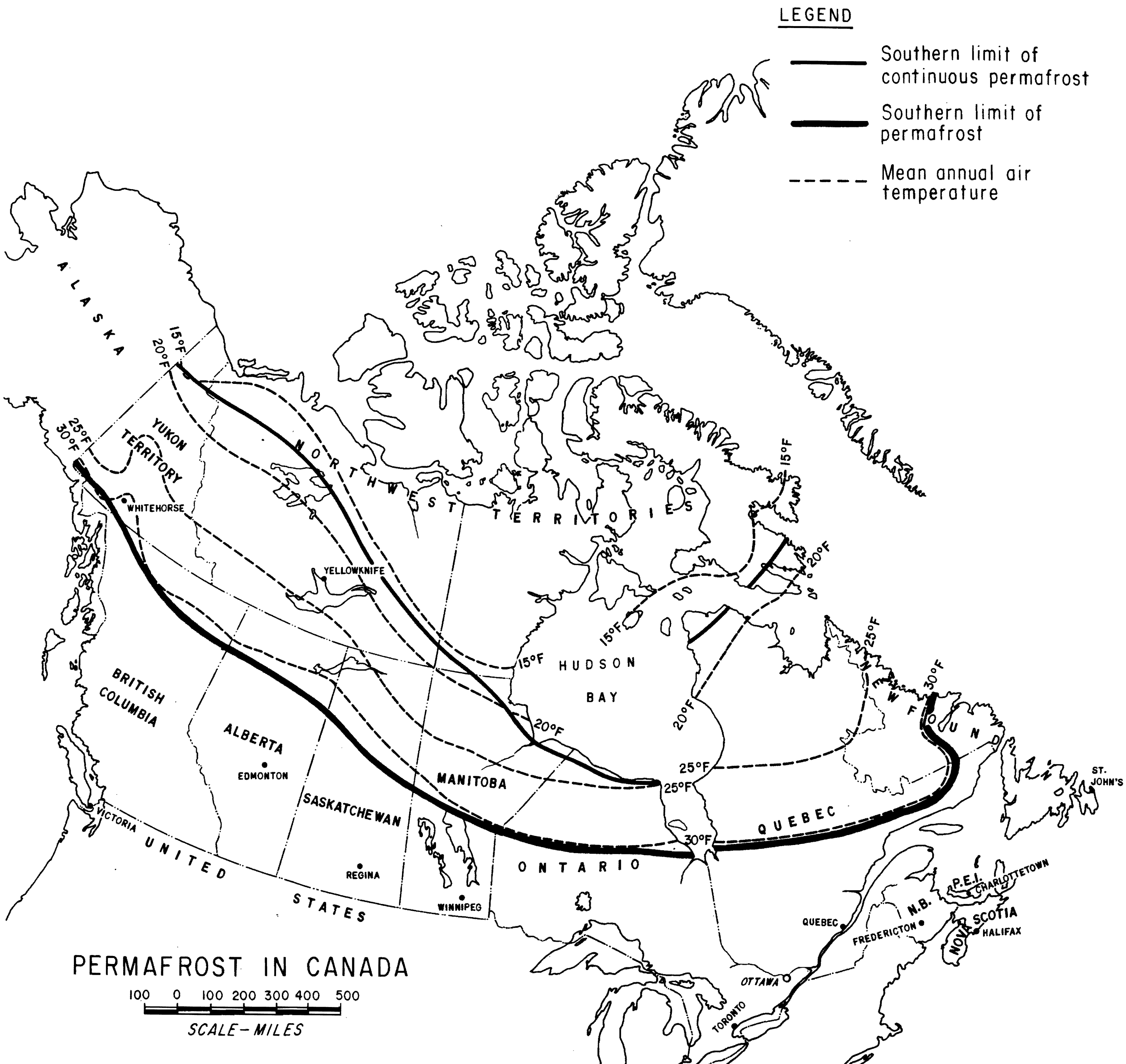
TM 76 Proceedings of the First Canadian Conference on Permafrost, 17 and 18 April 1962. Prepared by R. J. E. Brown, January 1963, 245pp.

The overall theme of the conference was permafrost in relation to northern development. A wide variety of topics was considered, including phases of basic research, design and practice as they pertain to problems arising from the existence of permafrost: geology, climate, vegetation, soil, heat flow, economics, site investigations and construction. Nineteen papers were presented at the conference of which thirteen are reproduced in their entirety in these proceedings and six are presented in summary form.

TM 86 Proceedings of the Canadian Regional Permafrost Conference, 1 and 2 December 1964 (Edmonton, Alberta). Prepared by R. J. E. Brown, September 1965, 148pp.

The overall theme of the conference was engineering problems in the discontinuous permafrost zone. Twelve papers were presented dealing with the distribution of permafrost in western Canada and Alaska, engineering site investigations and engineering design and construction – building foundations, roads and municipal services. Eight papers are reproduced in their entirety and four are presented in summary form.

Special Note In addition to the foregoing publications, a useful reference booklet on Canadian Wood Frame House Construction is available from Central Mortgage and Housing Corporation, Head Office, Montreal Road, Ottawa 7. (no charge)


LEGEND
Southern limit of continuous permafrost
Southern limit of permafrost
Mean annual air temperature
ALASKA
YUKON TERRITORY
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUND
N.B.
P.E.I.
NOVA SCOTIA
HUDSON BAY
UNITED STATES
WHITEHORSE
YELLOWKNIFE
EDMONTON
REGINA
WINNIPEG
VICTORIA
TORONTO
OTTAWA
QUEBEC
FREDERICTON
CHARLOTTETOWN
HALIFAX
ST. JOHN'S
15°F
20°F
25°F
30°F
PERMAFROST IN CANADA
100 0 100 200 300 400 500
SCALE-MILES