THE UNIVERSITY OF MANITOBA

ENERGY EFFICIENT HOUSING DESIGN

BY

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For my two sons, Kirk and Tod
and their friends, wishing them a
future without "scare-city".

With special appreciation to my
readers and advisors on this thesis

Professor Mario Carvalho
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And most of all to my wife, Lynda,
for her continued devotion, patience
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possible.

ABSTRACT

This thesis examines ways of conserving energy through a rational approach to housing design. It seeks to answer the following questions:

1. Can energy be conserved through appropriate housing design, and if so, by what rational principles of design?
2. Can these design principles be used as a basis for directing public policy and incentives programs toward encouraging the design and construction of energy efficient housing, and if so, how can this be done?

Within the scope of housing, however, this thesis concentrates on the single family, detached house because of its inherent challenge to energy efficiency. An examination is first made of the conventional house to determine ways in which its design may be made inherently more energy efficient. Two alternate, potentially energy efficient forms of construction are also examined. These are the "double shelled" house and the "earth sheltered" house.

By examining the role of the public sector in encouraging the design of energy efficient housing, this study discusses various existing and proposed incentive programs.

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PREFACE

The news media reminds us daily that the "energy crisis" is increasingly real and that it's full implications will be felt in almost all aspects of our lives. Energy, in fact, has become a dominant factor in issues ranging from national defence and security; national economic stability; to the individual citizen's ability to cope with the ever increasing energy costs in maintaining a home and automobile.

This is indeed a serious and complex situation calling for the combined efforts of many. Government and industry are continually working on new ways of increasing the production of energy supplies in Canada. On the demand side of the equation, some conservation efforts have been initiated by governments and the private sector. However, on both sides of the equation, it is recognized that much more work is needed if Canada is to achieve its nationally stated objective of being self-sufficient in her energy needs by 1990.

> "In April 1976, the Government of Canada, in support of the objective of energy self reliance, within ten years, proposed nine major policy thrusts. These policy elements provide a co-ordinated framework for the development of specific programs and measures. They include: (1) appropriate pricing; (2) energy conservation; (3) increased exploration and development; (4) increased resource information; (5) inter-fuel substitution; (6) new delivery systems; (7) emergency preparedness; (8) increased research and development; and (9) greater Canadian content and participation in resource development."[1]

1 Workshop on Alternate Energy Strategies (WAES) Energy Demand Studies: Major Consuming Countries, M.I.T. Press, 1976, page 52.

We should indeed be striving for more than just self-reliance, we should strive for the elimination of all waste, especially in our use of our non-renewable resources.

It has been stated that when viewed as a balanced equation between supply and demand, the cost of saving energy (reducing demand through conservation) is far less than the cost of producing the same unit of energy - especially at today's costs. As energy costs increase, this fact will become even more relevant.

> "The cheapest "source" of energy is conservation - energy efficiency - so that vehicles, equipment, buildings and appliances do their work with a minimum of waste".[1]

As planners and architects, we have a very significant role to play in addressing our efforts to the task of conserving energy. This role can be played by directing our focus on two broad areas of concern.

1. In designing buildings so that they are more energy efficient.
2. In designing cities and towns so that their inhabitants may conserve transportation energy (gasoline consumed by the private automobile) without sacrificing the convenience and enjoyment of living in cities, or without destroying the opportunity for the efficient movement of people, goods and service

1 "The Energy Crisis - A Program for the '80's" Special Report in Newsweek, New York, July 16, 1979 p.26

These two broad areas of focus are relevant because they strike at the two sources of energy in which both Canada and the U.S.A. have become increasingly vulnerable - namely "heating fuels and gasoline". Therefore, the need to conserve these fuels is of paramount importance.

However, in spite of this recognized vulnerability emphasized almost daily by the news media; despite the ever increasing price of fuels; despite the stated government objective of attaining self sufficiency by 1990; despite the fact that it has now been 7 years since the first Arab oil embargo on North America, it is almost inconceivable that builders and planners go on building the energy wasteful, sprawling suburbia filled with "conventionally designed houses" today. One has only to look at most Canadian cities, especially Edmonton and Calgary, Alberta, for proof of this continued wasteful practice with little regard for conserving non-renewable resources. No doubt, if this situation is allowed to persist, Canada will indeed be faced with very painful energy shortages in years to come.

We, as Canadians, cannot allow ourselves to fall into the trap of complacency by thinking that, because of our comparatively good supplies of natural resources, (when compared with the U.S.A.), we need not be concerned about the future. In fact, because of the extreme dependence on energy created by our harsh winters and a very large and sparsely populated country, our very survival as human beings and as a federate union depends heavily on adequate energy supplies. Also, Canada is heavily dependent on the U.S.A. as our trading partner as well as our "big brother" in our defence needs. Both our economic and national defence depend on the survival and strength of the U.S.A. Consequently, when viewed in this way, it must be recognized that the energy problems facing the U.S.A. are indirectly our own as well.

It is against this background of far reaching implications, that the importance of conserving energy and the proposals of this thesis should be viewed.

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INTRODUCTION

The primary purpose of this thesis is to determine whether or not energy can be conserved through a rational approach to the design of buildings and towns and if so, by what principles of design. These principles of design may then be used by planners, architects and builders in the future. This is discussed in PART A.

The second objective of this study is to illustrate to the public sector ways in which it may become involved and instrumental in encouraging the design and construction of energy efficient buildings and cities. By so doing, this thesis may be instrumental in guiding the way for co-ordinated and effective ACTIONS between the public and private sectors in attaining the national objective of energy self-sufficiency. This is discussed in PART B.

To concentrate the scope of this thesis, however, these discussions are approached from the perspective of housing design, and, more specifically, the single family detached house.

While it is recognized by the author that other forms of housing have a greater inherent potential for being energy efficient by virtue of party wall construction, shared roofs and floors (i.e. apartment blocks, townhouses, rowhouses, maisonettes, etc.), the single family house represents the most challenging conditions for designing an energy efficient building unit.

The lessons learned from this exercise can be extrapolated and applied (within threshold limits) to the design of other building units as well - be they multiple housing "blocks" or commercial or industrial buildings. Also, while this study concentrates on methods of designing new housing units, there is no reason why lessons learned here could not equally well be used as a basis for up-grading or "retrofitting" existing houses.

As well, it should be noted that the single family house is a very popular choice among Canadians in many cities.

> "At April 1975, single detached dwelling units were by far the most common form of housing, comprising 3,987,000 units or 60% of the total housing stock..."[1]

For most, it is a dream or major goal in life to own a house. If we are successful in designing an energy efficient house, this dream could become a reality for more Canadians who are increasingly being excluded from the market because of increasing energy costs. Also, the energy savings on a national scale would be obviously very significant if all housing units were to be made more energy efficient.

There is, therefore, "great mileage" to be gained by concentrating on the single family deatched house.

1 Central Mortgage and Housing Corporation:
<u>The Conservation of Energy in Housing</u>
CMHC, Ottawa 1977 p.13

Before proceeding with the central discussion, certain qualifications must be made to focus the perspective of this thesis.

The fundamental and primary role of a building is to provide shelter and protection to its inhabitants as they perform their activities. This protection is primarily directed at the ill effects of natural phenomenon such as the climatic elements. While the house may be required to serve many other important roles such as providing security, privacy, prestige, identity, etc., by far its most important purpose is that of providing a basic level of physiological comfort by sheltering its occupants and contents, (against the detrimental effects of the climatic environment). This is especially true in a climate as harsh as the North American prairie region.

In view of the growing energy crisis, this fundamental requirement of shelter is of even greater importance. Building design in North America has been less than optimum when viewed from an energy efficiency standpoint. From the author's observation, the modern building's architectural design has not been conceived of as playing a fundamental role in maximizing energy conservation. Instead, and because of an abundance of cheap fuels, the building's mechanical and electrical systems have been designed to provide the internal climate control requirements of heating, cooling, lighting and ventilation.

> ".....man and other creatures have always turned to the earth for protection from the elements and extremes of climate. It is only in the historically brief era of plentiful and cheap fossil fuel supplies that we have been able to design a house without regard to the climate and then to supply whatever equipment and energy may be necessary to keep us comfortable."[1]

Architectural design has been given to priorities of "higher" values. For example, the three "Master Builders" of our century have had a profound influence on the design and planning of buildings and cities in North America (and, in fact, much of the industrialized world). These are Frank Lloyd Wright, Le Corbusier and Mies Van Der Rohe. Students of architecture will quickly recognize that their priorities were definitely not with energy efficiency. Mies designed buildings to "express their structural integrity" in steel and glass - the two most inefficient materials when viewed from the standpoint of energy efficiency. Mr. Wright was more concerned with the design of "broadacres" (the original ancestor of suburbia) for living close to nature in "natural houses", which artfully manipulated the relationships of spaces and material in harmony with their surroundings - visually. However, Mr. Wright's houses often leaked, a fact which indicates his lack of concern for the building's fundamental function of providing shelter against the elements.

While the "higher" objectives of modern architecture are important and worthy of the pursuit of a society, these objectives can no longer

1 The Underground Space Centre: Earth Sheltered Housing Design
Van Nostrand Reinhold Company
New York 1979 p.4

be sought after at the expense of energy efficiency and with a heavy dependence on mechanical and electrical systems. For the purposes of this study, these priorities have been reversed so that the planning and architectural design are required to play a major role in providing these comfort requirements, while mechanical and electrical devices are used as back-up systems (to support the building's inherent ability to respond to nature in providing these comfort requirements). Because climate sensitive design will vary from region to region (and, infact, from one site to another,) it is necessary to limit the specific geographic context of this study. In addition, the following design parameters are to be noted:

1. Geographic and Climatic Context

Under consideration is the Canadian prairie region. This region encompasses such cities as Winnipeg, Regina, Saskatoon and Edmonton. (It should also be noted that the prairie region also extends into the U.S.A. as far south as Kansas City, so many topics discussed would also apply to the U.S. situation). Because this region is characterized by hot, dry sunny summers and long, very cold but sunny winters, use of the sun's energy is considered a major design determinant. See Figures 1 to 7 for climatic data on this region. Also, because this region is at the interface or meeting place of two major air masses (cold masses from the North and tropical air from the South), it is also characterized by strong winds, occasional tornadoes and thunderstorms in the warmer months. Winter months are characterized by cold north and northwesterly prevailing winds. Therefore, designing for maximum shelter from the winter winds is considered a major design determinant.

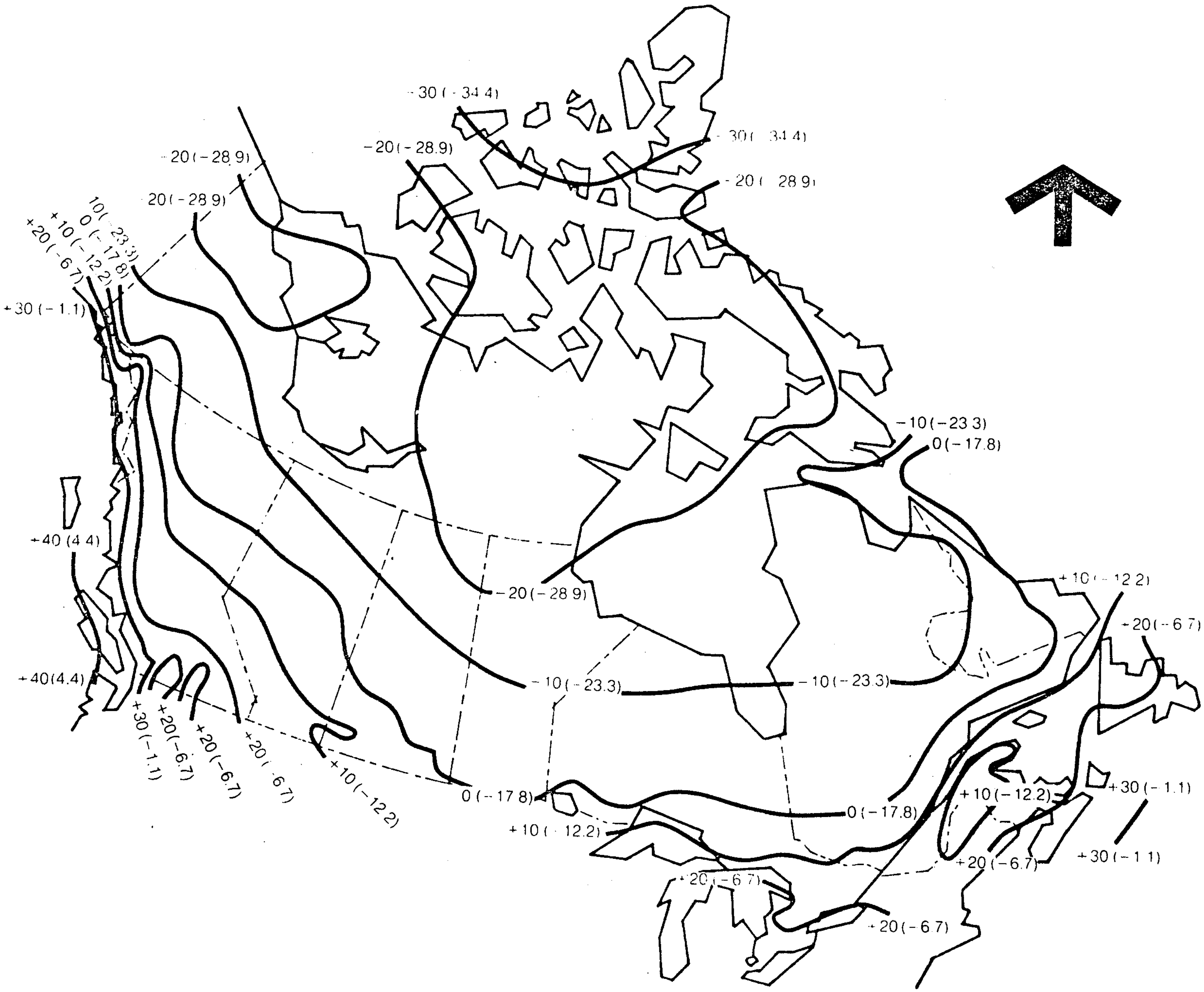
2. Technological Context

The technology under consideration is essentially as we know it today, or as we can realistically achieve within the next decade, without first requiring wholesale transformation of social values and customs or political revolution.

Because of the great number of sunshine hours experienced in this geographic region, the use of (natural) passive solar heat gain principles are under consideration (See "Definitions" for a comparison with active solar gain).

Conventional heating systems using oil, natural gas, electricity or wood as fuel may be used as back-up systems unless otherwise stated. This does not rule out the use of active systems as back-up in any of the designs discussed.

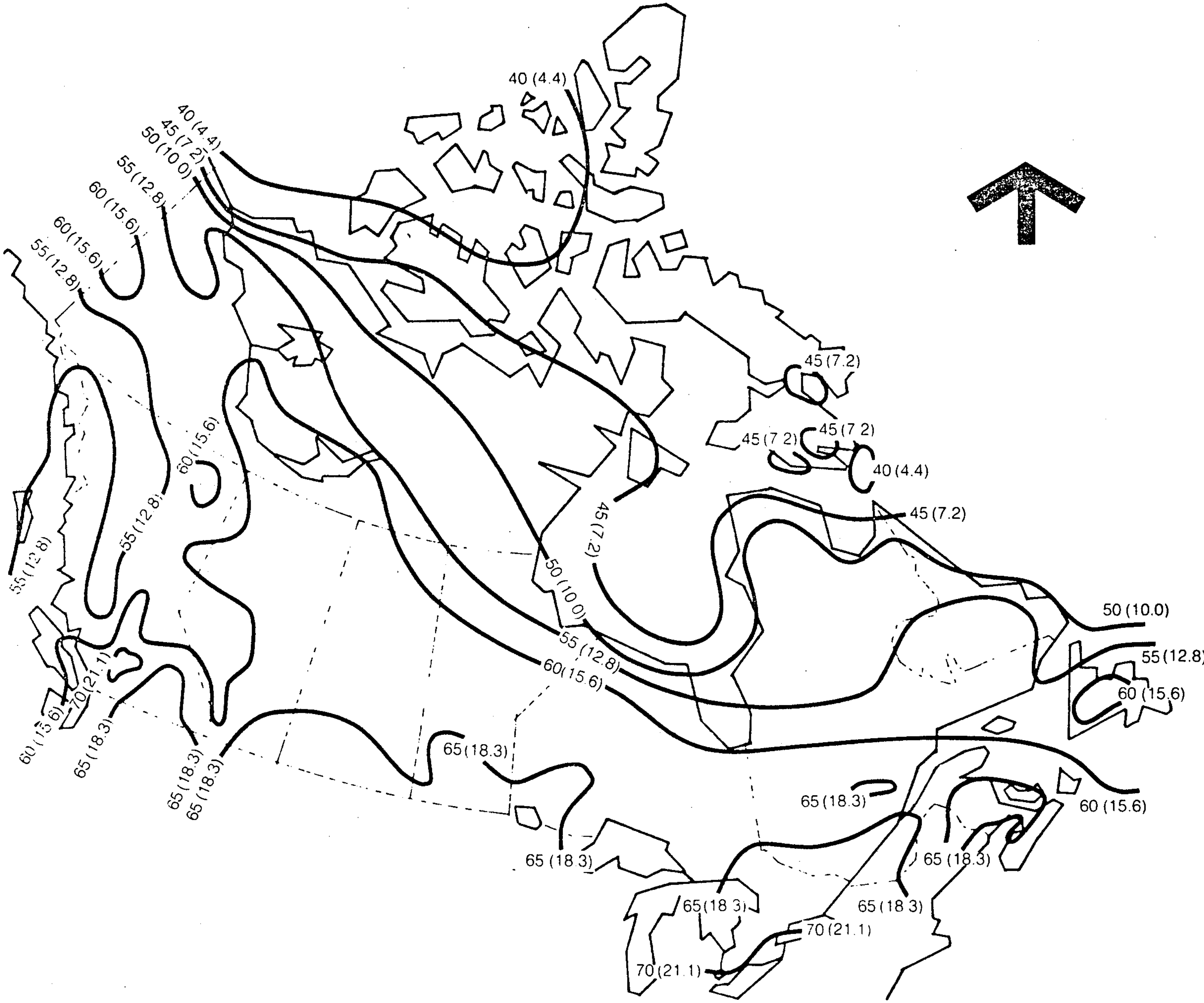
Cooling, ventilating and lighting by natural "means" is given a high design priority as well. Artifical or mechanical means of achieving these ends is considered necessary as back-up. It is also recognized



Source: *Climatological Atlas of Canada* (Ottawa: National Research Council of Canada and Department of Transport, 1953)

Fig. 1

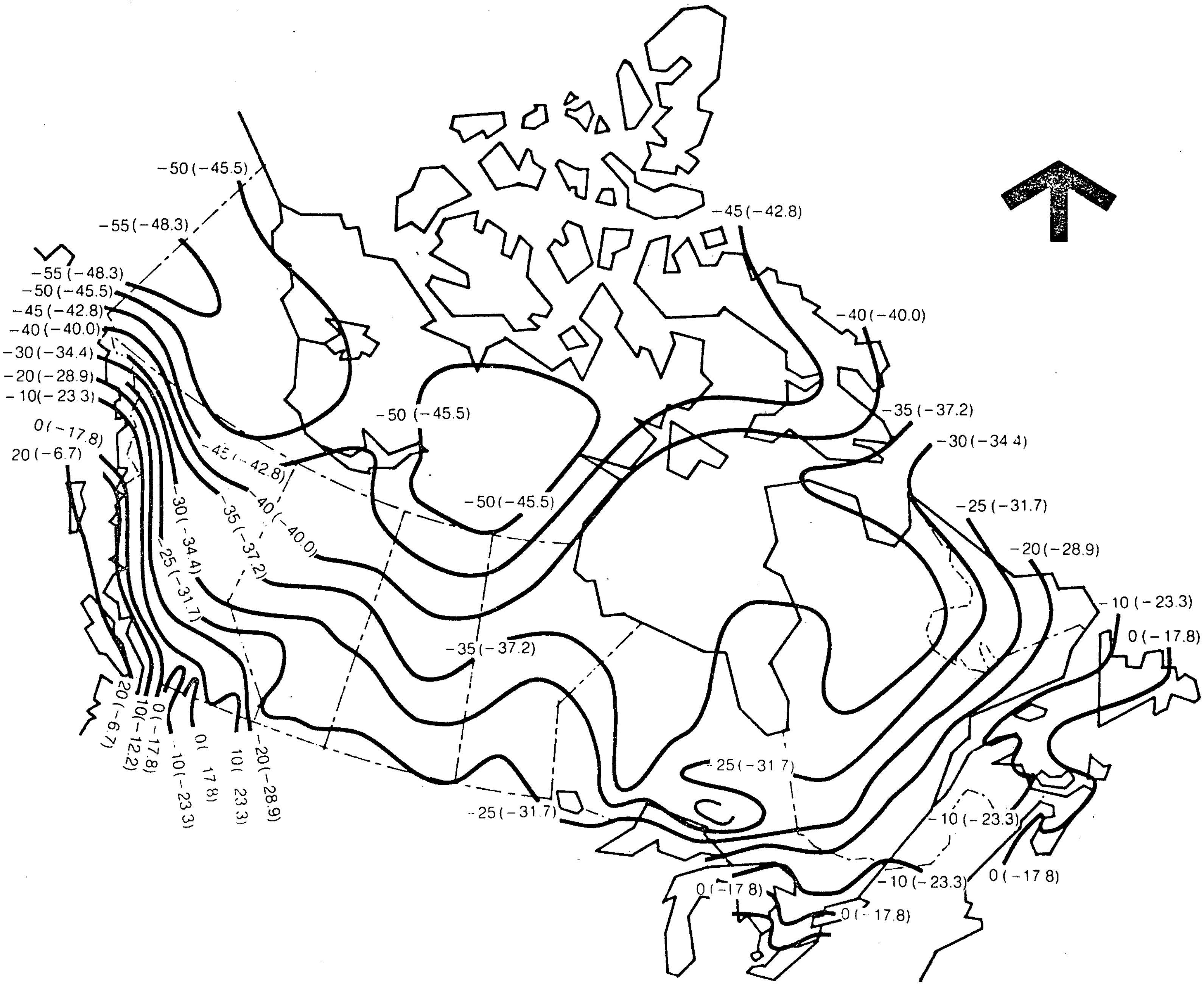
Mean January temperatures in Canada in Fahrenheit (with Celsius in parentheses)



Source: *Climatological Atlas of Canada* (Ottawa: National Research Council of Canada and Department of Transport, 1953).

Mean July temperatures in Canada in Fahrenheit (with Celsius in parentheses)

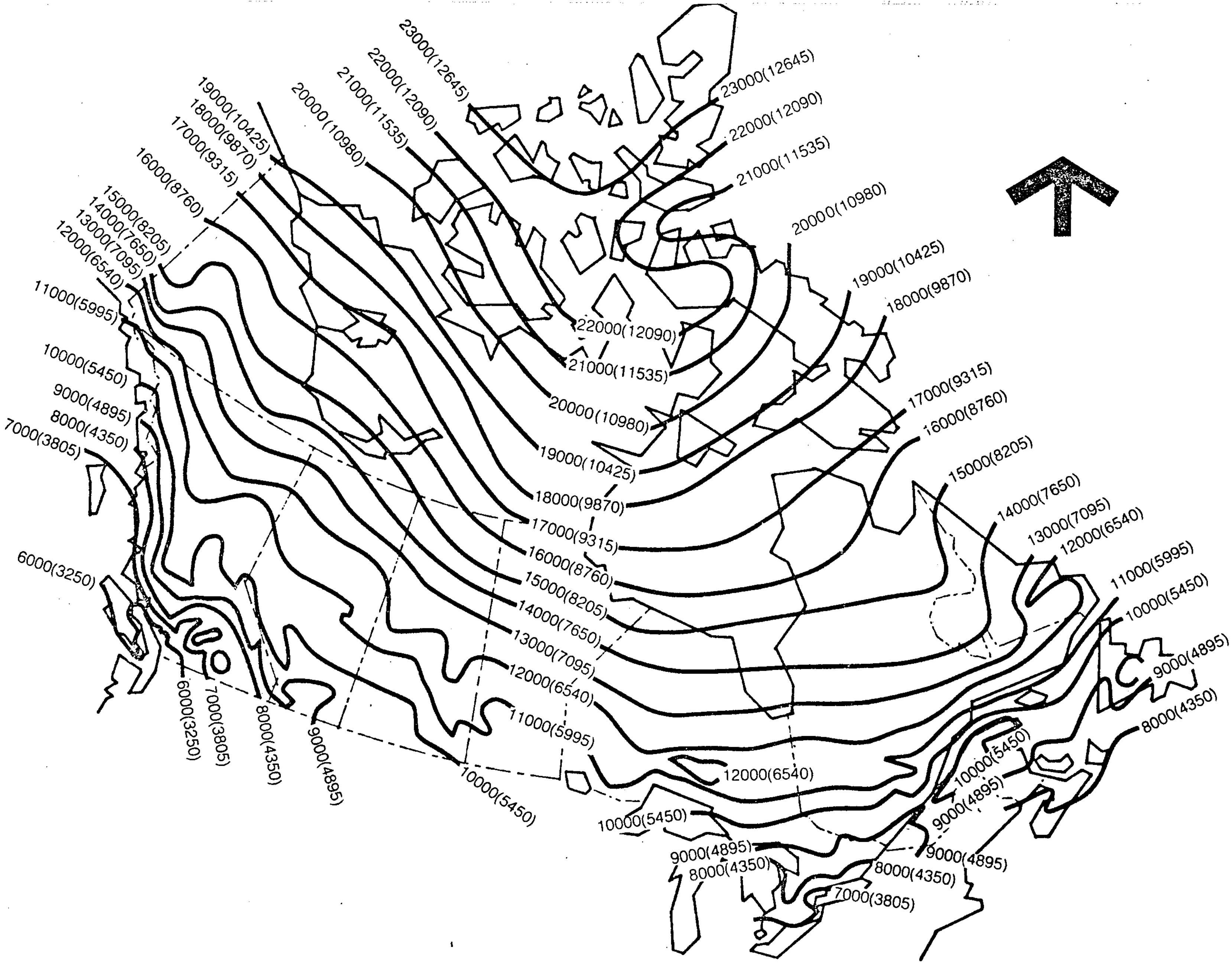
Fig. 2



Source: *Climatic Information for Building Designs in Canada, 1975* Supplement to the National Building Code of Canada, 1970 (Ottawa National Research Council of Canada)

January design temperatures for dwellings in Canada — In Fahrenheit (with Celsius in parentheses)

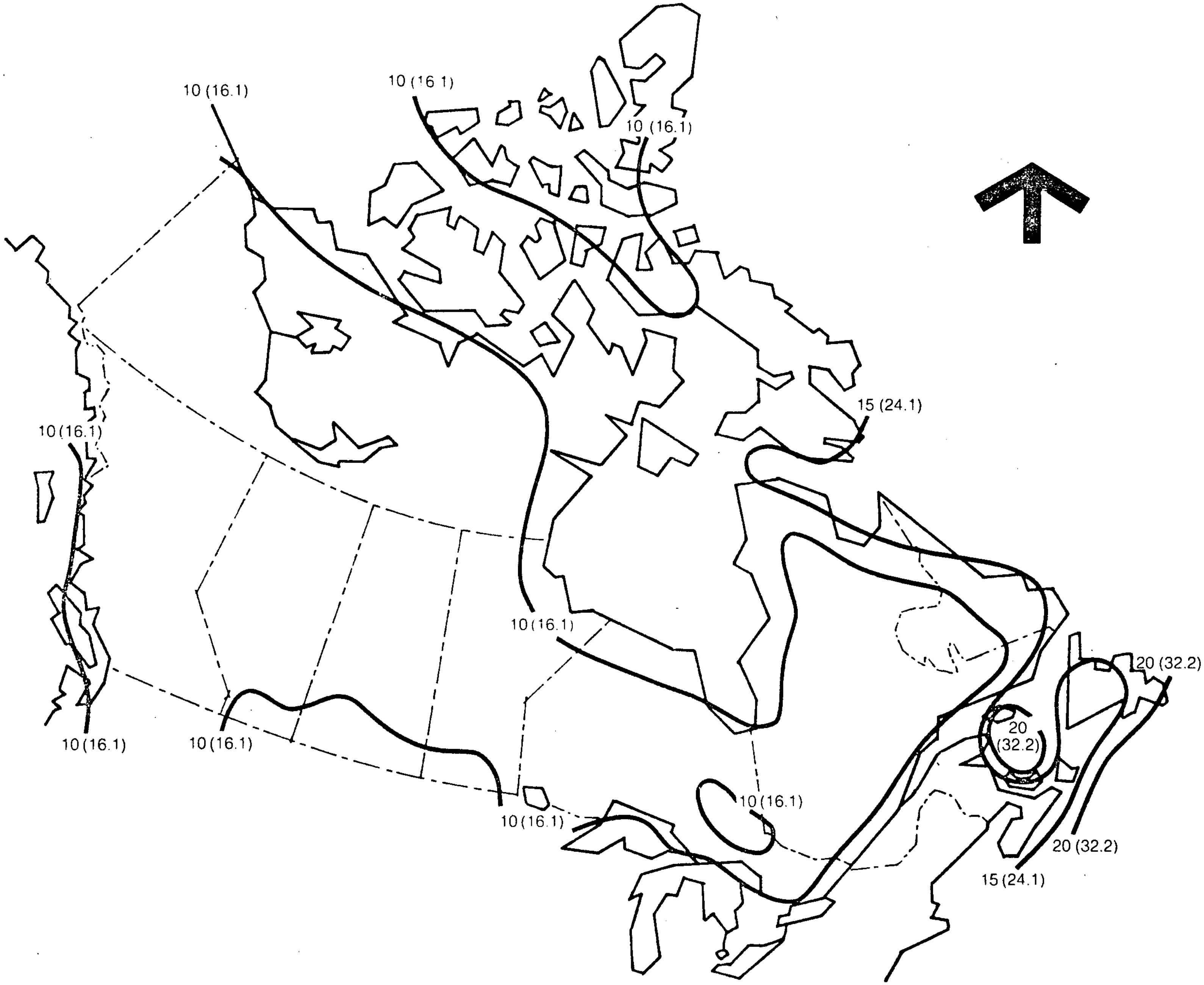
Fig. 3



Source: *Climatic Information for Building Designs in Canada, 1975.* Supplement to the National Building Code of Canada, 1970 (Ottawa: National Research Council of Canada).

Annual degree days in Canada in Fahrenheit (with Celsius in parentheses)

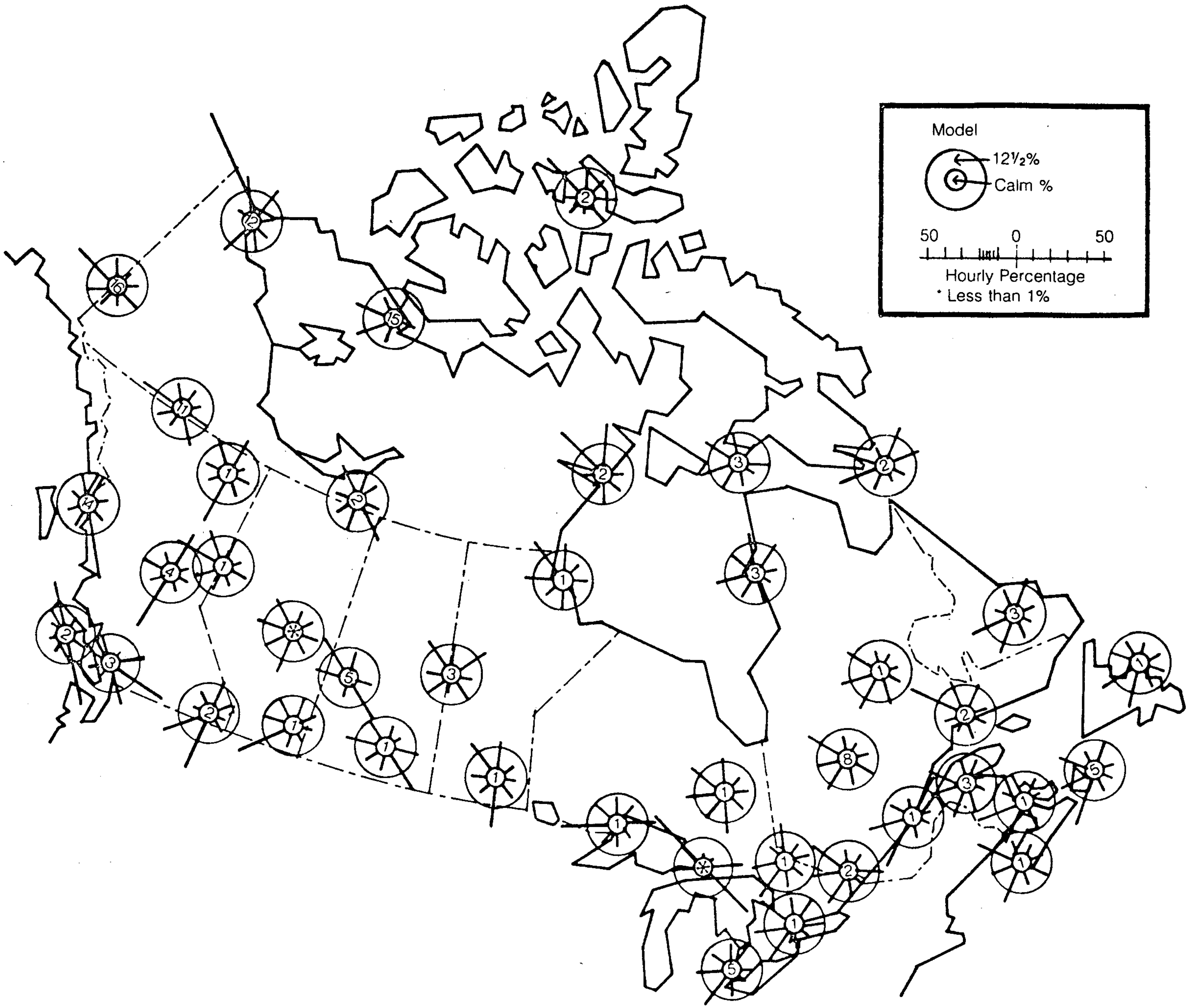
Fig. 4.



Source: *Climatological Atlas of Canada* (Ottawa: National Research Council of Canada and Department of Transport, 1953).

Mean winter wind speeds in Canada — In miles/hours (with km/h in parentheses)

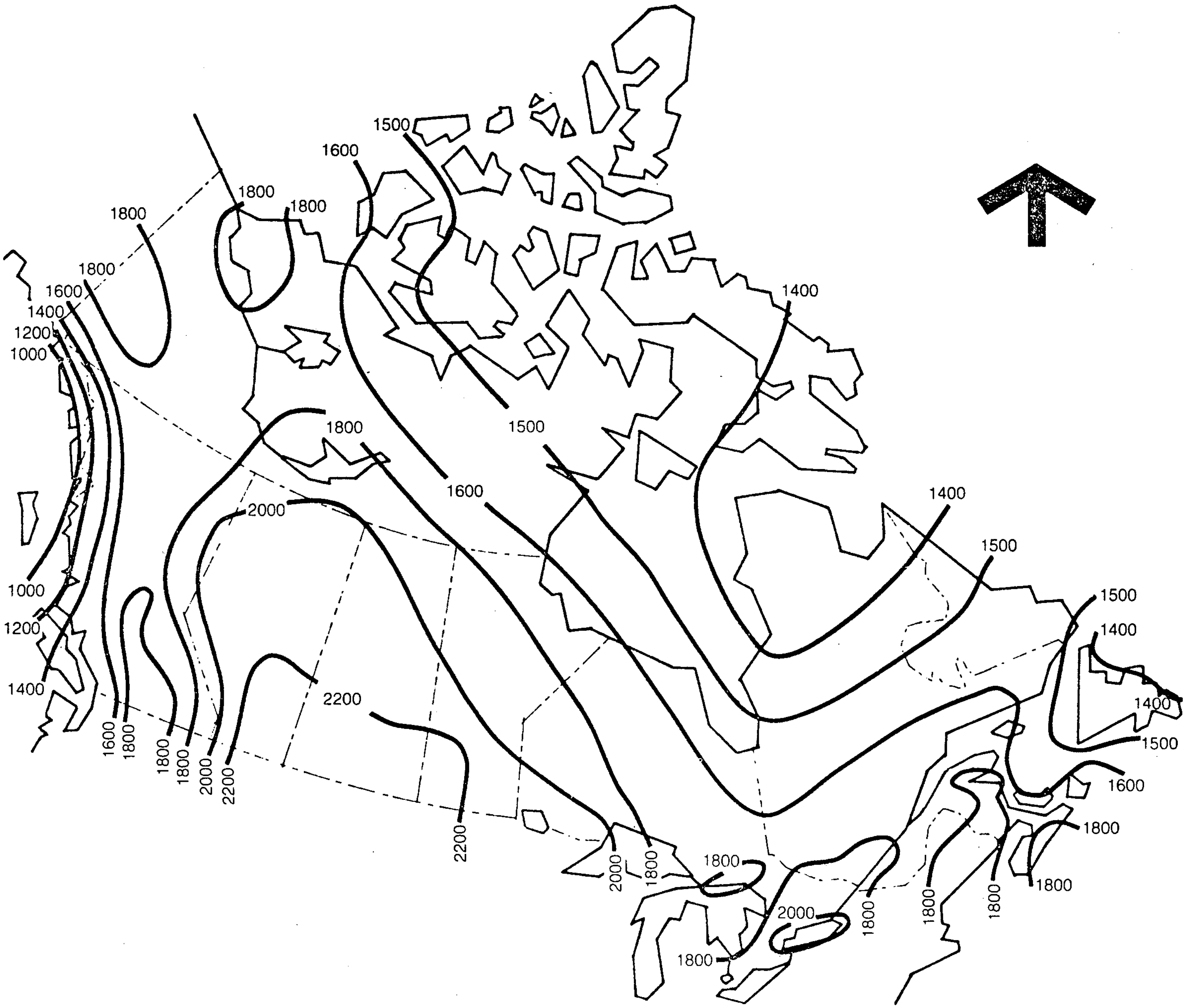
Fig. 5



Source *Climatological Atlas of Canada* (Ottawa National Research Council of Canada and Department of Transport, 1953)

Fig. 6

Direction of annual winds in Canada



Source: *Climatological Atlas of Canada* (Ottawa: National Research Council of Canada and Department of Transport, 1953).

Mean annual hours of sunshine in Canada

Fig. 7